**PROYECTO DE EJECUCIÓN**

**Parque eólico "P.E. Canraso" de 4,95 MW**

**e infraestructuras de evacuación para conexión a red**

**EMPLAZAMIENTO EÓLICO**

**Murchante [Navarra]**

**Parcelas 673, 674, 675 y 676 del Polígono 1**

**PROMOTOR**

**ANDRÓMEDA RENOVABLES 22 SL**

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**FECHA**

**Junio 2024**

# ANEXO I - INFORME DE CÁLCULO ESTIMADO DE PRODUCCIÓN

# Wind Energy Assessment Report (Preliminary)

## La Serna:
## Hornazos, Canraso & Barcelosa

Spain

Solvento

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# Contents

**1 Executive Summary** ..... 5
**2 Input Data** ..... 6
**2.1 Mesoscale Information & Summary** ..... 6
**3 Energy Assessment & Climatic Conditions** ..... 7
**4 Wind Power Plant Layout** ..... 8
**5 References** ..... 9

# 1 Executive Summary

This report presents a preliminary assessment of the proposed La Serna wind power plant.

The proposed wind power plant is located 6 kms from Tudela, Spain. The proposed installed capacity of the wind turbines is 15.0MW consisting of 3 x SI160 50 Wind Turbine Generator (WTG)s at a hub height of 119m with a rated power of 5.0MW per WTG.

The WTGs are to be installed at a semi-flat region with medium undulations at the site boundary. The WTG coordinates has been provided by the Customer for the proposed pad locations.

The Customer has not provided wind data or inputs and this assessment is based on wind data available online such as Mesoscale. It is strongly recommended to provide measured wind data to proceed in further analysis of Annual energy production and site suitability analysis.

SANY Renewable Energy reserves the right to ensure that the climatic conditions at the installed WTGs may be monitored during the operation to confirm the warranties provided if any.

If SANY Renewable Energy and the Customer do not execute a binding and definite contract for the supply, service & maintenance of the WTG for the La Serna wind power plant within 6 months after the revision date of this document, SANY Renewable Energy may update this energy assessment in order to include new relevant information to the wind power plant, additional wind data and to include any changes to the WTG standard documents and updates to the software and tools.

The results presented in this document is a preliminary estimate of Annual Energy Production (AEP) based on Mesoscale and shall be updated based on an actual measured wind data input. **This report does not include a load suitability assessment**. The energy estimate is subject to change based on new or additional wind data and subsequent load suitability assessment of the proposed WTG model based on the climatic conditions. SANY Renewable Energy reserves the right to introduce operational strategies that may be required, based on a load suitability assessment for a safe operation of a standard design lifetime of 20 years.

# 2 Input Data

The wind & site data specified in the following table have been used in the energy assessment of the wind power plant (hereinafter to be referred as "Site Data".)

Table 1 Wind Data Input La Serna

| Input | File Names | Source |
|---|---|---|
| Wind Data | EMDEuropeERA5_N4658454_E607665.zip | EMD WRF Europe+ (ERA5) |
| WTG Layout | La Serna Def-abril24.kmz | Customer |
| Height Contour | Height Contours_NASADEM_La Serna.wpo | NASADEM [1] |
| Roughness | ROUGHNESSLINE_ONLINEDATA_0.wpo | Corine Land Cover [2] |

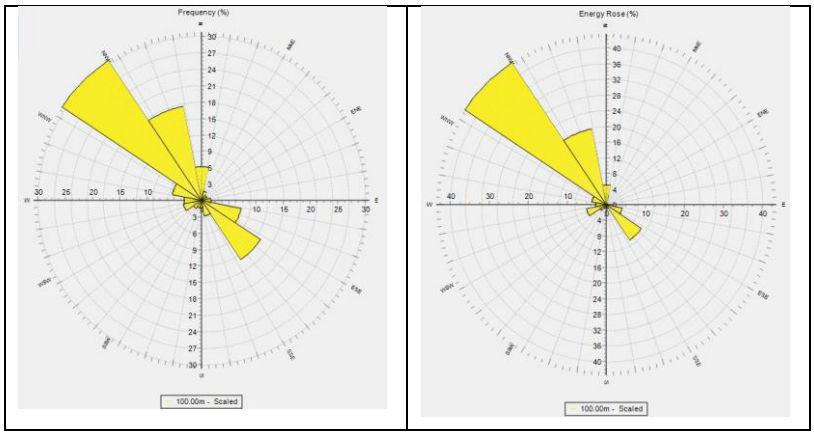
SANY Renewable Energy has not independently verified the quality, source & algorithms of the Mesoscale input data and assumes that the available information is accurate and represents the conditions at the project location.

## 2.1 Mesoscale Information & Summary

Table 2: Summary of Wind data: Mesoscale

| Input | EMD-WRF Europe+ (ERA5) |
|---|---|
| Mesoscale | UTM North WGS84 (Zone 30): 4658454 N, 607665E,<br>(elevation z=330m) |
| Available Heights | Wind Speed: 100m<br>Wind Direction: 100m |
| Data Availability | Effective Data: 100% (288 months)<br>Total Data: 288 months<br>(May 2000 – Apr 2024) |

Table 3: Frequency and Energy roses of Mesoscale



# 3 Energy Assessment & Climatic Conditions

Table 4: Annual Energy Production & Summary of Climatic Conditions

| WTG Layout | La Serna Hornazos 1 x SI160 50 119mHH | La Serna Canraso 1 x SI160 50 119mHH | La Serna Barcelosa 1 x SI160 50 119mHH |
|---|---|---|---|
| Hub Height [m] | 119 | 119 | 119 |
| Rotor Diameter [m] | 160 | 160 | 160 |
| Rated Power [kW] | 5000 | 5000 | 5000 |
| Park Rated Capacity [MW] | 5.0 | 5.0 | 5.0 |
| No. of WTGs | 1 | 1 | 1 |
| Average free mean wind speed [m/s] | 7.1 | 7.2 | 7.2 |
| Air Density [kg/m$^3$][1] | 1.17 | 1.17 | 1.17 |
| AEP Gross Incl. Wake [GWh/Year] | 17.6* | 17.7* | 17.5* |

*The AEP result is the Gross energy inclusive of wake losses. This includes wake losses from internal and the external wake from existing wind turbines around the proposed La Serna wind power plant. The energy estimate is subject to change based on new wind data and corresponding load & site suitability assessment.

The energy estimate does not include losses due to electrical, environmental, transmission, availability, turbine operational (Sector Management) and other losses. The AEP result & operational strategies are subject to change based on additional wind data and the final load suitability assessment.

[1] At WTG location, estimated based on Climate database from EMD windPRO and elevation data.

# 4 Wind Power Plant Layout

The WTG coordinates are presented in the coordinate system UTM (North) WGS84: Zone 30, in the table below.

Table 5: WTG Coordinates, La Serna

| Park Name | Turbine Name | WTG Model | Easting [m] | Northing [m] | Elevation [m] |
|---|---|---|---|---|---|
| La Serna | Hornazos | SI160 50 119mHH | 608676 | 4658311 | 310 |
| La Serna | Canraso | SI160 50 119mHH | 609211 | 4658052 | 310 |
| La Serna | Barcelosa | SI160 50 119mHH | 608767 | 4657751 | 310 |

The turbine positions are visualized in the map image below.

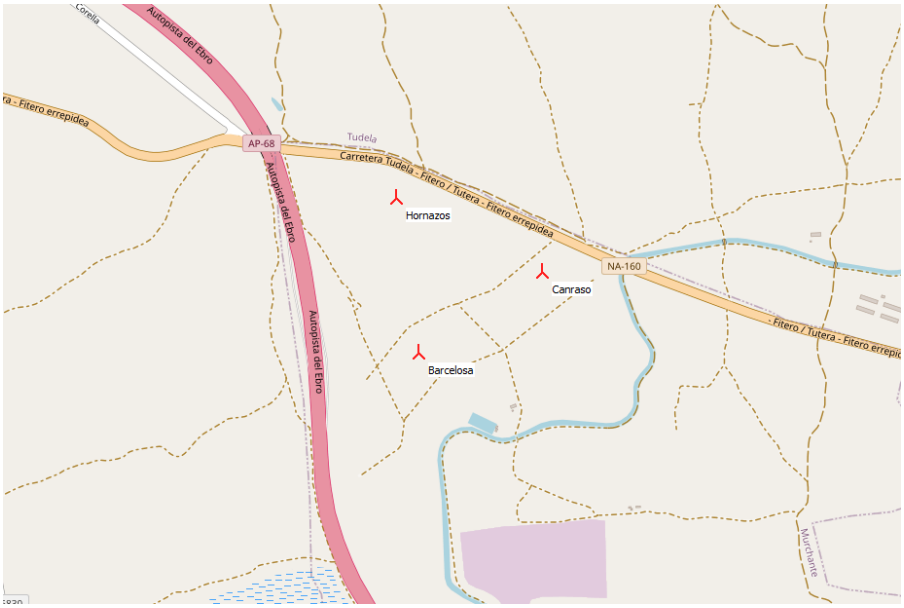



Figure 1: La Serna (3 WTGs) , (Map Source: EMD OpenStreetMap)

# 5 References

[1] The NASA Digital Elevation Models (DEM), based on the original Shuttle Radar Topography Mission (SRTM) http://help.emd.dk/mediawiki/index.php?title=NASA-DEM

[2] Corine Land Cover 2018, European Environment Agency (EEA). https://help.emd.dk/mediawiki/index.php?title=Corine_Land_Cover

[3] Power Curve Document of SI60 50, IEC S – Standard Document (Dec 2023 release), SANY Renewable Energy Co. Ltd.

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# ANEXO II – ESTUDIO AERONÁUTICO DE SEGURIDAD

# ESTUDIO AERONÁUTICO DE SEGURIDAD

# PARQUES EÓLICOS: SUBESTACIÓN TUDELA SUBESTACIÓN LA SERNA

JC Mont Fort Green Investments S.L.
B16857591
C/ Francisco de Vitoria 8, local
50008 Zaragoza

13/06/2024

airae

# ÍNDICE

1. INTRODUCCIÓN ..... 3
2. OBJETO ..... 5
3. DOCUMENTACIÓN DE REFERENCIA ..... 5
3.1. Normativa Aplicable ..... 5
3.2. Documentación consultada ..... 7
4. DEFINICIONES Y ABREVIATURAS ..... 8
5. CARTOGRAFÍA ..... 10
6. UBICACIÓN DE LA INSTALACIÓN ..... 10
7. ANÁLISIS DE SERVIDUMBRES AERONÁUTICAS ..... 13
7.1. Servidumbres de Aeródromo ..... 13
7.2. Servidumbres Radioeléctricas ..... 14
7.3. Servidumbres de Operación ..... 14
7.4. Evaluación de Servidumbres Aeronáuticas Civiles ..... 14
7.5. Evaluación de Servidumbres Aeronáuticas Militares ..... 14
8. PROCEDIMIENTOS INSTRUMENTALES DE VUELO ..... 16
8.1. Aeródromo Militar de Ablitas ..... 16
8.2. Base Aérea de Zaragoza ..... 16
8.3. Análisis de procedimientos instrumentales ..... 18
8.4. Mínimos de aproximación instrumental radar (Uso exclusivo militar) ..... 24
8.5. Carta de Altitud Mínima de Vigilancia ATC ..... 25
8.6. Altitud Mínima de Área (AMA) ..... 25
8.7. Aerovías de Espacio Aéreo Inferior ..... 26
9. PROCEDIMIENTOS VISUALES ..... 27
9.1. Compatibilidad del espacio aéreo circundante ..... 27
9.2. Análisis Cartas VFR / AD 2 - LEZG VAC 1 Y VAC2 ..... 31
9.3. Otra información de utilidad AIP-España (ZARAGOZA AD) ..... 34
10. MEDIDAS DE MITIGACIÓN DE RIESGOS, SEÑALIZACIÓN, ILUMINACIÓN Y PUBLICACIÓN EN AIP-ESPAÑA ..... 35
11. CONCLUSIONES ..... 38
ANEXO 1 ..... 40
ANEXO 2 ..... 41
ANEXO 3 ..... 42
ANEXO 4 ..... 43

## 1. INTRODUCCIÓN

En zonas afectadas por servidumbres aeronáuticas de aeródromos, helipuertos o radioayudas a la navegación aérea, o fuera de ellas para obstáculos que superen los 100 m de altura, cualquier construcción o instalación requiere autorización previa y preceptiva de la Agencia Estatal de Seguridad Aérea o del Ministerio de Defensa en caso de que se encuentren en zonas afectadas por servidumbres aeronáuticas militares, de acuerdo al *Decreto 584/1972, de 24 de febrero de Servidumbres Aeronáuticas,* modificado por el *Real Decreto 369/2023, de 16 de mayo*.

Se proyectan dos clústers de parques eólicos asociados a las Subestaciones Tudela y La Serna, en el término municipal de Murchante, que constan de un total de seis aerogeneradores, así como la grúa para su montaje, distribuidos de la siguiente manera:

- Subestación Tudela: PE Isaac Peral I-a, PE Isaac Peral I-b y PE Isaac Peral II
- Subestación La Serna: PE Hornazos, PE Canraso y PE Barcelosa

A los efectos de simplificar la nomenclatura, el presente documento se referirá al conjunto de Parques Eólicos como "Parque Eólico".

Los emplazamientos para la instalación del Parque Eólico analizados en este informe se sitúan próximos al Aeródromo Militar de Ablitas. A la fecha del presente informe no existe publicada ninguna superficie de servidumbres aeronáuticas correspondientes al D2039/1967, previo al D584/72 general de Servidumbres Aeronáuticas, modificado por el RD297/2013 y por el RD 369/2023. El Ministerio de Defensa tiene prevista la publicación de unas nuevas Servidumbres Aeronáuticas para dicho aeródromo, no aprobadas por el momento, a fecha del presente informe.

Por otro lado, y en línea con el Anexo 14 de OACI, el RD 1541/2003 abrió la posibilidad a que las superficies limitadoras de obstáculos alrededor de aeropuertos y helipuertos pudieran ser vulneradas por obstáculos siempre que se verificara mediante estudio aeronáutico que éstos no afectarían a la seguridad de las operaciones de las aeronaves.

Por ello, en el caso de superar los 100 m de altura o en caso de sobrepasar la altura de alguna de las superficies correspondientes a las servidumbres aeronáuticas de

aeródromo y/o de operación, según el *Real Decreto 369/2023*, el obstáculo puede ser autorizado si se cumple:

> Artículo 34. "*1. La autoridad nacional de supervisión civil o el órgano competente del Ministerio de Defensa, en el ámbito de sus respectivas competencias, podrán autorizar actuaciones en aquellos casos en que, a pesar de constituir un obstáculo de acuerdo con la definición dada en el artículo 3, por penetrar o vulnerar las servidumbres aeronáuticas, cuando quede acreditado, a juicio del órgano competente, que no se compromete la seguridad, ni queda afectada de modo significativo la regularidad de las operaciones de aeronaves.*
> *2. Asimismo, la autoridad nacional de supervisión civil o el órgano competente del Ministerio de Defensa, en el ámbito de sus propias competencias, podrán autorizar la construcción de edificaciones o instalaciones que estén apantallados por otros obstáculos naturales o artificiales ya existentes en los términos previstos en el artículo 7.*
> *3. A tales efectos previstos en los apartados 1 y 2, podrá requerirse a los promotores de nuevas actuaciones la presentación de estudio aeronáutico de seguridad en el que se justifique que no se compromete la seguridad, ni queda afectada de modo significativo la regularidad de las operaciones de aeronaves o que se trata de un supuesto de apantallamiento*".

Actualmente, no existe ninguna guía desarrollada por OACI en la que se establezcan los criterios para la realización de estudios aeronáuticos. Así, en la 12ª Conferencia de Navegación Aérea celebrada en Montreal los días 19 a 30 de noviembre de 2012, la OACI estableció la recomendación 6/14 sobre la necesidad de desarrollar guías completas para los Estados para la aplicación uniforme en el desarrollo de los estudios aeronáuticos que evalúan la permisibilidad de que las superficies limitadoras de obstáculos (SLOs) del Anexo 14 OACI estén vulneradas.

Por otro lado, el panel IFPP de OACI ha insistido en numerosas ocasiones sobre la insuficiencia de las superficies PANS-OPS para evaluar la afección operativa de las vulneraciones de las superficies del Anexo 14 OACI, tanto porque estas últimas son las únicas que protegen las operaciones VFR en el entorno aeroportuario, como porque además suponen de facto una protección frente al riesgo de colisión contra obstáculos para las operaciones "no-normales". Un volumen de espacio aéreo comprendido entre

el límite superior de las superficies SLOs del Anexo 14 OACI y el límite inferior de las superficies PANS-OPS despejado de obstáculos facilita la protección de las operaciones con visibilidad reducida, emergencias, procedimientos de contingencia del operador, errores de los sistemas de navegación o errores humanos crasos.

Por todo ello, los estudios aeronáuticos sólo disponen actualmente de criterios OACI para evaluar la afección operativa de las vulneraciones de las superficies SLOs en el caso de las operaciones IFR 'normales' (mediante los criterios PANS-OPS), no disponiéndose de criterios para evaluar las operaciones IFR 'no normales' ni las operaciones VFR. En relación con estas últimas, aunque el piloto es responsable de 'ver y evitar' los obstáculos, siempre será aconsejable que las superficies SLOs Anexo 14 OACI no estén vulneradas, y en caso de que no sea posible, al menos que estén señalizados e iluminados y en todo caso convenientemente publicados en el AIP para el conocimiento de las tripulaciones.

## 2. OBJETO

El objeto de este estudio es analizar la posible afección del Parque Eólico desde el punto de vista de la seguridad y la regularidad a las operaciones del Aeródromo Militar de Ablitas y de la Base Aérea de Zaragoza, y en su espacio aéreo circundante. Para ello se procederá al análisis de servidumbres aeronáuticas y de las áreas de protección de procedimientos de vuelo, obteniendo como resultado la existencia o no de interferencias con las operaciones, para cada uno de los emplazamientos planteados.

## 3. DOCUMENTACIÓN DE REFERENCIA

### 3.1. NORMATIVA APLICABLE

La normativa de aplicación a este estudio es:

- Real Decreto 369/2023, de 16 de mayo, por el que se regulan las servidumbres aeronáuticas de protección de la navegación aérea, y se modifica el Real Decreto 2591/1998, de 4 de diciembre, sobre la ordenación de los aeropuertos de interés general y su zona de servicio, en ejecución de lo dispuesto por el artículo 166 de la Ley 13/1996.
- Decreto 584/1972, de 24 de febrero, de servidumbres aeronáuticas, modificado por el Real Decreto 297/2013, de 26 de abril.

- Real Decreto 1541/2003, de 5 de diciembre, por el que se modifica el Decreto 584/1972, de 24 de febrero, de Servidumbres Aeronáuticas, y el Decreto 1844/1975, de 10 de julio, de Servidumbres Aeronáuticas en Helipuertos, para regular excepciones a los límites establecidos por las superficies limitadoras de obstáculos alrededor de aeropuertos y helipuertos.
- Ley 48/1960, de 21 de julio, sobre Navegación Aérea.
- Real Decreto 862/2009, de 14 de mayo, por el que se aprueban las normas técnicas de diseño y operación de aeródromos de uso público y se regula la certificación del aeropuerto de competencia del Estado.
- Orden FOM/2086/2011, de 8 de julio, por la que se actualizan las normas técnicas contenidas en el Anexo al Real Decreto 862/2009, de 14 de mayo, por el que se aprueban las normas técnicas de diseño y operación de aeródromos de uso público y se regula la certificación del aeropuerto de competencia del Estado.
- Decisión 2015/001/R, capítulo Q de las especificaciones de certificación para el diseño de aeródromos CS-ADR-DSN, adoptadas por la Decisión 2014/013/R, de 27 de febrero de 2014, del director ejecutivo de la Agencia Europea de Seguridad Aérea (EASA).
- Reglamento (UE) nº 139/2014 de la Comisión de 12 de febrero de 2014, por el que se establecen los requisitos y procedimientos administrativos relativos a los aeródromos, de conformidad con el Reglamento (CE) nº 216/2008 del Parlamento Europeo y del Consejo, de 20 de febrero de 2008.
- Documento 8168 – OPS/611. Operación de Aeronaves, Volumen I – Procedimientos de vuelo. 6ª Edición – 2018, Enmienda nº 8, fecha de aplicación 29/08/18, OACI.
- Documento 8168 – OPS/611. Operación de Aeronaves, Volumen II – Construcción de procedimientos de vuelo visual y por instrumentos. 6ª Edición – 2014, Enmienda nº 6, fecha de aplicación 23/04/14, OACI.
- Documento 8168 – OPS/611. Operación de Aeronaves, Volumen III – Procedimientos operacionales de aeronaves. 1ª Edición – 2018, fecha de aplicación 08/11/18, OACI.
- Anexo 2 – Reglamento del Aire. 10ª Edición, Julio 2005 – Enmienda nº 43 (15/11/12), OACI.
- Anexo 4 – Cartas Aeronáuticas. 11ª Edición – Julio 2009, Enmienda nº 57 (14/11/13), OACI.
- Anexo 6 – Operación de Aeronaves, OACI:

Parte I: Transporte Aéreo Comercial Internacional – Aviones. 9ª Edición – Julio 2010, Enmienda 37-A (14/11/13)

Parte II: Aviación General Internacional – Aviones. 7ª Edición – Julio 2008, Enmienda 32-A (14/11/13)

Parte III: Operaciones Internacionales – Helicópteros. 7ª Edición – Julio 2010, Enmienda 18-A (14/11/13).

- Anexo 11 – Servicios de Tránsito Aéreo. 13ª Edición – Julio 2001, Enmienda nº 49 (14/11/13), OACI.
- Anexo 14 – Aeródromos. Volumen I – Diseño y operaciones de aeródromos. 6ª Edición – Julio 2013, Enmienda 11-A, OACI.
- Anexo 15 – Servicios de Información Aeronáutica. 14 ª Edición – Julio 2013, Enmienda nº 37, OACI.
- Documento 8697 – Manual de Cartas Aeronáuticas. 2ª Edición – 1987, Enmienda 3 (26/05/2006), OACI.
- Documento 9137 – Manual de Servicios de aeropuertos. Parte 6 – Limitación de obstáculos. 2ª Edición – 1983.
- Reglamento (CE) nº 859/2008 de la Comisión, de 20 de agosto de 2008, por el que se modifica el Reglamento (CEE) nº 3922/91 del Consejo en lo relativo a los requisitos técnicos y los procedimientos administrativos comunes aplicables al transporte comercial por avión.
- Reglamento de Circulación Aérea (RCA) Tercera Edición – 2002, Enmienda 1/2013.
- Easy Access Rules for Standardised European Rules of the Air (SERA) - Diciembre 2018, EASA eRules.
- Real Decreto 552/2014, de 27 de junio, por el que se desarrolla el Reglamento del aire y disposiciones operativas comunes para los servicios y procedimientos de navegación aérea y se modifica el Real Decreto 57/2002, de 18 de enero, por el que se aprueba el Reglamento de Circulación Aérea.

## 3.2. DOCUMENTACIÓN CONSULTADA

- AIP-ESPAÑA de la Base Aérea de Zaragoza, actualizado hasta las enmiendas AIRAC 05/24 (13-JUN-24) y AMDT 381/24 (13-JUN-24).
- Decreto 2039/1967, de 22 de julio, por el que se confirman las servidumbres aeronáuticas en torno al Aeródromo de Ablitas (Navarra).

- Real Decreto 725/1991, de 26 de abril, sobre servidumbres aeronáuticas de la Base Aérea de Zaragoza, sus instalaciones radioeléctricas y de operación de aeronaves.

## 4. DEFINICIONES Y ABREVIATURAS

- **AD:** Parte 3 AIP-ESPAÑA: Aeródromos
- **AESA:** Agencia Estatal de Seguridad Aérea
- **AGL:** Sobre el nivel del suelo
- **AIP:** Publicación de Información Aeronáutica
- **AIRAC:** Reglamentación y Control de Información Aeronáutica
- **AMA:** Altitud Mínima de Área
- **AMDT:** Enmiendas regulares AIP-ESPAÑA
- **AMSL:** Sobre el nivel medio del mar
- **AOC:** Plano de obstáculos de aeródromo
- **ARP:** Punto de Referencia de Aeródromo
- **ATC:** Control de tránsito aéreo
- **ATCSMAC:** Carta de altitud mínima de vigilancia ATC
- **ATZ:** Zona de Tránsito de Aeródromo m.s.n.m. Medido Sobre el Nivel del Mar
- **CAT:** Categoría
- **CTR:** Zona de Control OACI Organización de Aviación Civil Internacional
- **CWY:** Zona libre de obstáculos
- **D:** Decreto
- **DGAC:** Dirección General de Aviación Civil
- **DME:** Equipo Medidor de Distancia SID Salida Instrumental Estándar
- **DVOR:** Doppler/Conventional VHF Omnidirectional Range
- **ENR:** Parte 2 AIP-ESPAÑA: En ruta
- **ETRS89:** Sistema de Referencia Terrestre Europeo 1989
- **FIR:** Región de información de vuelo
- **FL:** Nivel de vuelo
- **FOM:** Fomento
- **FT:** Pies
- **GEN:** Parte 1 AIP-ESPAÑA: Generalidades
- **GP:** Senda de planeo
- **Hobs:** Altura del obstáculo

- **IAC:** Carta de Aproximación Instrumental
- **ILS**: Sistema de Aterrizaje Instrumental
- **LETU**: Indicativo OACI Aeródromo Militar de Ablitas
- **LEZG**: Indicativo OACI Aeropuerto de Zaragoza
- **LOC:** Equipo Localizador
- **MOC:** Margen de Franqueamiento de Obstáculos
- **MSA:** Altitud Mínima de Sector
- **M:** Metros
- **MSNM:** Metros sobre el nivel del mar
- **NDB:** Radiofaro No Direccional
- **NM:** Millas náuticas
- **OACI:** Organización Internacional de Aviación Civil
- **PANS-OPS:** Procedimiento para los servicios de navegación aérea - Operaciones
- **RD:** Real Decreto
- **RNAV:** Navegación de área
- **RWY:** Pista de vuelo
- **SID:** Carta de salida normalizada
- **STAR:** Carta de llegada normalizada
- **TACAN:** Tactical Air Navigation
- **TMA:** Área de control terminal
- **THR:** Umbral de pista
- **TMA:** Área de Control Terminal
- **TWR:** Torre de control de tránsito aéreo
- **UTM:** Sistema de coordenadas transversal de Mercator
- **VAC:** Carta de aproximación visual
- **VFR:** Reglas de Vuelo Visual
- **VOR:** Radiofaro omnidireccional
- **WEF:** Con efecto a partir de

## 5. CARTOGRAFÍA

La información cartográfica utilizada en este estudio corresponde a la del AIP-España:

| AIP-España (Fecha de entrada en vigor) |
|---|
| AIRAC 05/24 (13-JUN-24) |
| AMDT 381/24 (13-JUN-24) |

**Tabla 1. AIP-España**

## 6. UBICACIÓN DE LA INSTALACIÓN

El Parque Eólico se sitúa en el término municipal de Murchante, en la provincia de Navarra, a una distancia aproximadamente de 5.62 km del Aeródromo Militar de Ablitas y a 66.85 km de la Base de Zaragoza:

**Figura 1. Detalle de los emplazamientos propuestos**

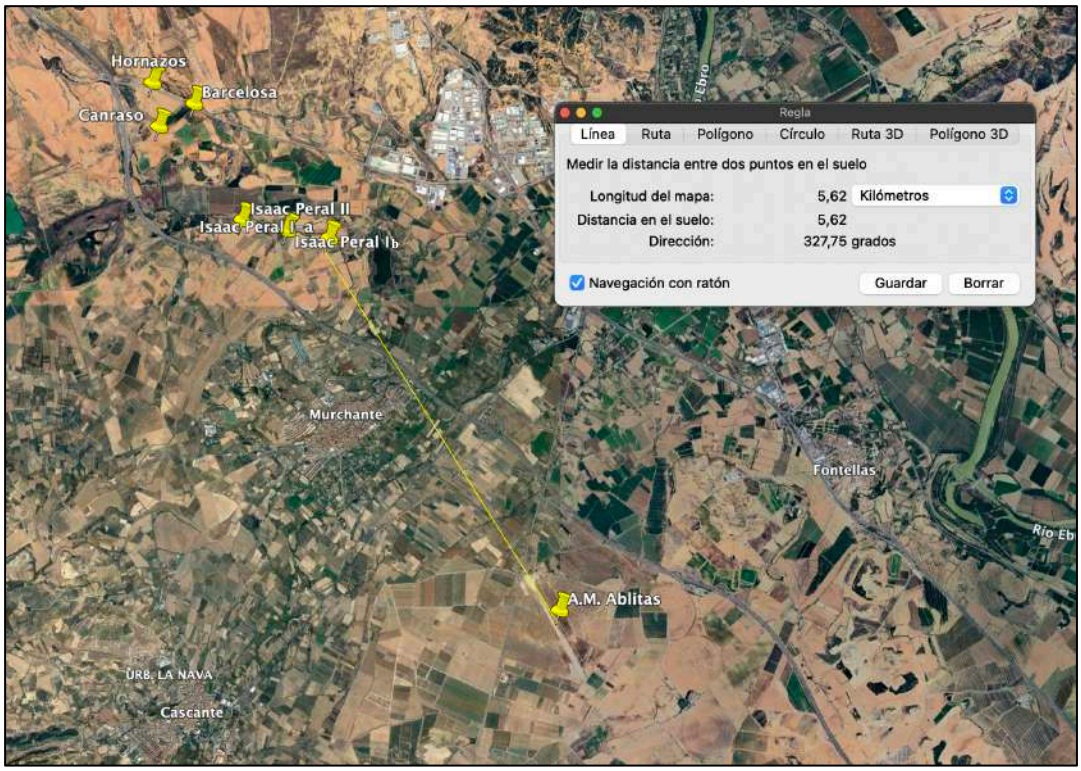


**Figura 2. Situación del parque eólico respecto al Aeródromo Militar de Ablitas**

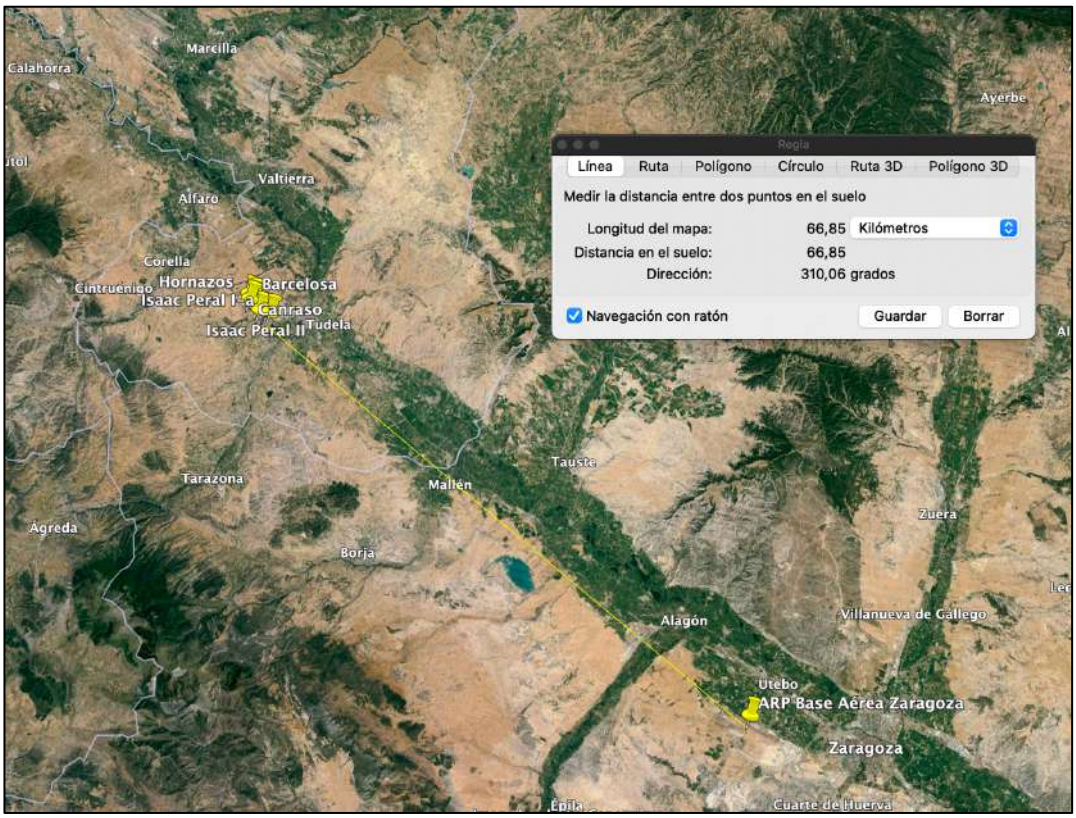


**Figura 3. Situación del parque eólico respecto a la Base Aérea de Zaragoza**

**Figura 4. Plano de ubicación del parque eólico**

A continuación, se muestran los datos de coordenadas, alturas y elevaciones de los 6 aerogeneradores que componen el Parque Eólico. Se incluye también la grúa que se usará para la instalación de dicho parque eólico en las coordenadas indicadas para los aerogeneradores.

| ID. | Sis. Ref. | Huso | UTM X (m) | UTM Y (m) | Cota * (msnm) | Altura (m) | Elev. (msnm) | Iluminación |
|---|---|---|---|---|---|---|---|---|
| Isaac Peral I-a | ETRS89 | 30 | 610978.00 | 4656359.00 | 305.00 | 200.00 | 505.00 | SÍ |
| Isaac Peral I-b | ETRS89 | 30 | 610436.00 | 4656449.00 | 304.00 | 200.00 | 504.00 | SÍ |
| Isaac Peral II | ETRS89 | 30 | 609859.00 | 4656571.00 | 308.00 | 200.00 | 508.00 | SÍ |
| Hornazos | ETRS89 | 30 | 608676.00 | 4658311.00 | 315.00 | 200.00 | 515.00 | SÍ |
| Canraso | ETRS89 | 30 | 608767.00 | 4657751.00 | 308.00 | 200.00 | 508.00 | SÍ |
| Barcelosa | ETRS89 | 30 | 609211.00 | 4658052.00 | 309.00 | 200.00 | 509.00 | SÍ |
| Grúa móvil | ETRS89 | 30 | - | - | - | 129.00 | - | SÍ |

*Aerogeneradores: Altura de buje: 120.00 metros. Diámetro de rotor: 160.00 metros.*

**Las coordenadas y la cota de la grúa se corresponden con las coordenadas y las cotas de cada uno de los aerogeneradores.*

***Si la grúa se utiliza en horario nocturno deberá iluminarse de acuerdo con lo propuesto en el Capítulo 10.*

**Tabla 2. Coordenadas, cotas, alturas, elevaciones e iluminación**

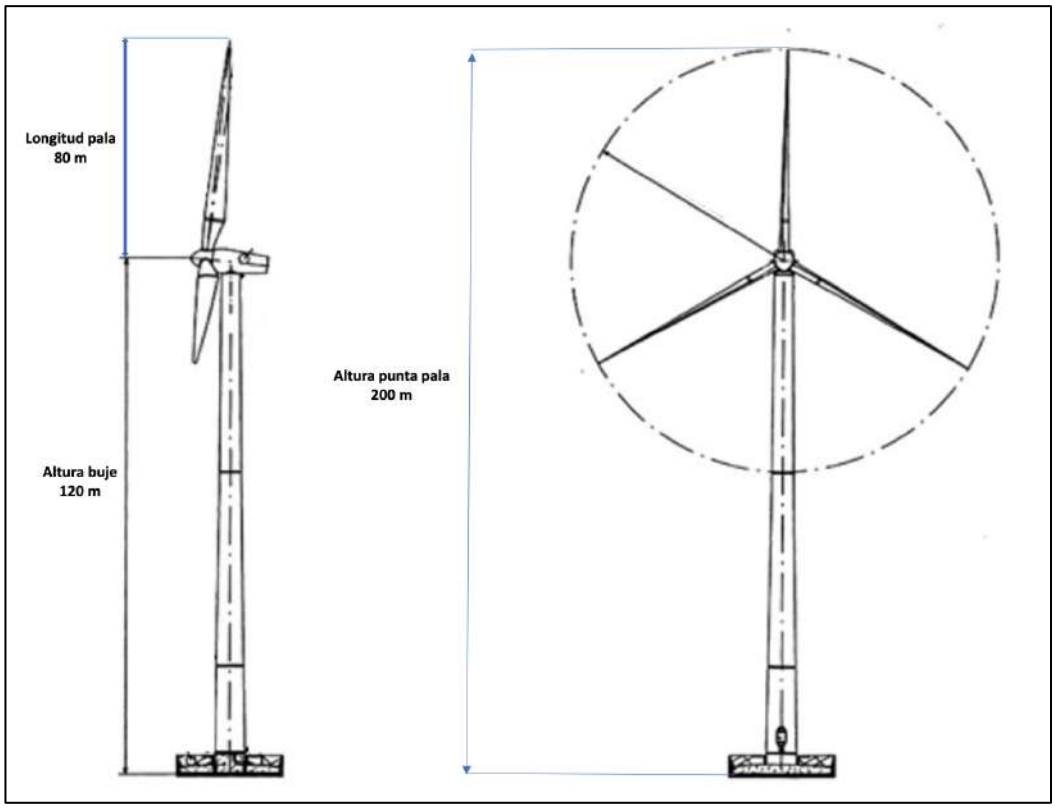


**Figura 5. Alzado correspondiente al modelo de aerogenerador**

## 7. ANÁLISIS DE SERVIDUMBRES AERONÁUTICAS

A continuación, se analiza la posible afección del parque eólico a las servidumbres aeronáuticas del Aeródromo Militar de Ablitas, definidas mediante el *Decreto 2039/1967, de 22 de julio,* y a las del Aeropuerto de Zaragoza, definidas mediante el *Decreto 725/1991 de 26 de abril*.

### 7.1. SERVIDUMBRES DE AERÓDROMO

La finalidad de las servidumbres de aeródromo es definir el espacio aéreo que debe mantenerse libre de obstáculos alrededor de un aeropuerto para que puedan llevarse a cabo con seguridad las operaciones de aeronaves previstas y evitar que el aeropuerto pueda quedar inutilizado por la multiplicidad de obstáculos en sus alrededores. Esto se logra mediante una serie de superficies limitadoras de obstáculos que marcan los límites hasta donde los objetos pueden proyectarse en el espacio aéreo sin que afecten a las operaciones.

### 7.2. SERVIDUMBRES RADIOELÉCTRICAS

Las servidumbres radioeléctricas son aquellas que garantizan el correcto funcionamiento de las instalaciones radioeléctricas, del que depende en gran parte la regularidad del tráfico aéreo.

### 7.3. SERVIDUMBRES DE OPERACIÓN

Las servidumbres de operación de aeronaves son aquellas necesarias para garantizar las diferentes fases de las maniobras de aproximación por instrumentos a un aeródromo.

### 7.4. EVALUACIÓN DE SERVIDUMBRES AERONÁUTICAS CIVILES

El Parque Eólico se ubica fuera de la proyección ortogonal de las servidumbres aeronáuticas de los aeropuertos civiles más próximos: Logroño, Pamplona y Huesca.

### 7.5. EVALUACIÓN DE SERVIDUMBRES AERONÁUTICAS MILITARES

A fecha del presente informe no existen publicadas unas superficies de servidumbres aeronáuticas para el Aeródromo de Ablitas. Sí existe el Decreto 2039/1967, de 22 de julio, -ver Anexo 1.1- donde no se establecen los datos de umbrales, punto de referencia ni elevaciones, necesarios para el establecimiento de unas superficies de protección. Además, este decreto es previo al decreto general de servidumbres aeronáuticas, D584/1972.

Con fecha de octubre de 2019, el Ejército del Aire publica Ficha Informativa con el objetivo de actualizar las servidumbres aeronáuticas del Aeródromo Militar de Ablitas -ver Anexo 1.2- en la que se indica que "*la actualización de dichas servidumbres se realizará en el plazo de seis años*". A fecha del presente Estudio no se han publicado unas servidumbres actualizadas para el Aeródromo Militar de Ablitas, por lo que no resulta posible su análisis.

Se concluye, por tanto, que el Parque Eólico no afecta a las servidumbres aeronáuticas de la Base Aérea de Ablitas.

Además, se comprueba en INSIGNIA que existen multitud de parques ya instalados y autorizados en las proximidades del aeródromo de Ablitas, con elevaciones más restrictivas que las propuestas para el Parque Eólico (la elevación máxima propuesta para el parque objeto de estudio es de 1690 ft, correspondiente al aerogenerador Hornazos y en la imagen se observan aerogeneradores instalados que alcanzan los 1870 ft).

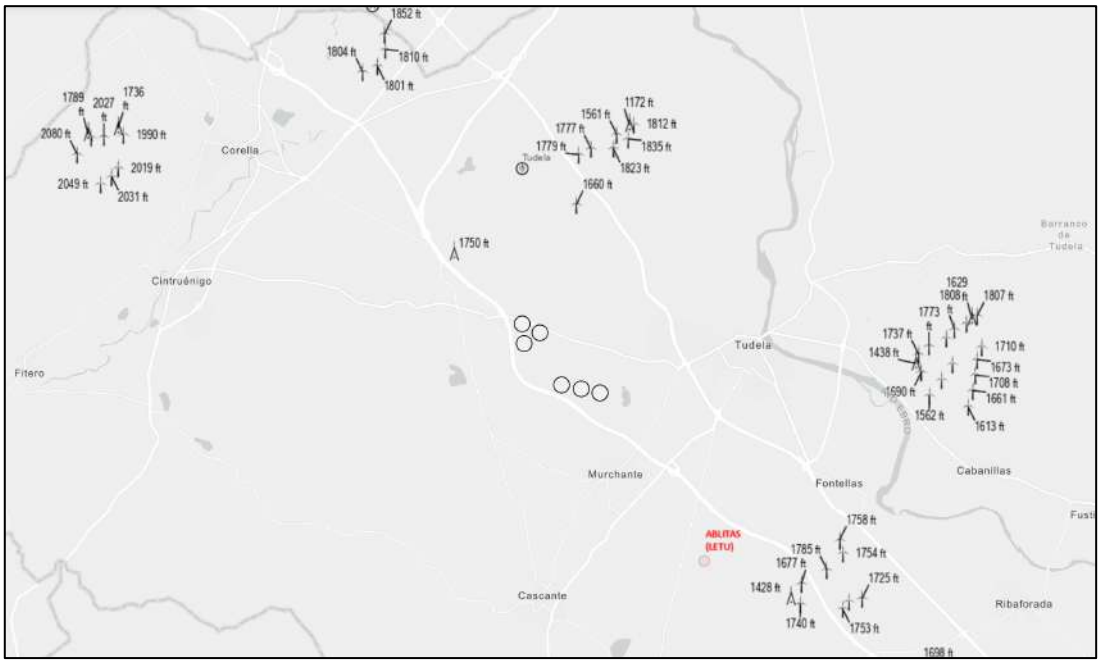


**Figura 6. Parques eólicos en las proximidades del aeródromo de Ablitas**

Se comprueba que el Parque Eólico se ubica fuera de la proyección ortogonal de las servidumbres militares correspondientes a la Base Aérea de Zaragoza.

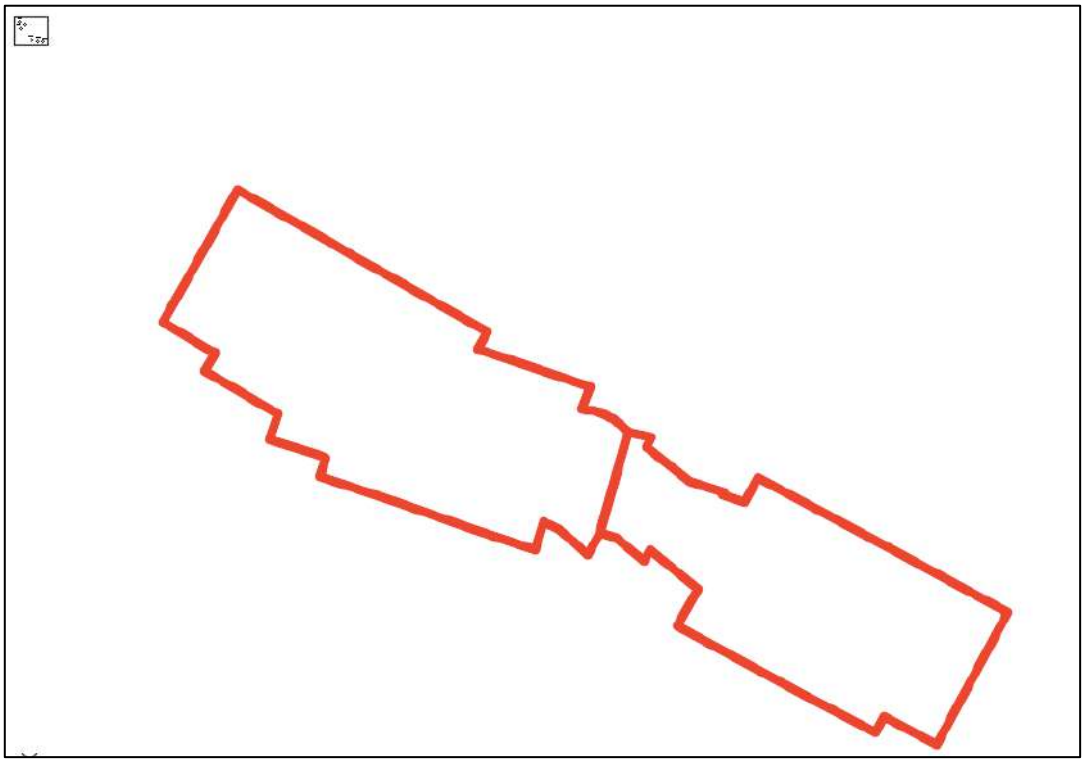

**Figura 7. Ubicación del parque eólico respecto a las servidumbres aeronáuticas militares de la Base Aérea de Zaragoza**

# 8. PROCEDIMIENTOS INSTRUMENTALES DE VUELO

## 8.1. AERÓDROMO MILITAR DE ABLITAS

A fecha de realización del presente informe, el aeródromo militar de Ablitas no dispone de información general del aeródromo, distancias declaradas, ayudas radioeléctricas ni de procedimientos instrumentales publicados en el AIP-España. Se analizan los correspondientes a la Base Aérea de Zaragoza, al ser la más próxima al Parque Eólico.

## 8.2. BASE AÉREA DE ZARAGOZA

Debido a la distancia a la Base Aérea de Zaragoza, en este capítulo se analiza la posible afección a los procedimientos instrumentales publicados en el AIP-España para la Base Aérea de Zaragoza, actualizado hasta las enmiendas AIRAC 05/24 (13-JUN-24) y AMDT 381/24 (13-JUN-24). A continuación, se muestra la información general del Aeropuerto, distancias declaradas, ayudas radioeléctricas y cartas aeronáuticas:

| Punto | Elevación (m/ft) | Coordenadas (ETRS89) |
|---|---|---|
| ARP | 263 / 862 | 403958N 0010230W |
| THR 12L | 251 / 823 | 414008.62N 0010223.40W |
| THR 30R | 254 / 834 | 413919.42N 0010029.94W |
| THR 12R | 254 / 834 | 414048.74N 0010456.54W |
| THR 30L | 263 / 862 | 413948.46N 0010237.37W |

**Tabla 3. Información general de la Base Aérea de Zaragoza**

| RWY | TORA (m) | TODA (m) | ASDA (m) | LDA (m) |
|---|---|---|---|---|
| 12L | 3032 | 3722 | 3332 | 3032 |
| 30R | 3032 | 3032 | 3217 | 3032 |
| 12R | 3718 | 4568 | 4018 | 3718 |
| 30L | 3718 | 4568 | 4018 | 3718 |

**Tabla 4. Distancias declaradas de la Base Aérea de Zaragoza**

| Instalación | Frecuencia | Coordenadas (ETRS89) | Elevación (m/ft) |
|---|---|---|---|
| VOR (0°) ZAR | 113.000 MHz | 413928.4N 0010151.1W | - |
| DME ZAR | CH 77X | 413928.4N 0010151.1W | 270 / 886 |
| TACAN (0°) ZZA | CH 64X | 414037.6N 0010330.6W | 240 / 787 |
| NDB (0°) ZRZ | 389.000 kHz | 414349.9N 0011136.0W | - |
| LOC 30R (0°) IZZA | 109.500 MHz | 414017.0N 0010242.8W | - |
| GP 30R | 332.600 MHz | 413920.9N 0010043.8W | - |
| ILS/DME 30R IZZA (ILS CAT II/III) | CH 32X | 413920.9N 0010043.8W | 255 / 837 |

**Tabla 5. Ayudas radioeléctricas de la Base Aérea de Zaragoza**

Se procede al análisis de las siguientes cartas aeronáuticas publicadas en AIP-España:

| Identificación AIP | Procedimiento | RWY | Fecha Publicación |
|---|---|---|---|
| AD 2 - LEZG SID 1.1 | Salida Normalizada | 12 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG SID 2.1 | Salida Normalizada | 30 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG DEP 1.1 | Salida | 12/30 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG DEP 2.1 | Salida | 12/30 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG STAR 1.1 | Llegada Normalizada | 12 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG STAR 2.1 | Llegada Normalizada | 30 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG CDA 1.1 | Llegada. Descenso continuo | 12R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG CDA 2.1 | Llegada. Descenso continuo | 30R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG ARR 1.1 | Llegada | 12/30 | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/1 | Aproximación VOR | 12R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/2 | Aproximación NDB Z | 12R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/3 | Aproximación NDB Y | 12R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/4 | Aproximación TACAN | 12R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/5 | Aproximación HI-TACAN | 12R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/6 | Aproximación VOR/DME | 30L | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/7 | Aproximación ILS/DME CAT II&III | 30R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/8 | Aproximación LOC | 30R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/9 | Aproximación VOR | 30R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/10 | Aproximación TACAN | 30R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG IAC/11 | Aproximación HI-TACAN | 30R | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG VAC/1.1 | Aproximación Visual | - | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| AD 2 - LEZG VAC/2.1 | Aproximación Visual | - | WEF 13-JUN-24 (AIRAC AMDT 05/24) |
| ENR 3.1-1 | Rutas ATS Convencionales | - | AMDT 381/24 (13-JUN-24) |
| TMA BARCELONA ATCSMAC ENR 6.2-1 | Carta de Altitud Mínima de Vigilancia ATC - OACI | - | AMDT 381/24 (13-JUN-24) |

**Tabla 6. Cartas aeronáuticas de la de la Base Aérea de Zaragoza**

Para cada una de estas cartas se han analizado todas las maniobras publicadas y su posible afección respecto al parque eólico objeto de estudio.

En las siguientes tablas se resume el escenario más restrictivo, correspondiente al caso en el que existe un menor margen entre la altitud mínima de procedimiento y la elevación de la parcela para la que se da esa condición.

## 8.3. ANÁLISIS DE PROCEDIMIENTOS INSTRUMENTALES

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| AD 2 - LEZG SID 1.1 | 12 | CMA3D | NO | - | - | - | - | - | - | - |
| | | GRAUS2H | NO | - | - | - | - | - | - | - |
| | | MARIO2C | NO | - | - | - | - | - | - | - |
| | | PONEN2A | NO | - | - | - | - | - | - | - |
| | | SURCO2C | NO | - | - | - | - | - | - | - |
| | 12/30 | MSA ZAR | NO | - | - | - | - | - | - | - |
| | 30 | ALEPO2B | SÍ | NDB ZRZ - ALEPO | TODOS 1690 / 515 | 1630 / 497 | 7500 / 2286 | 4180 / 1274 | NO | 5870 / 1789 |
| | | CMA2E | NO | - | - | - | - | - | - | - |
| | | GRAUS1M | NO | - | - | - | - | - | - | - |
| | | MARIO1D | NO | - | - | - | - | - | - | - |
| | | PONEN1B | NO | - | - | - | - | - | - | - |
| | | SURCO1D | NO | - | - | - | - | - | - | - |
| | | SURCO1E | NO | - | - | - | - | - | - | - |
| AD 2 - LEZG DEP 1.1 | 12 | BARDENAS | NO | - | - | - | - | - | - | - |
| | | TANGO | NO | - | - | - | - | - | - | - |
| | 12 / 30 | MSA ZZA | NO | - | - | - | - | - | - | - |
| | 30 | BARDENAS | NO | - | - | - | - | - | - | - |
| | | TANGO | NO | - | - | - | - | - | - | - |

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| AD 2 - LEZG DEP 2.1 | 12 | ZULU | SÍ | R180 PPN | TODOS 1690 / 515 | 2000 / 610 | 8000 / 2438 | 4310 / 1314 | NO | 6000 / 1829 |
| | 12 / 30 | MSA ZZA | NO | - | - | - | - | - | - | - |
| | 30 | VICTOR | NO | - | - | - | - | - | - | - |
| | | ZULU | SÍ | R180 PPN | TODOS 1690 / 515 | 2000 / 610 | 8000 / 2438 | 4310 / 1314 | NO | 6000 / 1829 |

**Tabla 7. Análisis de las afecciones sobre los Procedimientos Instrumentales de Salida. Base Aérea de Zaragoza**

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| AD 2 - LEZG STAR 1.1 | 12 | ALEPO3A | SÍ | ALEPO - NDB ZRZ | TODOS 1690 / 515 | 984 / 300 | 5000 / 1524 | 2326 / 709 | NO | 4016 / 1224 |
| | | BRITO1A | NO | - | - | - | - | - | - | - |
| | | CMA2A | NO | - | - | - | - | - | - | - |
| | | CMA2B | NO | - | - | - | - | - | - | - |
| | | GRAUS1U | NO | - | - | - | - | - | - | - |
| | | LOBAR1U | NO | - | - | - | - | - | - | - |
| | | MLA1K | NO | - | - | - | - | - | - | - |
| | | MLA1L | NO | - | - | - | - | - | - | - |
| | | MARIO1A | NO | - | - | - | - | - | - | - |
| | | SURCO1A | NO | - | - | - | - | - | - | - |
| | 12 / 30 | Espera VOR/DME ZAR 108 | NO | - | - | - | - | - | - | - |

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Espera VOR/DME ZAR 319 | NO | - | - | - | - | - | - | - |
| | | Espera VOR/DME ZAR 327 | NO | - | - | - | - | - | - | - |
| | | Espera BUROV | NO | - | - | - | - | - | - | - |
| | | Espera NDB TON | NO | - | - | - | - | - | - | - |
| | | Espera NDB ZRZ | NO | - | - | - | - | - | - | - |
| | | MSA ZAR | NO | - | - | - | - | - | - | - |
| | 30 | BRITO1A | NO | - | - | - | - | - | - | - |
| | | CMA2B | NO | - | - | - | - | - | - | - |
| | | CMA3C | NO | - | - | - | - | - | - | - |
| | | GRAUS2V | NO | - | - | - | - | - | - | - |
| | | LOBAR2V | NO | - | - | - | - | - | - | - |
| | | MLA1L | NO | - | - | - | - | - | - | - |
| | | MLA2M | NO | - | - | - | - | - | - | - |
| | | MLA2Q | NO | - | - | - | - | - | - | - |
| | | MARIO2B | NO | - | - | - | - | - | - | - |
| | | SURCO2B | NO | - | - | - | - | - | - | - |
| AD 2 - LEZG CDA 1.1 | 12R | ALEPO2DCA | SÍ | R-315 ZAR | TODOS 1690 / 515 | 984 / 300 | 5000 / 1524 | 2326 / 709 | NO | 4016 / 1224 |
| | | CMA2DCA | NO | - | - | - | - | - | - | - |

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **GRAUS1DCA** | **NO** | - | - | - | - | - | - | - |
| | | **LOBAR1DCA** | **NO** | - | - | - | - | - | - | - |
| | | **MLA1DCA** | **NO** | - | - | - | - | - | - | - |
| | | **RONKO1DCA** | **NO** | - | - | - | - | - | - | - |
| | | **SURCO1DCA** | **NO** | - | - | - | - | - | - | - |
| | | **XEMIL1DCA** | **NO** | - | - | - | - | - | - | - |
| | | **MSA ZAR** | **NO** | - | - | - | - | - | - | - |
| **AD 2 - LEZG CDA 2.1** | **30R** | **ALEPO2DCB** | SÍ | R-315 ZAR | TODOS 1690 / 515 | 984 / 300 | 5000 / 1524 | 2326 / 709 | **NO** | 4016 / 1224 |
| | | **CMA2DCB** | **NO** | - | - | - | - | - | - | - |
| | | **GRAUS1DCB** | **NO** | - | - | - | - | - | - | - |
| | | **LOBAR1DCB** | **NO** | - | - | - | - | - | - | - |
| | | **MLA2DCB** | **NO** | - | - | - | - | - | - | - |
| | | **RONKO1DCB** | **NO** | - | - | - | - | - | - | - |
| | | **SURCO1DCB** | **NO** | - | - | - | - | - | - | - |
| | | **XEMIL1DCB** | **NO** | - | - | - | - | - | - | - |
| | | **MSA ZAR** | **NO** | - | - | - | - | - | - | - |
| **AD 2 - LEZG ARR 1.1** | **12** | **BARDENAS** | **NO** | - | - | - | - | - | - | - |
| | **30** | **BARDENAS** | **NO** | - | - | - | - | - | - | - |
| | **12 / 30** | **MSA ZZA** | **NO** | - | - | - | - | - | - | - |

**Tabla 8. Análisis de las afecciones sobre los Procedimientos Instrumentales de Llegada. Base Aérea de Zaragoza**

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| **AD 2 - LEZG IAC/1** | **12R** | **VOR** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/2** | **12R** | **NDB Z** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/3** | **12R** | **NDB Y** | SÍ | MSA NDB ZRZ | TODOS 1690 / 515 | 984 / 300 | 4500 / 1372 | 1826 / 557 | **NO** | 3516 / 1072 |
| | | | NO | Resto de fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/4** | **12R** | **TACAN** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/5** | **12R** | **HI-TACAN** | SÍ | R-181 DME ZZA | TODOS 1690 / 515 | 984 / 300 | 20000 / 6096 | 17326 / 5281 | **NO** | 19016 / 5796 |
| | | | NO | Resto de fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/6** | **30L** | **VOR/DME** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/7** | **30R** | **ILS/DME CAT II & III** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/8** | **30R** | **LOC** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/9** | **30R** | **VOR** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |
| **AD 2 - LEZG IAC/10** | **30R** | **TACAN** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |

| Carta AIP-España | RWY | Maniobra | Sobrevuelo (SÍ/NO) | Tramo | Obstáculo (ft/m) | MOC (ft/m) | Altitud Mínima (ft/m) | Margen (ft/m) | Afección (SÍ/NO) | Alt Max Obs (ft/m) |
|---|---|---|---|---|---|---|---|---|---|---|
| **AD 2 - LEZG IAC/11** | **30R** | **HI-TACAN** | NO | Todas las fases de la aproximación | - | - | - | - | - | - |

**Tabla 9. Análisis de las afecciones sobre los Procedimientos de Aproximación Instrumental. Base Aérea de Zaragoza**

Del análisis anterior, se concluye que el Parque Eólico no afecta a los procedimientos de vuelo instrumental (salidas, llegadas y aproximaciones) publicados en AIP-España para la Base Aérea de Zaragoza, al cumplirse el margen de franqueamiento de obstáculos correspondiente a cada maniobra, según los criterios de los PANS-OPS de OACI.

## 8.4. MÍNIMOS DE APROXIMACIÓN INSTRUMENTAL RADAR (USO EXCLUSIVO MILITAR)

En AIP-España AD 2-LEZG 12 (WEF 13-JUN-24 (AIRAC AMDT 05/24)) se detallan los mínimos de aproximación instrumental radar, de uso exclusivo militar y que se protegen mediante las superficies asociadas de Aproximación de precisión PAR, *Capítulo 5, Sección 1, PARTE II* del DOC. 8168, y de Aproximación de no precisión SRE, *Capítulo 6, Sección 2, PARTE II* del DOC. 8168.

MINIMOS DE APROXIMACIÓN INSTRUMENTAL RADAR (USO EXCLUSIVO MILITAR)
RADAR INSTRUMENT APPROACH MINIMA (EXCLUSIVE MILITARY USE).

| | RWY | GP/TCH/RPI | CAT | DA/MDA-VIS | HAT/HAA | CEIL-VIS |
|---|---|---|---|---|---|---|
| PAR | 30R | 3° / 52 / 983 | ALL | 1034 - 800 m | 200 | (200 - 800 m) |
| PAR | 12L | 3° / 60 / 1152 | ALL | 1023 - 800 m | 200 | (200 - 800 m) |
| SRE | 30R | | A - B | 1490 - 800* m | 647 | (700 - 800* m) |
| SRE | 30R | | C | 1490 - 2000* m | 647 | (700 - 2000* m) |
| SRE | 30R | | D - HPMA | 1490 - 2400* m | 647 | (700 - 2400* m) |
| SRE | 30R | | E | 1490 - 2800* m | 647 | (700 - 2800* m) |
| SRE | 12L | | A - B | 1250 - 1200** m | 426 | (400 - 1200** m) |
| SRE | 12L | | C - D - HPMA | 1250 - 1600** m | 426 | (400 - 1600** m) |
| SRE | 12L | | E | 1250 - 2000** m | 426 | (400 - 2000** m) |
| SRE | 30L | | A - B | 1550 - 1600 m | 684 | (700 - 1600 m) |
| SRE | 30L | | C | 1550 - 3200 m | 684 | (700 - 3200 m) |
| SRE | 30L | | D - HPMA | 1550 - 3600 m | 684 | (700 - 3600 m) |
| SRE | 30L | | E | 1550 - 4000 m | 684 | (700 - 4000 m) |
| SRE | 12R | | A - B | 1340 - 800* m | 501 | (500 - 800* m) |
| SRE | 12R | | C - D - HPMA | 1340 - 1600* m | 501 | (500 - 1600* m) |
| SRE | 12R | | E | 1340 - 2000* m | 501 | (500 - 2000* m) |
| CIR | | | A | 1550 - 1600 m | 687 | (700 - 1600 m) |
| CIR | | | B | 1610 - 2000 m | 747 | (800 - 2000 m) |
| CIR | | | HPMA | 2000 - 3200 m | 1137 | (1200 - 3200 m) |
| CIR | | | C - D | 2600 - 4800 m | 1737 | (1800 - 4800 m) |
| CIR | | | E | 2700 - 4800 m | 1837 | (1900 - 4800 m) |

**Figura 8. Mínimos de aproximación instrumental radar (uso exclusivo militar)**

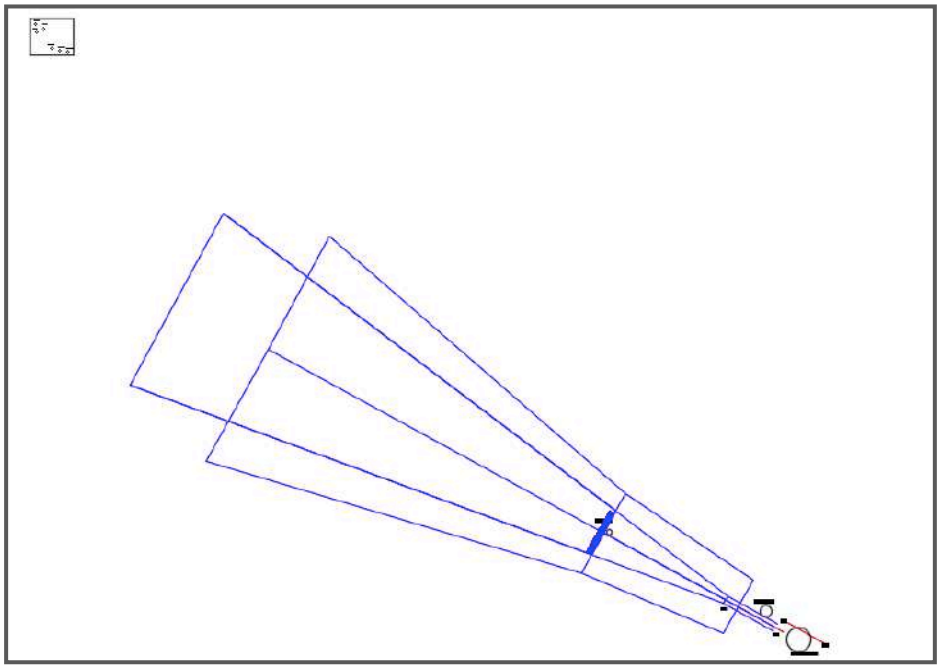

**Figura 9. Superficies de protección PAR y SRE**

El parque eólico se ubica fuera de las áreas de protección de dichas superficies por lo que se puede concluir que no existe afección a los mínimos operativos.

## 8.5. CARTA DE ALTITUD MÍNIMA DE VIGILANCIA ATC

En el AIP-España, no existe una Carta de Altitud Mínima de Vigilancia ATC para el aeródromo militar de Ablitas ni para la Base Aérea de Zaragoza. Además, las cartas de altitud mínima de vigilancia ATC publicadas en el AIP España están alejadas de la ubicación del Parque Eólico.

Las altitudes mínimas de sector establecidas garantizan un margen mínimo de 984 ft por encima de todos los obstáculos situados a menos de 3 NM del límite del sector hasta 20 NM de la antena radar o a menos de 5 NM del límite cuando se trate de distancias de más de 20 NM desde la antena radar (Parte II, Sección 2, Capítulo 6 del Doc. 8168 de OACI).

Se concluye que al situarse el parque eólico fuera de las cartas de Altitud Mínima de Vigilancia ATC publicadas en AIP, no existirá afección por parte de los aerogeneradores sobre las mismas.

## 8.6. ALTITUD MÍNIMA DE ÁREA (AMA)

El Parque Eólico se ubica en el sector de 6500 ft, y en el área tope de los sectores de 9600 ft de la carta de Altitud Mínima de Área (AMA) publicada en AIP-España.

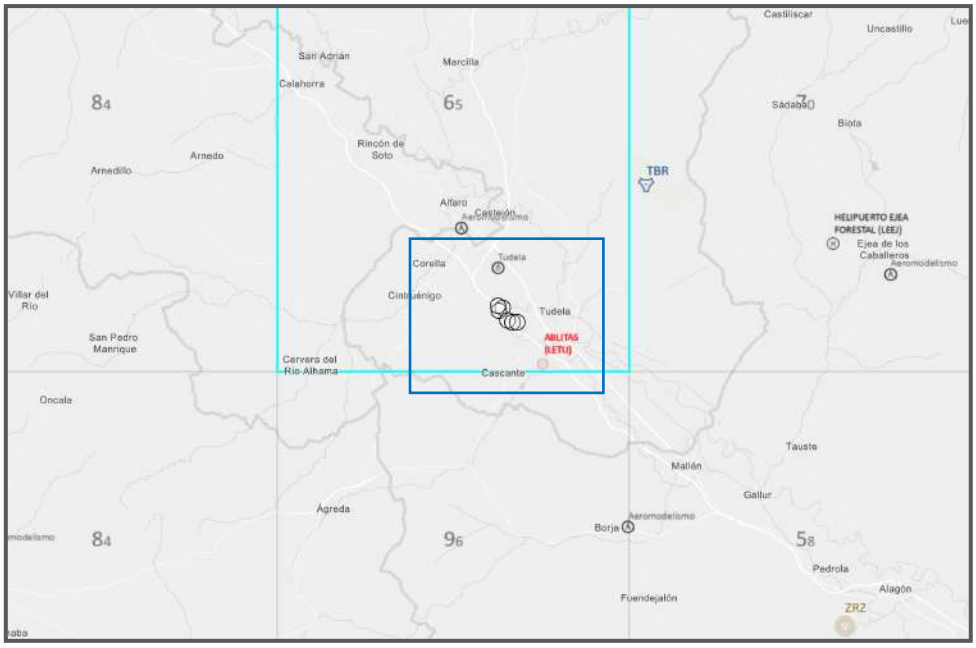


**Figura 10. Altitud Mínima de Área (AMA)**

| Obstáculos (ft/m) | MOC (ft/m) | Altitud Mínima de Área (ft/m) | Comprobación Hobs+MOC<Altitud Mínima (ft) |
|---|---|---|---|
| TODOS 1690 / 515 | 984 / 300 | 6500 / 1981 | 1690 + 984 = 2674 < 6500 |
| TODOS 1690 / 515 | 984 / 300 | 9600 / 2926 | 1690 + 984 = 2674 < 9600 |

**Tabla 10. Análisis de la afección a la Altitud Mínima de Área (AMA)**

Por lo tanto, se concluye que el parque eólico objeto de estudio no afecta al mínimo operativo definido, según los criterios del PANS-OPS de OACI.

## 8.7. AEROVÍAS DE ESPACIO AÉREO INFERIOR

El parque se ubica bajo del área de protección de la aerovía del espacio aéreo inferior UM176 (FL 145).

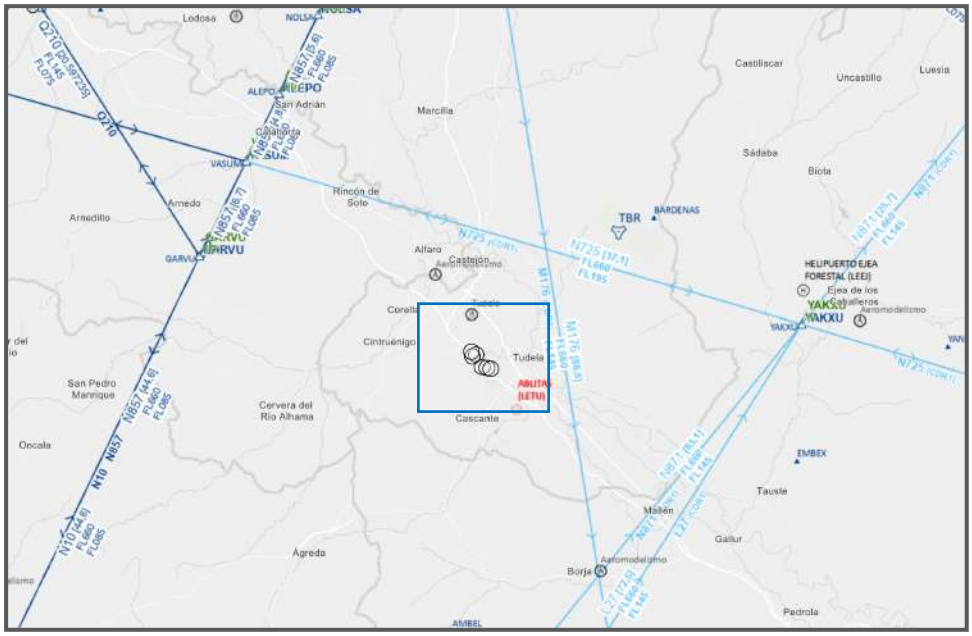


**Figura 11. Aerovías del Espacio Aéreo Inferior**

Considerando esta restricción de altitud y el MOC correspondiente:

| Aerovías | Obstáculo (ft / m) | MOC (ft/m) | Altitud (ft/m) | Comprobación Hobs+MOC<Altitud Mínima (ft) |
|---|---|---|---|---|
| M176 | TODOS 1690 / 515 | 984 / 300 | 14500 / 4420 | 1690 + 984 = 2674 < 14500 |

**Tabla 11. Análisis de la afección sobre las Aerovías del Espacio Aéreo Inferior**

Por lo tanto, se concluye que el parque eólico cumple con los criterios de franqueamiento de obstáculos de los PANS-OPS de OACI, respecto a las aerovías analizadas.

## 9. PROCEDIMIENTOS VISUALES

En los vuelos VFR, el piloto es responsable de separarse de otros tráficos y de los obstáculos naturales y artificiales que haya en el entorno de la aeronave *(Anexo 2 OACI. Capítulo 2, 2.3.1. Capítulo 3, 3.1.2, 3.2. Capítulo 4, 4.6)*. No obstante, para que este tipo de operaciones puedan realizarse con márgenes de seguridad adecuados, es necesario que en el entorno próximo al aeródromo la configuración de obstáculos permita realizar las maniobras de aproximación y salida siguiendo los procedimientos visuales estándar, que tienen en cuenta tanto las actuaciones de la aeronave como las técnicas de vuelo y los tiempos de respuesta del piloto.

En este apartado se analizan las posibles afecciones operativas de los obstáculos sobre los procedimientos de vuelo visual publicados en AIP España para la Base Aérea de Zaragoza.

### 9.1. COMPATIBILIDAD DEL ESPACIO AÉREO CIRCUNDANTE

A continuación, se muestra la situación del parque eólico respecto del Aeródromo Militar de Ablitas:

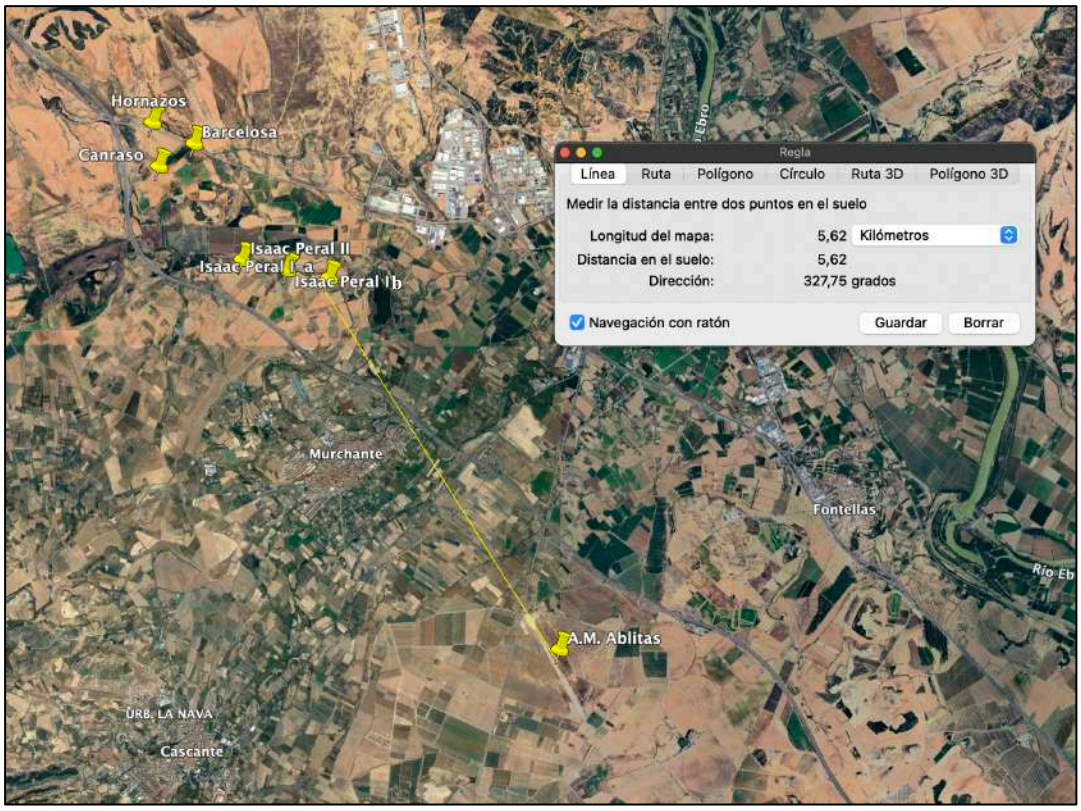


**Figura 12. Ubicación del parque eólico respecto del Aeródromo Militar de Ablitas**

En la siguiente tabla se detalla la distancia a la que se encuentran los aeropuertos del espacio aéreo circundante respecto del parque eólico objeto de estudio:

| Aeropuertos | Distancia al obstáculo (km) |
|---|---|
| Ablitas | 5.6 |
| Zaragoza | 66.9 |

**Tabla 12. Distancia a los aeropuertos del espacio aéreo circundante**

Los aeródromos, helipuertos y campos de vuelo más próximos a la ubicación de los aerogeneradores son:

| Aeropuertos | Distancia al obstáculo (km) |
|---|---|
| Aeródromo Tudela* | 4.5 |

**Sin servidumbres Aeronáuticas publicadas*

**Tabla 13. Distancia a Aeródromos/Helipuertos/Campos de Vuelo/Aeromodelismo**

Las radioayudas más cercanas al Parque Eólico, se ubican a las distancias indicadas en la siguiente tabla:

| Radioayudas | Distancia al obstáculo (km) |
|---|---|
| TACAN TBR – Bárdenas Reales- | 22.3 |
| NDB ZRZ –Zaragoza- | 52.3 |

**Tabla 14. Distancia a las radioayudas del espacio aéreo circundante**

A continuación, se muestra la situación relativa del parque eólico respecto los distintos elementos del espacio aéreo circundante.

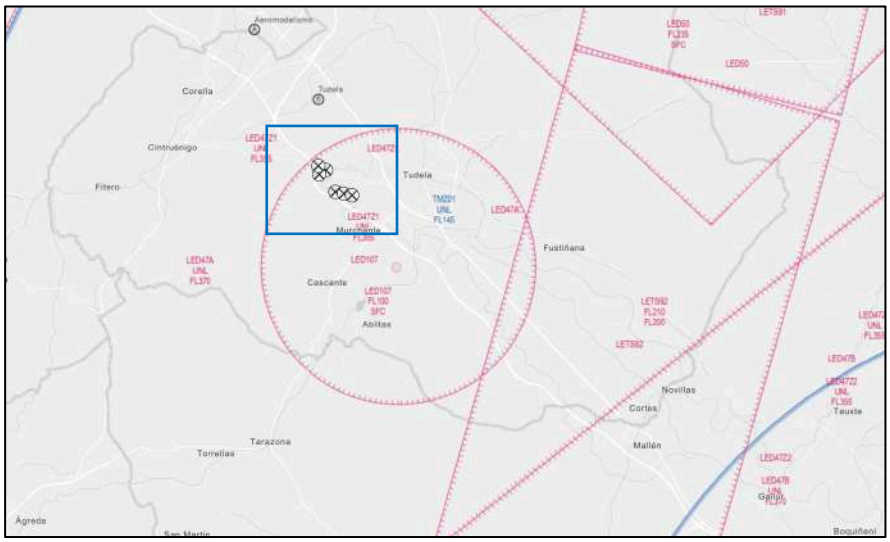


**Figura 13. Ubicación del parque eólico respecto del Espacio Aéreo Circundante**

El emplazamiento propuesto para el parque eólico se halla en:

**- TMA/CTA:** TACC119.3
TMA ZARAGOZA
C FL195 - FL245; D 3300ft AGL - FL195; E 1000ft AGL - 3300ft AGL
Excluyendo el FIZ HUESCA ÁREA 2.

**- FIR/UIR:** Upper Flight Information Region LECM, C FL195-FL660; G FL660-UNL
Flight Information Region LECM, C FL145-FL195; G SFC-FL145

Analizando las zonas LEP/D/R y TSA, se determina que los obstáculos estudiados se ubican bajo las siguientes zonas prohibidas, restringidas, peligrosas o de fauna sensible:

- **LED107**
  SFC-FL100
  Definida mediante un círculo de 5NM centrado en 420030N 0013716W
  Se anunciará por NOTAM la ampliación del límite superior hasta FL120 // Ejercicios de paracaidismo, lanzamiento de carga y maniobras de aproximación de aeronaves. Se anunciará por NOTAM cualquier otra actividad. Coordinación con ZARAGOZA APP.

Es decir, la zona LED 107 se define desde el suelo hasta el nivel de vuelo 100, correspondiente a 10000 ft. El aerogenerador de mayor elevación del parque eólico es el Hornazos, con 1690 ft, por lo que existe un margen de 8310 ft (2533 m) hasta el techo de la zona LED 107.

En cuanto a las actividades llevadas a cabo en el interior de la propia zona peligrosa: ejercicios de paracaidismo, lanzamiento de carga y maniobras de aproximación de aeronaves, cabe indicar que tanto la Agencia Estatal de Seguridad Aérea como el Ministerio de Defensa han autorizado parques eólicos de forma previa en esa misma zona LED y con elevaciones máximas mucho más restrictivas, que alcanzan los 1785 ft, que las propuestas para el Parque Eólico, con un máximo de 1690 ft.

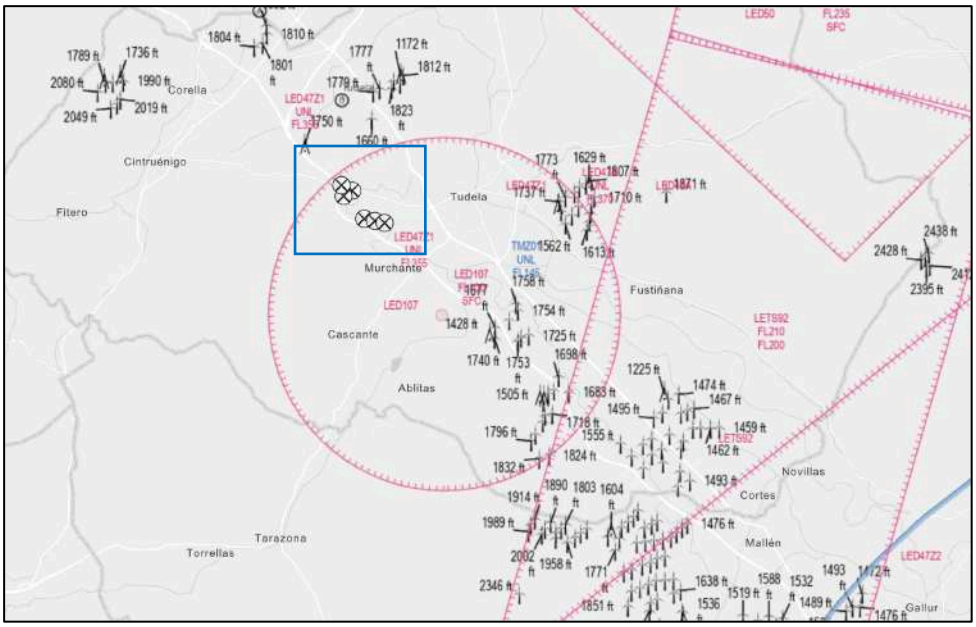


**Figura 14. Ubicación de otros parques eólicos dentro de la zona LED107**

Por tanto, el Ministerio de Defensa ha autorizado de forma previa parques eólicos en el área afectada por la zona LED107, en la que ya se llevaban a cabo las mismas actividades definidas hoy en día, por lo que el parque eólico objeto de estudio no supondría una nueva afección.

- **LED47A**
  FL370-UNL. Área expresamente designada para vuelos supersónicos de aeronaves militares: BTN FL370 - UNL. Ejercicios aéreos. Otra actividad anunciada por NOTAM.

Esta zona peligrosa comienza a un nivel de vuelo 370 (37000 ft) y ascendente, por lo que los aerogeneradores objeto de estudio no suponen una afección a la misma.

- **LED47Z1**
  FL355-UNL. Uso exclusivo para la planificación del vuelo.

Esta zona peligrosa comienza a un nivel de vuelo 355 (35500 ft) y ascendente, por lo que los aerogeneradores objeto de estudio no suponen una afección a la misma.

No se localiza ninguna zona de fauna sensible en las inmediaciones del parque eólico objeto de estudio.

En resumen, no se han identificado afecciones sobre aeropuertos, aeródromos, radioayudas, zonas prohibidas o restringidas ni sobre los elementos de la estructura del espacio aéreo próximo.

## 9.2. ANÁLISIS CARTAS VFR / AD 2 - LEZG VAC 1 Y VAC2

El Aeródromo Militar de Ablitas no dispone de cartas VAC publicadas en el AIP-España. Las más próximas corresponden a las de la Base Aérea de Zaragoza, que cuenta con dos cartas VAC en las que se indica el modo de operación visual para dicho aeródromo.

Por otro lado, según el RD552/2014 y SERA.5005 letra f) apartado 2):

*"Excepto cuando sea necesario para el despegue o el aterrizaje, o cuando se tenga autorización de la autoridad competente, los vuelos VFR no se efectuarán:*

1) *Sobre aglomeraciones de edificios en ciudades, pueblos o lugares habitados, o sobre una reunión de personas al aire libre a una altura menor de 300 m (1000 ft) sobre el obstáculo más alto situado dentro de un radio de 600 m desde la aeronave;*

2) *En cualquier otra parte distinta de la especificada en 1), a una altura menor de 150 m (500 ft) sobre tierra o agua, o 150 m (500 ft) sobre el obstáculo más alto situado dentro de un radio de 150 m (500 ft) desde la aeronave."*

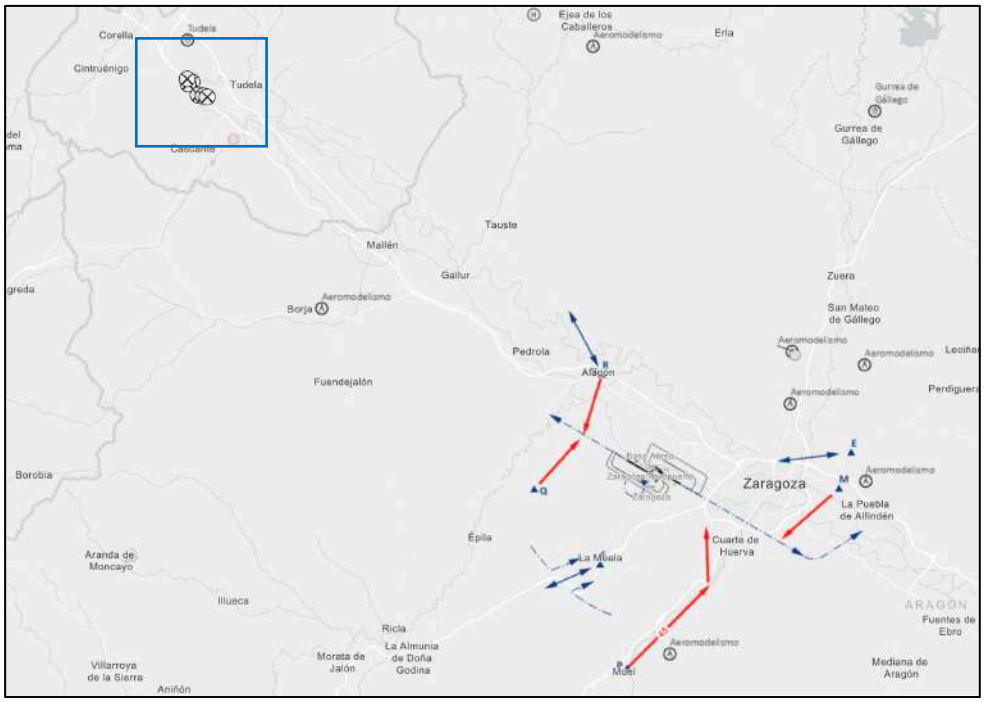


**Figura 15. Ubicación del Parque Eólico respecto de los pasillos visuales de las Cartas de Aproximación Visual VAC 1.1 y VAC 2.1 de la Base Aérea de Zaragoza.**

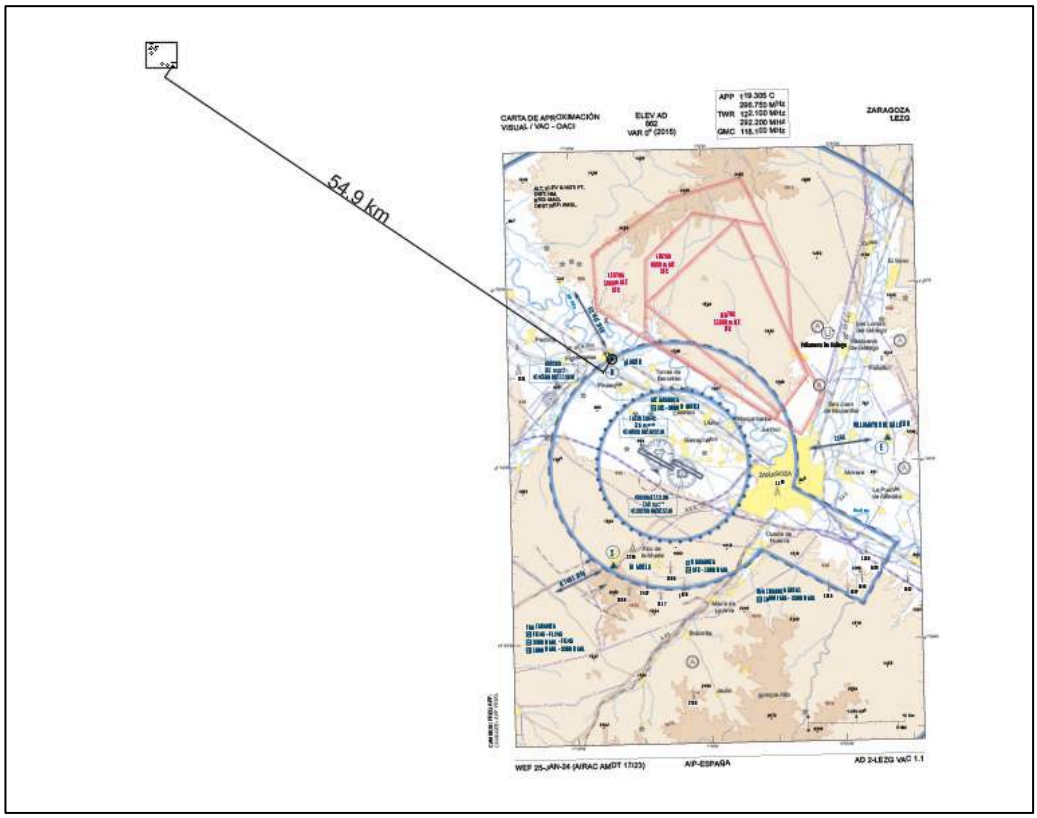


**Figura 16. Carta de Aproximación Visual VAC1 de la Base Aérea de Zaragoza**

En la carta AD 2-LEZG VAC1 (WEF 13-JUN-24 (AIRAC AMDT 05/24)), publicada en AIP-España para la Base Aérea de Zaragoza, se describen los procedimientos de llegada que se apoyan en 3 puntos de notificación, 1 exterior al CTR y 2 interiores. También cuenta con un procedimiento de fallo de comunicaciones y un circuito de tránsito de aeródromo.

Tal y como se observa en la figura anterior, el parque eólico se ubica fuera del CTR de Zaragoza, fuera de los pasillos visuales que se establecen en la carta, siendo el más cercano el definido por el punto de notificación N-ALAGÓN a una distancia aproximada de 54.9 km (área de protección del pasillo considerando una semianchura de 1NM).

Se puede concluir que el parque eólico no supone un obstáculo a la carta VAC1.

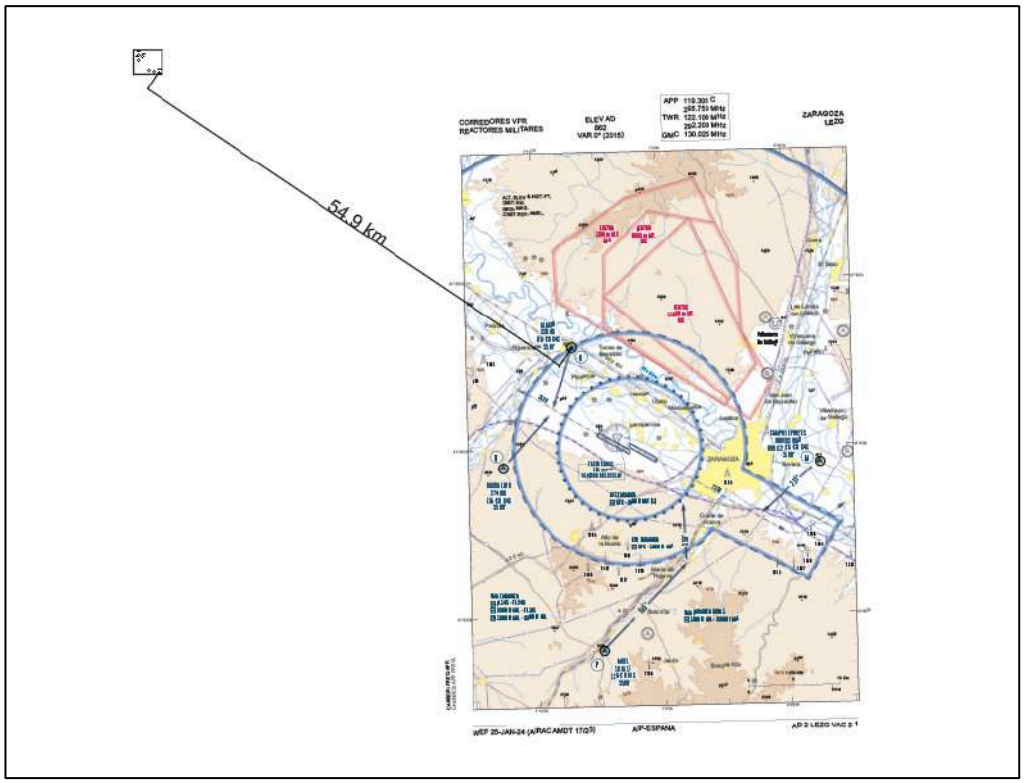


**Figura 17. Carta de Aproximación Visual VAC2 de la Base Aérea de Zaragoza**

En la carta AD 2-LEZG VAC2 (WEF 13-JUN-24 (AIRAC AMDT 05/24)) publicada en AIP-España para la Base Aérea de Zaragoza, se describen los procedimientos de llegada que se apoyan en 4 puntos de notificación, 3 exteriores al CTR y 1 interior. También cuenta con un procedimiento de fallo de comunicaciones y un circuito de tránsito de aeródromo.

Tal y como se indica en la figura anterior, el parque eólico se ubica fuera del CTR de Zaragoza, fuera de los pasillos visuales que se establecen en la carta, siendo el más cercano el definido por el punto de notificación R-ALAGÓN a una distancia aproximada de 54.9 km (área de protección del pasillo considerando una semianchura de 1NM).

Se puede concluir que el parque eólico no supone un obstáculo a la carta VAC2.

### 9.3. OTRA INFORMACIÓN DE UTILIDAD AIP-ESPAÑA (ZARAGOZA AD)

Al no existir información publicada en el AIP-España para el Aeródromo Militar de Ablitas, se analiza la información correspondiente al aeródromo más cercano, Zaragoza AD:

**a) Ítem 21 Procedimientos de atenuación de ruidos**

Según lo expuesto en el Ítem 21 de AIP-España de procedimientos de atenuación de ruidos de la Base Aérea de Zaragoza, AD 2 – LEZG 9 (WEF 13-JUN-24 (AIRAC AMDT 05/24)):

*"PRUEBA DE MOTORES EN TIERRA*
*Las pruebas de motores en tierra se realizarán:*
*- En el puesto de estacionamiento de la plataforma civil si se realiza al ralentí; o*
*- En el apartadero de A-5 a potencias declaradas superiores."*

Con respecto a los procedimientos de atenuación de ruido expuestos en el Ítem 21 del AIP España para la Base Aérea de Zaragoza, no se han detectado afecciones operativas sobre los mismos por parte del parque eólico objeto de estudio.

**b) Ítem 22 Procedimientos de Vuelo**

Con respecto a los procedimientos de vuelo expuestos en el Ítem 22 del AIP España para la Base Aérea de Zaragoza, no se han detectado afecciones operativas sobre los mismos por parte del parque eólico. (El análisis correspondiente al circuito de tránsito puede verse en el apartado 8.3).

## 10. MEDIDAS DE MITIGACIÓN DE RIESGOS, SEÑALIZACIÓN, ILUMINACIÓN Y PUBLICACIÓN EN AIP-ESPAÑA

La señalización y/o iluminación de obstáculos es una medida de mitigación de riesgos para las aeronaves, que facilita la localización del peligro al piloto y permite que el obstáculo pueda ser visto claramente por los pilotos en cualesquiera condiciones meteorológicas y de visibilidad *(Anexo 14 OACI, Capítulo 6 y Doc. 9137 OACI, Parte 6 Capítulo 2)*.

De acuerdo con los criterios establecidos en la Guía de AESA, como norma general, la distancia máxima entre aerogeneradores iluminados debe ser de 900 m, por lo que se propone la señalización y el balizamiento de todos los aerogeneradores del Parque Eólico.

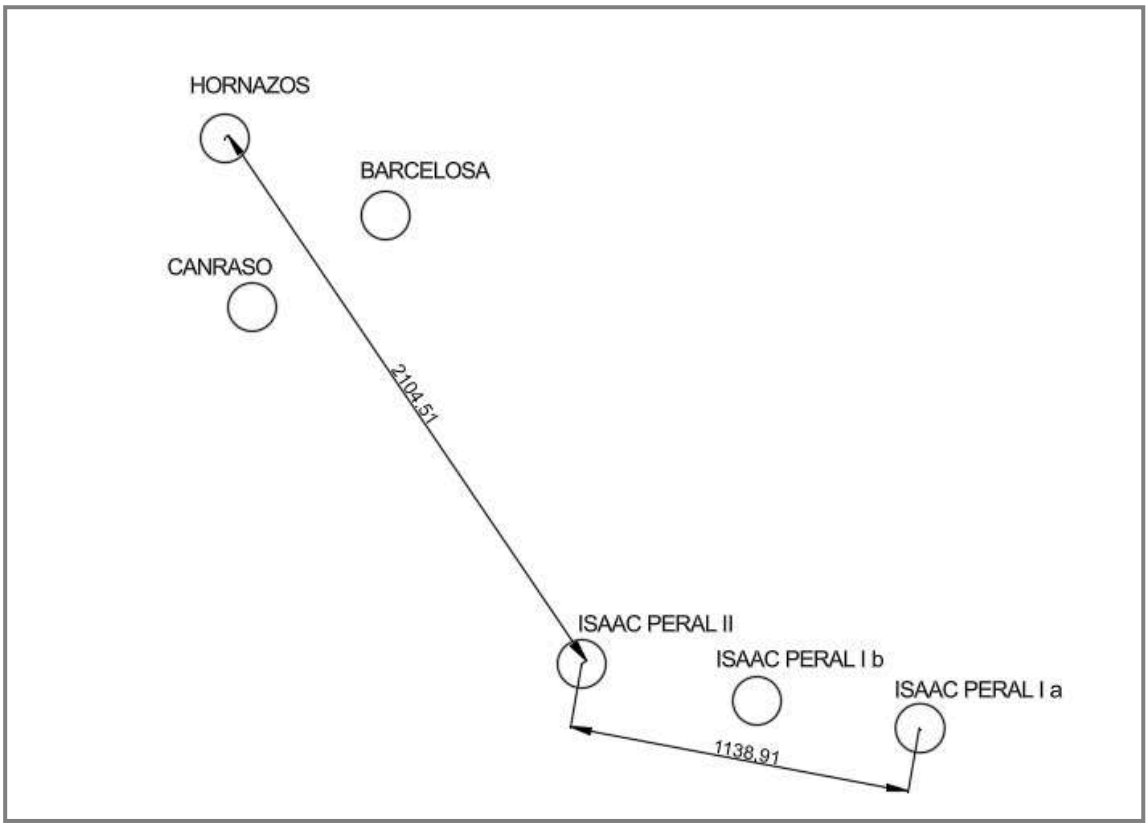


**Figura 18. Propuesta de balizamiento de aerogeneradores Parque Eólico**

La propuesta de señalamiento e iluminación para el Parque Eólico es:

**1).** Señalizar e iluminar el **parque eólico** de acuerdo con los criterios indicados en la Tabla Q-2 del Capítulo Q de las especificaciones de certificación para el diseño de aeródromos *CS-ADR-DSN* del *Reglamento (UE) nº 139/2014 de la Comisión de 12 de febrero de 2014*:

- Se señalizarán todos los aerogeneradores del parque eólico. Para ello, se pintarán íntegramente de color blanco las palas del rotor, la barquilla y los 2/3 superiores del mástil de soporte de todas las turbinas eólicas.

- Se balizarán todos los aerogeneradores con un **sistema dual de media intensidad tipo A / media C**. Durante el día y el crepúsculo (luminancia de fondo superior a 500 cd/m2, y entre 50 cd/m2 y 500 cd/m2, respectivamente) la iluminación será exclusivamente de *mediana intensidad de tipo A*, mientras que de noche (luminancia de fondo inferior a 50 cd/m2) ésta será exclusivamente de *mediana intensidad de tipo C*.

Además de la luz de mediana intensidad instalada en la barquilla, se deberá proporcionar una segunda luz que sirva de alternativa en caso de falla de la luz en funcionamiento. Las luces deberán instalarse asegurándose de que la potencia luminosa de cada luz no quede obstruida por la otra.

La secuencia de parpadeos de las luces de obstáculo de todos los aerogeneradores iluminados debe sincronizarse de manera que la secuencia de pulsos se inicie en 00.00.00 segundos según UTC con un desplazamiento admisible del punto cero de ±50 ms.

**2).** Iluminar la **grúa de montaje** de acuerdo con los criterios indicados en la Tabla Q-2 del Capítulo Q de las especificaciones de certificación para el diseño de aeródromos *CS-ADR-DSN* del *Reglamento (UE) nº 139/2014 de la Comisión de 12 de febrero de 2014*:

- Si la grúa se utiliza en horario nocturno, se iluminará en la parte más alta de la misma con una luz de **media intensidad de tipo C**.

Se adjunta a continuación la Tabla Q-2 del Capítulo Q de las especificaciones de certificación para el diseño de aeródromos CS-ADR-DSN del Reglamento (UE) nº139/2014 de la Comisión de 12 de febrero de 2014:

**Tabla Q-2. Características de las luces de obstáculos**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Intensidad máxima (cd) a una luminancia de fondo dada | | | | Intensidad (cd) a ángulos de elevación dados cuando el elemento luminoso está a igual nivel [d] | | | | |
| Tipo de luz | Color | Tipo de señal/ (régimen de intermitencia) | Más de 500 cd/m² | 50-500 cd/m² | Menos de 50 cd/m² | Difusión mínima del haz [c] | -10° [e] | -1° [f] | ±0° [f] | +6° | +10° |
| Baja intensidad Tipo A (obstáculo fijo) | Rojo | Fija | N/A | 10 mín | 10 mín | 10° | - | - | - | 10 mín [g] | 10 mín [g] |
| Baja intensidad Tipo B (obstáculo fijo) | Rojo | Fija | N/A | 32 mín | 32 mín | 10° | - | - | - | 32 mín [g] | 32 mín [g] |
| Baja intensidad Tipo C (obstáculo móvil) | Amarillo/Azul [a] | Destellos (60-90 fmp) | N/A | 40 mín [b] 400 máx | 40 mín [b] 400 máx | 12° [h] | - | - | - | - | - |
| Baja intensidad Tipo D (vehículo guía) | Amarillo | Destellos (60-90 fmp) | N/A | 200 mín [b] 400 máx | 200 mín [b] 400 máx | 12° [i] | - | - | - | - | - |
| Intensidad mediana Tipo A | Blanco | Destellos (20-60 fmp) | 20 000 [b] ±25% | 20 000 [b] ±25% | 2 000 [b] ±25% | 3° mín | 3% máx | 50% mín 75% máx | 100% mín | - | - |
| Intensidad mediana Tipo B | Rojo | Destellos (20-60 fmp) | N/A | N/A | 2 000 [b] ±25% | 3° mín | - | 50% mín 75% máx | 100% mín | - | - |
| Intensidad mediana Tipo C | Rojo | Fija | N/A | N/A | 2 000 [b] ±20% | 3° mín | - | 50% mín 75% máx | 100% mín | - | - |
| Alta intensidad Tipo A | Blanco | Destellos (40-60 fmp) | 200 000 [b] ±25% | 20 000 [b] ±25% | 2 000 [b] ±25% | 3° - 7° | 3% máx | 50% mín 75% máx | 100% mín | - | - |
| Alta intensidad Tipo B | Blanco | Destellos (40-60 fmp) | 100 000 [b] ±25% | 20 000 [b] ±25% | 2 000 [b] ±25% | 3° - 7° | 3% máx | 50% mín 75% máx | 100% mín | - | - |

[a] Véase CS ADR DSN Q.850, (d) (3).
[b] Intensidad efectiva, determinada de conformidad con el Doc. 9157, Manual de diseño de aeródromos, Parte 4, Ayudas Visuales.
[c] La apertura de haz se define como el ángulo entre dos direcciones en un plano para el cual la intensidad es igual al 50% del valor de tolerancia más bajo de la intensidad que se indica en las columnas 4, 5 y 6. La configuración del haz no es necesariamente simétrica alrededor del ángulo de elevación en el que se produce la intensidad máxima.
[d] Para los ángulos de elevación (verticales) se toma como referencia la horizontal.
[e] Intensidad a cualquier radial horizontal como porcentaje de la intensidad máxima real al mismo radial cuando funciona a las intensidades indicadas en las columnas 4, 5 y 6.
[f] Intensidad a cualquier radial horizontal como porcentaje del valor de tolerancia más bajo de la intensidad indicada en las columnas 4, 5 y 6.
[g] Además de los valores indicados, la intensidad de las luces será suficiente para asegurar la perceptibilidad a ángulos de elevación de entre ±0° y 50°.
[h] La intensidad máxima debe estar ubicada aproximadamente a 2,5° vertical.
[i] La intensidad máxima debe estar ubicada aproximadamente a 17° vertical.

fpm = destellos por minuto; N/A = no se aplica

**Figura 19. Tabla Q-2, Capítulo Q de las especificaciones CS-ADR-DSN, Reglamento (UE) nº 139/2014 de la Comisión de 12 de febrero de 2014**

La propuesta de publicación en el AIP-España para el parque eólico es:

- Comunicar a ENAIRE y a la Agencia Estatal de Seguridad Aérea el plan de obra 6 meses antes del montaje de las turbinas y de la torre meteorológica del parque eólico, de acuerdo con la "*Guía de Comunicación a AESA de datos de obstáculos con altura superior a 100 m*", para su publicación como obstáculos a la navegación aérea en el AIP-España por el Servicio de Información Aeronáutica.

- Comunicar a ENAIRE y a la Agencia Estatal de Seguridad Aérea la instalación definitiva del parque eólico de acuerdo con la "Guía de Comunicación a AESA de datos de obstáculos con altura superior a 100 m", de AESA.

- La medición y comunicación deberá realizarse en los 3 meses siguientes a la instalación de los obstáculos.

- Envío de coordenadas definitivas a ENAIRE. Una vez recibida la respuesta favorable de AESA relativa a los datos de coordenadas definitivas del parque eólico, el promotor deberá enviar, en el plazo de 1 semana, un correo electrónico a ENAIRE (con copia a AESA) adjuntando la documentación indicada en el punto 4.4. de la citada "Guía de Comunicación a AESA de datos de obstáculos con altura superior a 100 m".

  Para: ais@enaire.es
  CC: servidumbres.aesa@seguridadaerea.es

## 11. CONCLUSIONES

De acuerdo con los criterios especificados en el Documento 8168 de OACI (PANS-OPS), RD862/2009, RD369/2023, D584/1972 y RD1838/2009, la instalación de los Parques Eólicos Isaac Peral I-a, PE Isaac Peral I-b y PE Isaac Peral II, asociados a la Subestación Tudela, y los PE Hornazos, PE Canraso y PE Barcelosa, asociados a la Subestación La Serna, en el término municipal de Murchante, en la provincia de Navarra:

- No se encuentra afectado por servidumbres aeronáuticas civiles ni militares. En concreto, el parque eólico se ubica fuera de la proyección ortogonal de las servidumbres aeronáuticas de la Base Aérea de Zaragoza y del Aeródromo Militar de Ablitas al no existir ninguna superficie definida en el D2039/1967, previo al D584/72, modificado por el RD369/2023.
- No existen procedimientos de vuelo instrumental ni visuales publicados en el AIP-España para el Aeródromo Militar de Ablitas.
- No afecta a los procedimientos de vuelo instrumental (salidas, llegadas y aproximaciones) – OACI publicados en AIP-España, actualizado hasta las enmiendas AIRAC 05/24 (13-JUN-24) y AMDT 381/24 (13-JUN-24), para la Base Aérea de Zaragoza, al cumplirse el margen de franqueamiento de obstáculos (MOC) correspondiente a cada una de las maniobras.
- No afecta a la Carta de Altitud Mínima de Vigilancia ATC, a la Altitud Mínima de Área (AMA) ni a las Aerovías del Espacio Aéreo Inferior publicadas a fecha de realización de este documento, cumpliéndose con los márgenes de franqueamiento de obstáculos (MOC) aplicables.
- No afecta a los procedimientos según reglas de vuelo visual de la Base Aérea de Zaragoza.
- Se propone la señalización de todos los aerogeneradores pintando íntegramente de color blanco las palas del rotor, la barquilla y los 2/3 superiores del mástil de soporte de todas las turbinas eólicas y la iluminación de todos los aerogeneradores con un sistema dual de media intensidad tipo A / media C.
- Se propone la iluminación de la grúa de montaje -si ésta se utiliza en horario nocturno- con luces de obstáculo de mediana intensidad tipo C, en su parte más alta.
- Los aerogeneradores (de altura superior a 100 metros) deberán publicarse como obstáculo en el AIP-España por el Servicio de Información Aeronáutica conforme establecen las *Normas y Métodos Recomendados Internacionales Anexo 15 al*

*Convenio sobre Aviación Civil Internacional: Servicios de Información Aeronáutica.*

Por todo lo anterior, cabe concluir que no se han identificado afecciones a las operaciones instrumentales ni visuales como consecuencia de la instalación del parque eólico y, por lo tanto, no se ven afectadas la seguridad ni la regularidad de las operaciones, ni tampoco se requerirían modificaciones de las mismas.

Los resultados obtenidos en este estudio serán válidos únicamente para las coordenadas y altitudes mostradas en el mismo, entendiéndose que cualquier variación de las mismas supondría necesariamente un nuevo análisis.

Como Anexo 1 a este estudio se incluye el Decreto 2039/1967, de 22 de julio, por el que se confirman las servidumbres aeronáuticas en torno al Aeródromo de Ablitas (Navarra), Anexo 1.1, y la Ficha Informativa del Ejército del Aire sobre su actualización, Anexo 1.2.

Como Anexo 2 a este estudio se incluye el Real Decreto 725/1991, de 26 de abril, sobre servidumbres aeronáuticas de la Base Aérea de Zaragoza, como Anexo 3 se incluye el AIP-ESPAÑA de la Base Aérea de Zaragoza.

Como Anexo 4 se incluyen los planos de ubicación del Parque Eólico y el plano de alzado para los aerogeneradores.

Madrid, junio de 2024
Ingeniera Aeronáutica
Nº Colegiada: 4686

**ANEXO 1**

Se incluye a este estudio el Decreto 2039/1967, de 22 de julio, por el que se confirman las servidumbres aeronáuticas en torno al Aeródromo de Ablitas (Navarra), como Anexo 1.1, y la Ficha Informativa del Ejército del Aire sobre la Actualización de las servidumbres aeronáuticas del Aeródromo de Ablitas, como Anexo 1.2.

**ANEXO 2**

Se incluye a este estudio el Real Decreto 725/1991, de 26 de abril, sobre servidumbres aeronáuticas de la Base Aérea de Zaragoza, sus instalaciones radioeléctricas y de operación de aeronaves.

**ANEXO 3**

Se incluye a este estudio el AIP-ESPAÑA de la Base Aérea de Zaragoza.

**ANEXO 4**

Se incluye a este estudio los planos en planta y en alzado de los aerogeneradores del Parque Eólico:

- Anexo 4.1: Plano ubicación PPEE
- Anexo 4.2: Plano alzado aerogenerador

**PROYECTO DE EJECUCIÓN**

**Parque eólico "P.E. Canraso" de 4,95 MW**

**e infraestructuras de evacuación para conexión a red**

**EMPLAZAMIENTO EÓLICO**

**Murchante [Navarra]**

**Parcelas 673, 674, 675 y 676 del Polígono 1**

**PROMOTOR**

**ANDRÓMEDA RENOVABLES 22 SL**

**CIF B72433451**

**AUTOR**

**Colegiado 3.509 de ingenierosVA**

**FECHA**

**Junio 2024**

# ANEXO III - HOJAS DE CARACTERÍSTICAS

| | | |
|---|---|---|
| SANY RENEWABLE ENERGY | Version No.: V5.0 | |
| | Confidentiality: Internal Disclosure | 34 pages in total |

# SI-16050 Wind Turbine Technical Description


**Prepared by: Yang Ziyan**

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**Sany Renewable Energy Co., Ltd.**


29 May 2023

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## Version History

| Version | Date | Author | Major changes |
|---|---|---|---|
| V9.0 | 2023-05-29 | Yang Ziyan | ● Deleted Chapter 3.<br>● Increased DNV certification related requirements. |
| V8.0 | 2023-03-24 | Yang Ziyan | ● Modified the general technical parameters of wind turbine. |
| V7.0 | 2022-12-27 | Yang Ziyan | ● Optimized content. |
| V6.0 | 2022-08-18 | Ren Xing | ● Optimized the description of cooling system. |
| V5.0 | 2022-07-25 | Ren Xing | ● Optimized the description of braking system and design standards of the wind turbine.<br>● Deleted the content of ventilation and hear dissipation. |
| V4.0 | 2022-06-23 | Ren Xing | ● Increased the content of high temperature protection.<br>● Optimized the description of lightning protection and earth termination system. |
| V3.0 | 2022-05-06 | Ren Xing | ● Optimized the version. |
| V2.0 | 2021-11-05 | Ren Xing | ● Modified the yaw speed. |
| V1.0 | 2021-07-30 | Zhao Qiang | ● Created the document. |

# About this document

## Purpose

This document aims to provide information on the structure and principle of SI-16050 wind turbines manufactured by Sany RE.

Please read this document carefully for correct product information. In case of any errors or suggestions in relation to this document, please reach us.

## Target readers

The target readers of this document are:

- Marketing personnel
- Technical service personnel
- Operation and maintenance personnel

## Symbol conventions

The following symbols will appear in the document, which serve as eye-catching prompts to readers.

| Symbol | Meaning |
|---|---|
| DANGER | Indicates a hazardous situation which, if not avoided, will result in death or serious injury. |
| WARNING | Indicates a hazardous situation which, if not avoided, could result in death or serious injury. |
| CAUTION | Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury. |
| NOTICE | Indicates a hazardous situation which, if not avoided, could result in equipment damage, property loss, or environmental damage. |
| NOTE | Indicates additional information that should be highlighted. No injury or damage is involved. |

# Table of Contents

1. Introduction ..... 6
1.1 Product overview ..... 6
1.2 Wind turbine structure ..... 6
1.3 Working principle ..... 7
1.4 Main features of wind turbine ..... 7

2. Description of subsystems and components ..... 9
2.1 Rotor system ..... 9
2.1.1 General information ..... 9
2.1.2 Rotor blades ..... 9
2.1.3 Rotor hub ..... 10
2.1.4 Spinner ..... 10
2.1.5 Pitch system ..... 11
2.2 Nacelle system ..... 13
2.2.1 Nacelle bedplate ..... 13
2.2.2 Nacelle cover ..... 13
2.3 Drivetrain ..... 14
2.3.1 General information ..... 14
2.3.2 Main shaft device ..... 14
2.3.3 Gearbox ..... 15
2.3.4 Coupling ..... 16
2.3.5 Protective cover of coupling ..... 16
2.3.6 High-speed shaft brake ..... 16
2.4 Power generator system ..... 17
2.4.1 General information ..... 17
2.4.2 Generator ..... 17
2.4.3 Converter ..... 17
2.4.4 Transformer ..... 18
2.4.5 High-voltage switchgear ..... 18
2.5 Yaw system ..... 19
2.6 Control system ..... 19
2.6.1 General Information ..... 19
2.6.2 Main control system ..... 19
2.7 Tower system ..... 21
2.8 Auxiliary systems ..... 23
2.8.1 Lubrication system ..... 23
2.8.2 Hydraulic system ..... 23
2.8.3 Cooling system ..... 23
2.9 Auxiliary equipment ..... 23
2.9.1 Hoist ..... 23
2.9.2 Wind sensors ..... 24
2.9.3 Aviation obstruction light ..... 24

3. Protection system of the wind turbine ..... 25

3.1 Safety chain ..... 25
3.1.1 Composition and principle ..... 25
3.1.2 Triggering of the safety chain ..... 25
3.2 Braking system ..... 25
3.3 Lightning protection and earth-termination system ..... 26
3.3.1 General information ..... 26
3.3.2 External lightning protection device ..... 26
3.3.3 Internal lightning protection device ..... 27
3.3.4 Earth-termination system ..... 27
3.4 Low-temperature protection ..... 27
3.5 High-temperature protection ..... 27
3.6 Corrosion protection ..... 28

4. Personal safety design ..... 29
4.1 Personal protective equipment ..... 29
4.2 Safety passage and work platform ..... 29
4.3 Lighting facilities ..... 29
4.4 Fall protection equipment ..... 29
4.5 Fire protection facilities ..... 30
4.6 Electrical protection ..... 30
4.7 Warnings and signs ..... 30

Appendix ..... 31
A Overall technical parameters ..... 31
B Design standards ..... 33
C Terms and abbreviations ..... 33
D Reference table for unit conversation ..... 34

# 1. Introduction

## 1.1 Product overview

SI-16050 is a type of high-speed, doubly-fed, and grid-connected wind turbine with a horizontal axis and three rotor blades. Refer to Figure 1-1.

Refer to "Appendix B Design standards" for the main design standards of the wind turbine.

Figure 1-1 Wind turbine

## 1.2 Wind turbine structure

The wind turbine mainly consists of rotor system, nacelle system, drivetrain, power generation system, yaw system, control system, tower system, auxiliary system, and auxiliary equipment. Refer to Figure 1-2.
For the overall technical parameters, refer to "Appendix A Overall technical parameters."

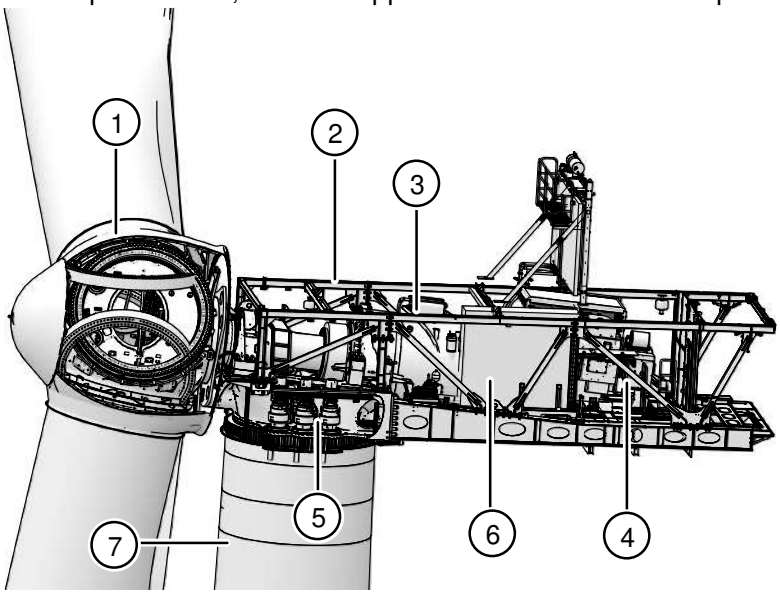


Figure 1-2 Overall structure of the wind turbine

1. Rotor system
2. Nacelle system
3. Drivetrain
4. Power generation system
5. Yaw system
6. Control system
7. Tower system

## 1.3 Working principle

A wind turbine is an electrical equipment that converts wind energy into mechanical energy and mechanical energy into electrical energy. The working principle of the wind turbine is that wind drives the rotor to rotate and the rotor drives the generator to produce electricity through the drivetrain, that is, the kinetic energy in the wind is converted into the kinetic energy of the generator rotor, which in turn is converted into electrical energy. The produced electrical energy is then regulated by a rectifying device and transmitted to the power grid at a constant output power through transmission lines. Refer to Figure 1-3.

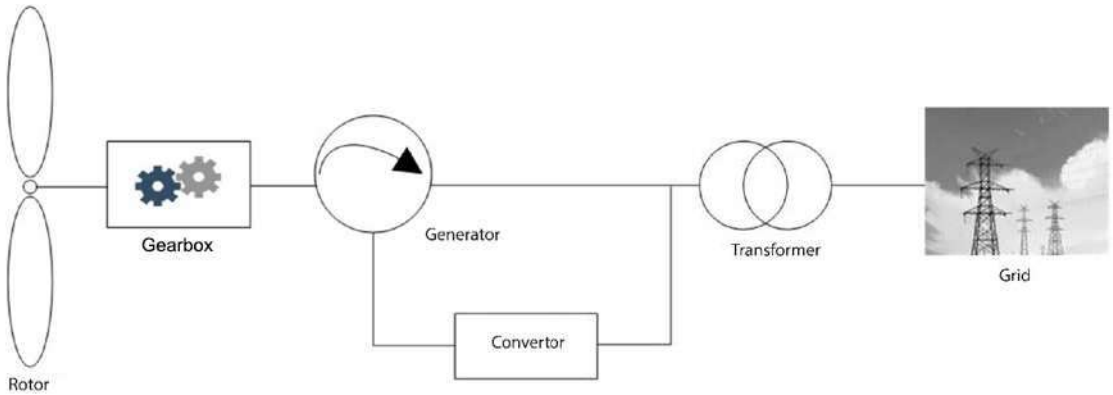


Figure 1-3 Schematic diagram of doubly-fed power generation

The rotor of the doubly fed induction generator (DFIG) is connected to the grid through a bidirectional converter, allowing for bidirectional power flow. The converter realizes the constant frequency control of the wind turbine by adjusting the frequency and phase of the output current of the generator rotor according to the change in the wind speed and the generator speed.
The power generation system consisting of generator and converter and the transformer make sure that the wind turbine can always supply power to the grid stably.

## 1.4 Main features of wind turbine

The wind turbine features high power generation capacity, and is safe and reliable, grid friendly, environmentally friendly, and easy for maintenance.

**High power generation capacity**

- Wind energy absorption: The rotor blades meet the requirements for maximum absorption of wind energy.
- Electrical energy conversion: The wind turbine meets mechanical and electrical efficiency requirements.
- Pitch control: The wind turbine responds quickly to wind speed changes to meet the requirements for maximum conversion of wind energy.
- Yaw control: The wind turbine meets the requirements for maximum absorption of wind energy when the wind direction changes.

**Safe and reliable**

- Reliability design: Redundancy design, margin design, environmental adaptability design, and other reliability design methods are adopted and subjected to computer simulation and verification.
- Bearing capacity: All components and subsystems adopt structural reinforcement design and ultimate and fatigue load calculations and strength checks under all operating conditions are performed in strict accordance with applicable international design standards to ensure the safe and reliable operation of the wind turbine.
- Heat dissipation capacity: The gearbox and the converter are water-cooled with high heat dissipation efficiency and good reliability to ensure reliable operation of the components.

- Control safety: With the functions of normal shutdown, safety shutdown, and safety chain shutdown, the wind turbine meets the shutdown protection requirements under various operating conditions.
- Lightning protection and earth-termination: The wind turbine meets the requirements for lightning protection, electromagnetic compatibility, and interference immunity.
- Personnel safety: The wind turbine adopts safety designs such as fall protection, fire protection devices, and escape apparatus to ensure personnel safety.

**Grid friendly**

- Grid adaptation: The wind turbine meets the requirements for active power, reactive power, and frequency regulation and inertia response when the grid voltage or frequency fluctuates.
- Voltage ride through: The wind turbine meets the requirements for low voltage ride through and high voltage ride through in case of grid voltage transients.

**Environmentally friendly**

- Environmental adaptation: The wind turbine is designed to operate in high temperature, low temperature, high altitude, high humidity, and other environmental conditions to meet relevant requirements.
- Sand and dust prevention: The nacelle, rotor blades, internal electrical cabinets, and connections between rotating and static parts are sealed to effectively prevent sand and dust.

**Easy for maintenance**

- Wind turbine maintenance: The split nacelle cover and spinner and sufficient work space in the nacelle improve the inspection and maintenance efficiency and reduce the maintenance difficulty and cost.

# 2. Description of subsystems and components

## 2.1 Rotor system

### 2.1.1 General information

The rotor system is in the front of the wind turbine. The main function of the rotor is to capture the wind energy and convert it into mechanical energy in the form of motion.

The rotor system consists of rotor blade, spinner, rotor hub, and pitch system. Refer to Figure 2-1. Each rotor blade is equipped with an independent pitch system that automatically adjusts the rotor blade pitch angle according to the wind speed and power output.

The rotor speed is regulated by controlling the pitch angle of the rotor blade and the torque of the power generation system. Under normal operating conditions, the wind turbine is in the windward position, and the rotor rotates clockwise when viewed from the front.

The wind turbine adopts the pitch regulated power regulation method.

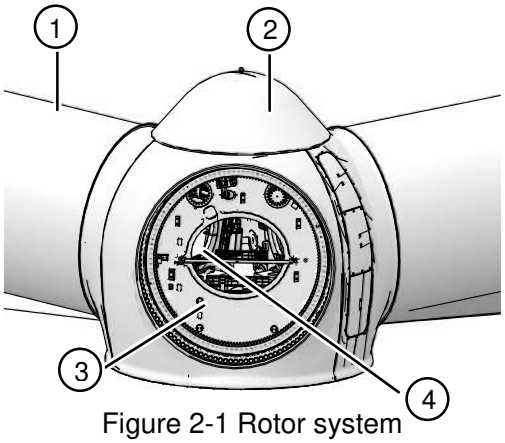

Figure 2-1 Rotor system

1. Rotor blade
2. Spinner
3. Rotor hub
4. Pitch system

### 2.1.2 Rotor blades

Rotor blades are one of the most important components of the rotor and are used to capture wind energy.
The rotor blades are made of fiber reinforced plastic. The surface is coated with anti-pollution and weatherproof paint. Refer to Figure 2-2. The rotor blade is provided with a built-in lightning protection system. Lightning receptors are installed on the blade tip and the pressure and suction sides at a certain distance from the blade root, and connected to the blade root through cables and then led into the ground. The lightning protection system meets the requirements of IEC 61400.

Figure 2-2 Rotor blade

The rotor blades have the following characteristics:

- The rotor blade adopts the airfoil with high lift-to-drag ratio and low roughness sensitivity, which matches the wide speed range of the wind turbine and improves the power generation performance.
- The rotor blade surface is fully coated to enhance anti-pollution, anti-wear, anti-low temperature, and anti-ultraviolet performance. The leading edge of the rotor blade is further protected against corrosion by the supplementary coating.
- The blade roots are bolt connected. The metal connecting pieces are made up of high-strength steel. The surface of the steel material is dacrotized, and the corrosivity category meets the requirements of ISO 9227.
- Each rotor blade is equipped with a set of pitch angle detection device and independent pitch mechanism to effectively reduce the unbalanced load on the rotor blade. This improves the reliability of key components and extend the service life.

- Reliable air braking system can perform quick feathering when necessary (including power grid outage). Each rotor blade is equipped with at least two 90º limit protection devices. The second limit protection will be triggered in case of failure of the first limit protection.
- Lifting points are marked on the rotor blades.

### 2.1.3 Rotor hub

The rotor hub is made of ductile iron and has a spherical hollow structure. Refer to Figure 2-3. The rotor hub has three rotor blade bearing flange surfaces and one main shaft flange surface. These flange surfaces are respectively connected to the three rotor blades and the main shaft by using high-strength bolts. After the rotor is locked, the personnel can enter the rotor hub from the nacelle to inspect and maintain the pitch system and rotor blades, provided that their safety is guaranteed.

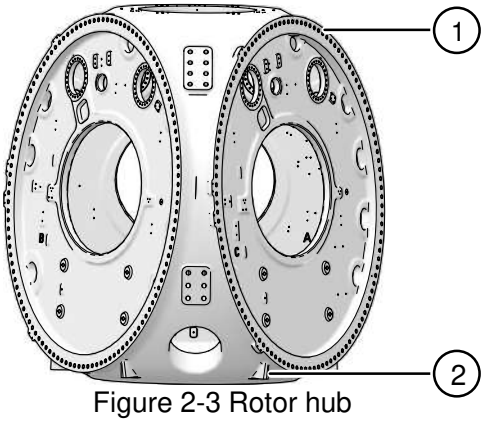

Figure 2-3 Rotor hub

1. Flange surfaces of the rotor blade bearing
2. Flange surface of the main shaft

### 2.1.4 Spinner

The spinner consists of spinner top, spinner wall, and front and rear supports. Refer to Figure 2-4. The spinner top and the spinner wall are made up of gel coat, polyester resin, and glass fiber fabric. The spinner is connected to the rotor hub through the front and rear supports.

The function of the spinner is to protect the rotor hub and the pitch system, so that the wind turbine can operate normally under harsh meteorological environmental conditions such as wind, rain, snow, salt spray, and ultraviolet radiation. The streamlined design of the spinner can reduce the impact of wind flowing through the rotor on the wind turbine.

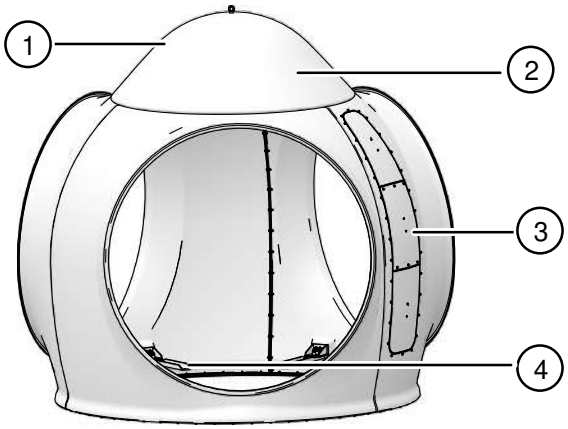

Figure 2-4 Spinner

1. Spinner top
2. Front support
3. Spinner wall
4. Rear support

## 2.1.5 Pitch system

The pitch system consists of pitch mechanism and pitch control system. The pitch mechanism includes pitch bearing and pitch gearbox, and the pitch control system includes pitch control cabinet and pitch motor. Refer to Figure 2-5.

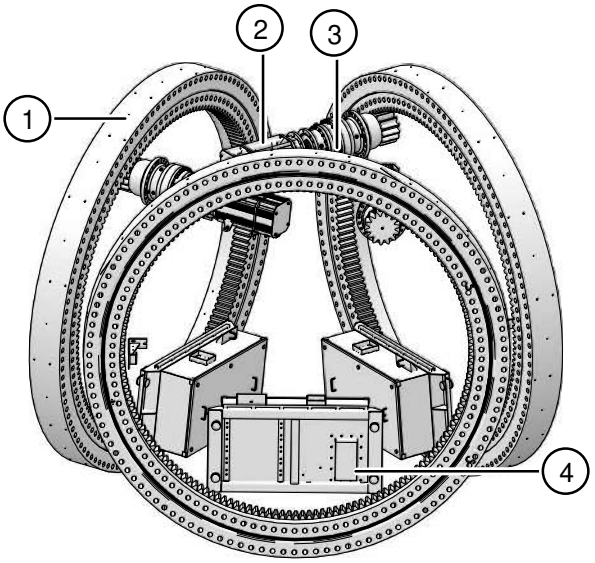


Figure 2-5 Pitch system

1. Pitch bearing
2. Pitch motor
3. Pitch gearbox
4. Pitch control cabinet

**Pitch mechanism**

The function of the pitch mechanism is to adjust the pitch angle according to the commands issued by the main controller based on the real-time wind speed, so that the wind turbine converts the maximum wind energy under the minimum load. In addition, the pitch mechanism can make the rotor blades perform quick feathering in case of fault or failure of the wind turbine. This helps to prevent the possible overloading to the wind turbine structure and tower foundation, thus protecting the safety of the wind turbine.
Each rotor blade is equipped with a set of independent pitch mechanism, including pitch bearing and pitch gearbox. The pitch gearbox is installed on the rotor hub, the inner ring of the pitch bearing is installed on the rotor blade, and the outer ring of the rotor blade bearing is installed on the rotor hub. When the pitch system is powered on, the pitch motor drives the output shaft pinion of the pitch gearbox to rotate, and the pinion engages with the inner ring of the pitch bearing, thereby driving the inner ring of the pitch bearing and the rotor blades to rotate together to get the correct pitch angle.

**Pitch control system**

The pitch control system consists of pitch control cabinet and pitch motor. The pitch motor is used for position feedback for the rotor blades to make sure that the three rotor blades operate simultaneously. During grid operation, the pitch motor is driven by the driver. In case of grid failure, the pitch motor is powered by the backup power supply. The backup power supply adopts supercapacitor. The pitch control system calculates the capacitance of the supercapacitor based on the charging and discharging current and voltage of the supercapacitor to make sure that the supercapacitor is capable of emergency feathering. The three pitch control cabinets operate independently. If one pitch mechanism fails, the other two can ensure the correct shutdown of the wind turbine.

For the main principle of the pitch system, refer to Figure 2-6.

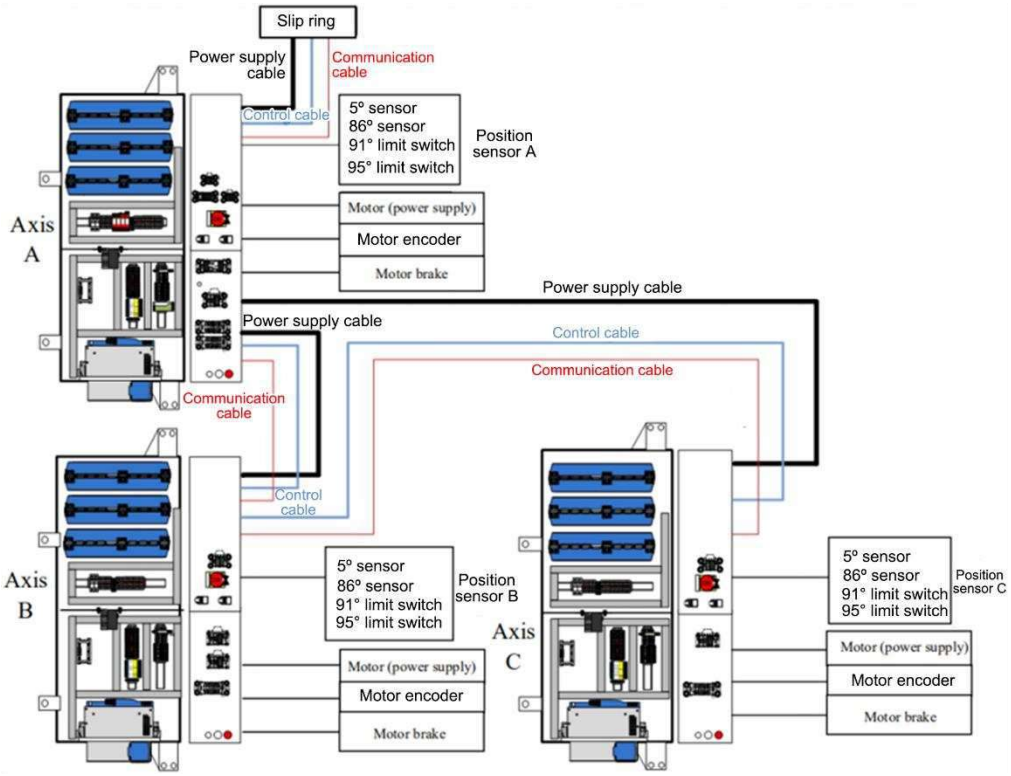


Figure 2-6 Main principle of the pitch system

The main control system of the wind turbine communicates with the pitch system using CANOPEN protocol. The main control system sends the pitch command to the pitch system through the communication bus. The pitch system executes the command to complete pitching. When other parts of the wind turbine fail, the main control system will trigger the safety chain and notify the pitch system to enter the state of emergency stop and feathering. When a fault occurs inside the pitch system, the pitch system will also enter the state of emergency stop and feathering. When the power supply system fails, the backup power supply will enter the state of an emergency stop, and notify the main control system.

**Mode of operation**

The pitch system has the following four modes of operation:

- Commissioning mode: The corresponding commissioning function is realized by connecting the commissioning software to the pitch control cabinet.
- Manual mode: The rotor blades are controlled to rotate at a predetermined speed by controlling the manual button on the pitch control cabinet.
- Safe mode: The pitch system does not receive commands from the main control system and automatically completes the feathering and shutdown at the emergency feathering speed.
- Auto mode: The pitch system rotates following the position command given by the main control system.

## 2.2 Nacelle system

### 2.2.1 Nacelle bedplate

The nacelle bedplate consists of main frame, rear bedplate, nacelle frame, and structural accessories. Refer to Figure 2-7. The nacelle bedplate is mainly to bear and install the part above the tower, including the main bearing, bearing housing, gearbox, generator, converter, transformer, and electric control cabinet. The lower part of the nacelle bedplate is connected to the yaw bearing and the tower.

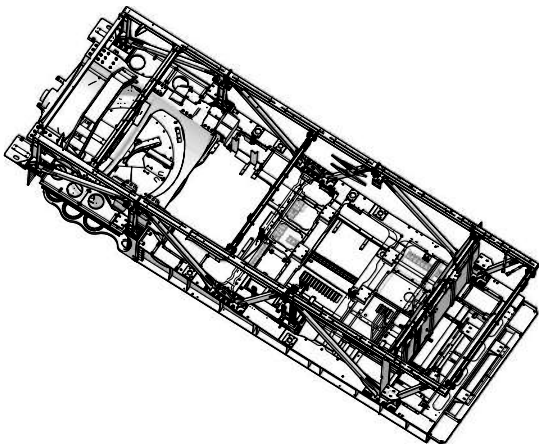

Figure 2-7 Nacelle bedplate

### 2.2.2 Nacelle cover

The nacelle cover is made up of gel coat, polyester resin, composite material, glass fiber fabric, and other materials. The main function of the nacelle cover is to protect the facilities inside the wind turbine from the external environment and reduce noise emissions. Refer to Figure 2-8. The nacelle cover is connected to the nacelle bedplate through the bracket.

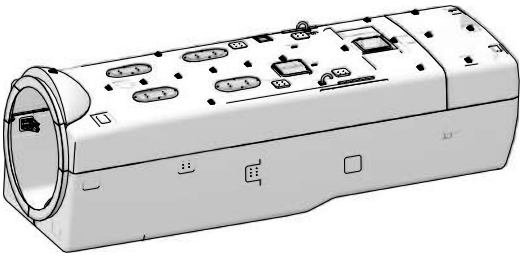

Figure 2-8 Nacelle cover

There are plate stiffeners inside the nacelle cover to increase the rigidity and strength of the casing. The bottom platform of the nacelle cover can be used as the maintenance platform. Personnel can perform disassembly, installation, and maintenance activities on the bottom platform.

There is a maintenance hatch and a hoist hatch on the top of the nacelle cover. Personnel can access the top of the nacelle from inside through the maintenance hatch. The hoist hatch is used for the lifting and installation of the wind turbine.

## 2.3 Drivetrain

### 2.3.1 General information

The drivetrain connects the rotor system to the generator, and its main function is to output the power input from the rotor system to the generator through a series of components.

The drivetrain consists of main shaft device, gearbox, coupling, and high-speed shaft brake. Refer to Figure 2-9. The main shaft is connected to the inner hole of the planetary carrier of the gearbox and is clamped tightly by the shrink disc of the gearbox. The high-speed shaft of the gearbox is connected to the input shaft of the generator through the coupling. The gearbox is installed with a high-speed shaft brake, which is braked by the brake disk of the friction coupling.

The main mechanical components in the drivetrain (such as gearbox and main bearing) are all under real-time monitoring, and various faults and hidden risks can be tracked and identified in a timely manner.

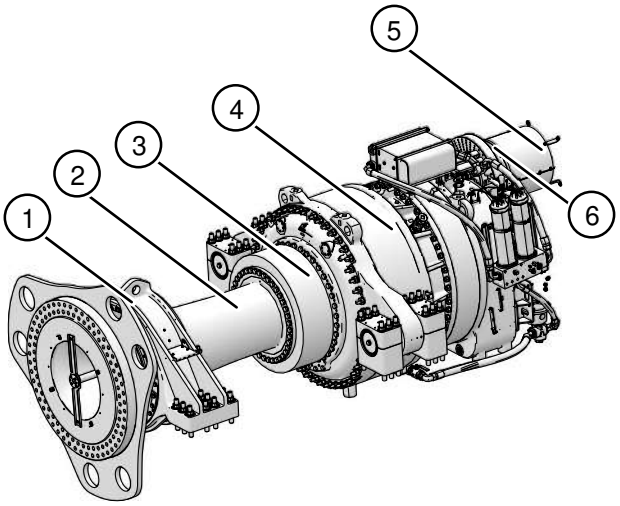


Figure 2-9 Drivetrain

| | | | |
|---|---|---|---|
| 1. | Bearing housing | 2. | Main shaft |
| 3. | Gearbox shrink disc | 4. | Gearbox |
| 5. | Protective cover of coupling | 6. | High-speed shaft brake |

### 2.3.2 Main shaft device

The main shaft device connects the rotor hub to the gearbox and consists of the main shaft, main bearing, and bearing housing. Refer to Figure 2-10.

- Main shaft: The front end of the main shaft is rigidly bolted to the rotor. The rear end of the main shaft is connected to the gearbox through the gearbox shrink disc. By tightening the high-strength bolts, pressure and friction are generated on the female surface. This avoids weakening the strength of the parts due to key connection while transmitting load, thereby increasing the fatigue strength and reliability of the parts. The clearance hole on the main shaft axis is used for routing the wires. The axial expansion and contraction of the main shaft in service caused by temperature changes and the bearing mounting errors can be compensated by the gearbox installed in the form of elastomeric mount.

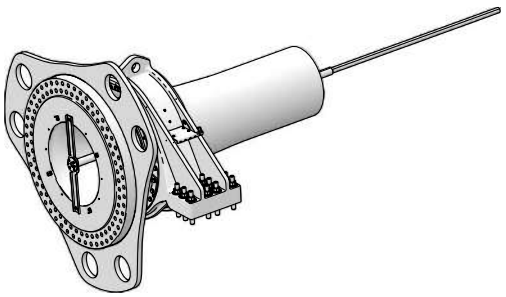

Figure 2-10 Main shaft device

- Main bearing: The main bearing is a self-aligning roller bearing installed at one end of the main shaft to support and hold the main shaft. The inner ring of the bearing is secured to the shaft by using the shaft sleeve, and the outer ring is installed in the bearing housing. The main bearing can carry and transmit the axial force, radial force, bending moment, and torque generated by the rotor.

- Bearing housing: The bearing housing is fixed to the nacelle bedplate to support the main bearing.

### 2.3.3 Gearbox

The gearbox is fixed to the nacelle bedplate through the damper. Its main function is to provide variable speed and power to the generator. Refer to Figure 2-11.

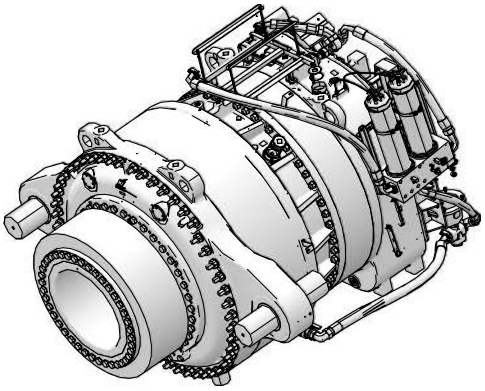

Figure 2-11 Gearbox

The gearbox has the following structural characteristics:

- Three-stage drive: Two-stage planetary helical gears and one-stage parallel-shaft helical gears.

- The sun gear inside the gearbox is of floating structure, which compensates for the assembly error of the gear drive and improves the smoothness and service life of the gearbox to a certain extent.

- The gear with high degree of engagement, shaft and bearing with high rigidity, and reasonably arranged shaft and gear drives ensure the low noise operation of the gearbox.

To ensure stable operation, the gearbox is equipped with the following devices:

- High-speed shaft brake: It is installed on the base at the high-speed end of the gearbox.

- Damping device: The damper is installed at the connection between the gearbox and the nacelle bedplate, and is composed of annularly arranged elastomer layers. It can compensate the axial and radial assembly errors of the gearbox and reduces the vibration transmitted from the gearbox to the main frame. This prevents and reduces the vibration and noise in the nacelle to ensure the smooth operation of the gearbox.

- Oil circulation cooling device: It makes sure that the working temperature of the gearbox is not too low or too high.

- Self-circulating lube oil pump: Forced lubrication and splash lubrication are used to lubricate gears and bearings.

- Remote detection system: The gearbox is connected to the remote detection system. The data uploaded to the system include oil sump temperature, oil level, oil pressure, differential pressure, and bearing temperature at the drive end and non-drive end of the high-speed shaft.

- PT100 temperature sensor: Temperature sensors are installed on the high-speed shaft, oil sump, and distributor for temperature monitoring. The monitoring results can be displayed on the online monitoring system.

- Gearbox: Sight glasses are provided at key locations to check the bearings inside the gearbox and the operating conditions.

### 2.3.4 Coupling

The coupling connects the high-speed shaft of the gearbox to the generator. Refer to Figure 2-12. The coupling has good insulation performance and is equipped with a torque limiter, which can withstand loads such as torque, speed, and vibration, and correct deviation.

At 20 ºC, under 2 kV DC voltage, the impedance of the coupling is greater than or equal to 10 MΩ, and it can withstand the high voltage of 2 kV. This conforms to DIN VDE 0100-600 and effectively prevents the parasitic current from flowing through the generator rotor to the gearbox.

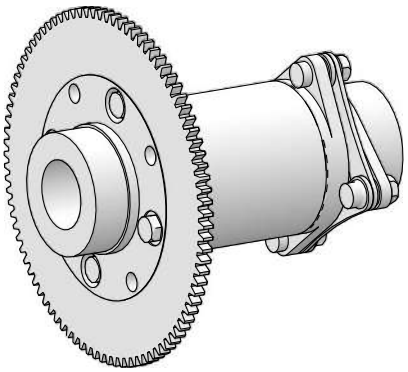

Figure 2-12 Coupling

### 2.3.5 Protective cover of coupling

The high-speed rotating part of the coupling is equipped with a protective cover made of aluminum alloy, which is light in weight and easy for maintenance. The cover body is provided with a sight glass to directly check whether the coupling slips.

### 2.3.6 High-speed shaft brake

The high-speed shaft brake is installed on the base of the high-speed end of the gearbox and consists of casing, piston, and brake lining. The main function of the high-speed shaft brake is to lock the coupling brake disk. Normally, it is powered by the hydraulic station. In grid outage, it can be operated by the accumulator.

The high-speed shaft brake is the secondary brake of the wind turbine (the primary brake is the pitch system), which is not a safety brake device. It is generally used for shutdown and maintenance.

The working principle of the high-speed shaft brake is as follows. The hydraulic oil enters the hydraulic cylinder to push the piston to move towards the coupling brake disk. The two brake linings respectively press one side of the coupling brake disk to generate clamping braking forces. When the hydraulic oil is released, the return spring installed on the brake lining pulls the brake lining back and the piston returns into the hydraulic cylinder. Then the braking force disappears, and the coupling brake disk can rotate freely.
The high-speed shaft brake can detect the wear limit of the brake lining. When the wear of the brake lining reaches the limit, it will send an alarm signal to the main control system.

## 2.4 Power generator system

### 2.4.1 General information

The main function of the power generation system is to convert mechanical energy into electrical energy and ensure the supply of stable electrical power to the grid. The power generation system consists of generator, converter, and transformer.

### 2.4.2 Generator

The wind turbine generator is doubly-fed generator, with the rotor connected to the converter and the stator connected directly to the grid. Refer to Figure 2-13.

The generator has the following design features:

- Short-circuit and overload protection devices are installed.
- Temperature sensors are installed in places such as stators and bearings to keep the generator under continuous monitoring.
- Damping devices are installed to ensure stable operation.

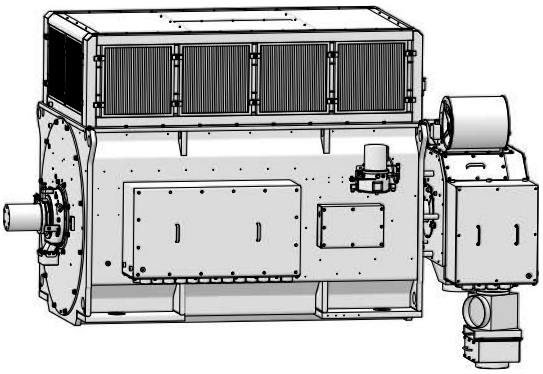

Figure 2-13 Generator

### 2.4.3 Converter

The converter and its optional accessories are mainly used in doubly-fed wind turbines. The main function of the converter is to control the generator torque and feed the electric energy to the power grid, achieving variable-speed constant-frequency control of the doubly fed induction generator. With certain reactive power compensation capability, it is one of the key components of the wind turbine. The converter communicates with the main controller of the wind turbine, receives control commands from the main controller, and uploads the status information of the converter to the main controller or the remote monitoring system.

- When the generator is in subsynchronous operation, the rotor excitation frequency $f_2$ is greater than 0, and the converter offers positive phase sequence excitation to the generator rotor. The slip $s$ is greater than 0, the input power of rotor $p_2$ is greater than 0, and the converter outputs active power to the rotor.

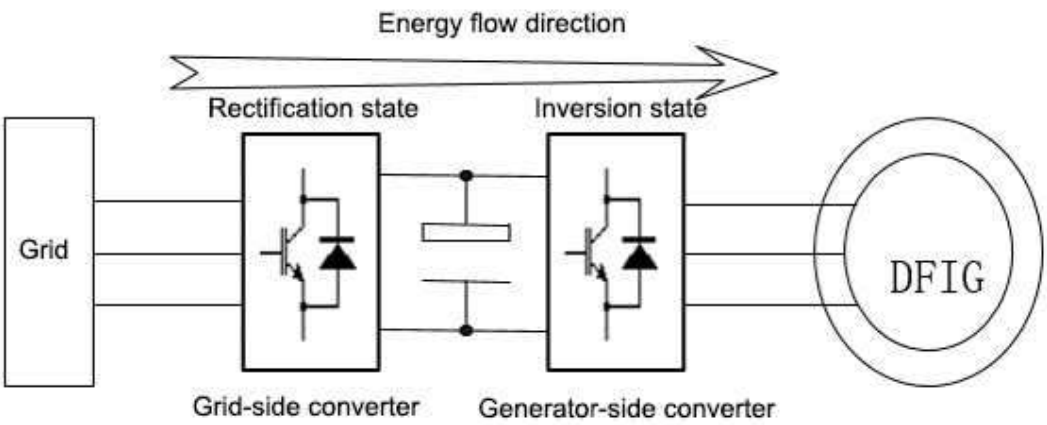


Figure 2-14 Illustration of subsynchronous operation

- When the generator is in supersynchronous operation, the rotor excitation frequency $f_2$ is less than 0, and the converter offers negative phase sequence excitation to the generator rotor. The slip $s$ is less than 0, the input power of rotor $p_2$ is less than 0, and the rotor windings outputs active power to the converter.

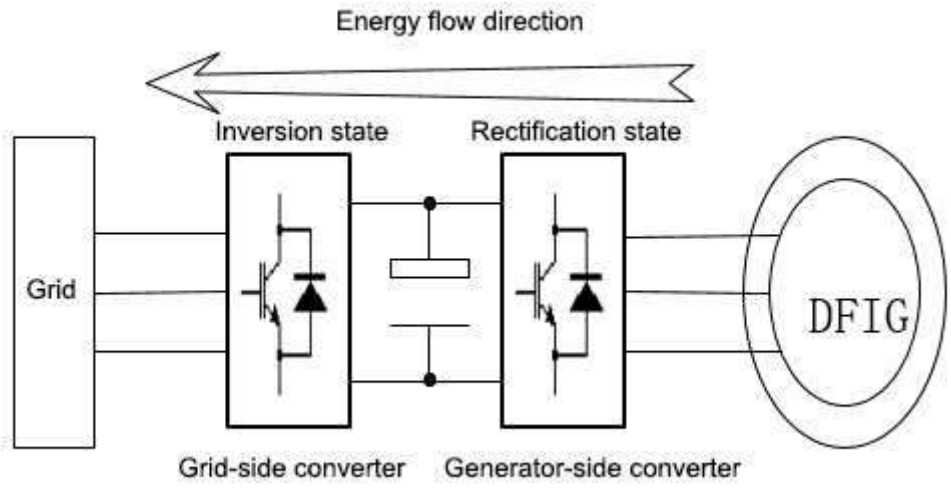


Figure 2-15 Illustration of supersynchronous operation

### 2.4.4 Transformer

The transformer is installed inside the wind turbine nacelle. Its function is to connect the wind turbine to the power collection network of the wind farm to step up the electric energy output by the wind turbine and feed it to the power grid.

### 2.4.5 High-voltage switchgear

The high-voltage switchgear is suitable for the ring network power supply or dual radial power supply of the 40.5 kV power supply line. It can change the original single radial power supply mode. In a line fault, it can quickly restore the transformer circuit power supply, considerably improving the reliability and availability of power supply. In addition, the high-voltage switchgear is safe to use, weatherproof, simple to install, requires little maintenance, and saves space.

## 2.5 Yaw system

The yaw system is located between the tower and the main frame. Its main function is to make the nacelle rotate on the tower. In addition, the yaw system can detect the twist of the cable and untwist the cable if necessary.

The yaw system consists of yaw brake disk, yaw bearing, yaw drive, and yaw brake. The outer ring of the yaw bearing is secured to the tower and the inner ring of the yaw bearing is connected to the nacelle bedplate.

The yaw system adopts active yawing to align with the wind. When the wind direction changes, the wind vane sends the signal to the control system. The yaw drive receives the signal from the control system and drives the pinion to rotate on the gear ring, thereby driving the nacelle to rotate and orienting the rotor into the wind. The nacelle can rotate in two directions and the direction of rotation is detected by a proximity switch. When the angle at which the nacelle rotates in the same direction reaches the cable untwist angle, the main control system controls the wind turbine to untwist the cable.

## 2.6 Control system

### 2.6.1 General Information

The control system is one of the most core components of a wind turbine. Its basic function is to convert wind energy into electrical energy to the greatest extent while ensuring the safe and reliable operation of the wind turbine.

### 2.6.2 Main control system

The control system of the wind turbine is a comprehensive control system, which not only monitors the power grid, wind conditions, and operating parameters of the wind turbine, and controls the grid connection and disconnection of the wind turbine to ensure safety and reliability during operation, but also optimizes the control of the wind turbine based on the change of wind speed and direction to improve the operation efficiency and power generation of the wind turbine. To achieve the functions of power generation control, safety control, and wind turbine monitoring, and in combination with the spatial structure characteristics of the wind turbine, the main control system adopts distributed control. The tower base master station, the nacelle slaver station, the converter, and the pitch system form the control system of the wind turbine. The main control system communicates with the monitoring center server through the fiber ring network switch.

Refer to Figure 2-16 for the illustration of main control system.

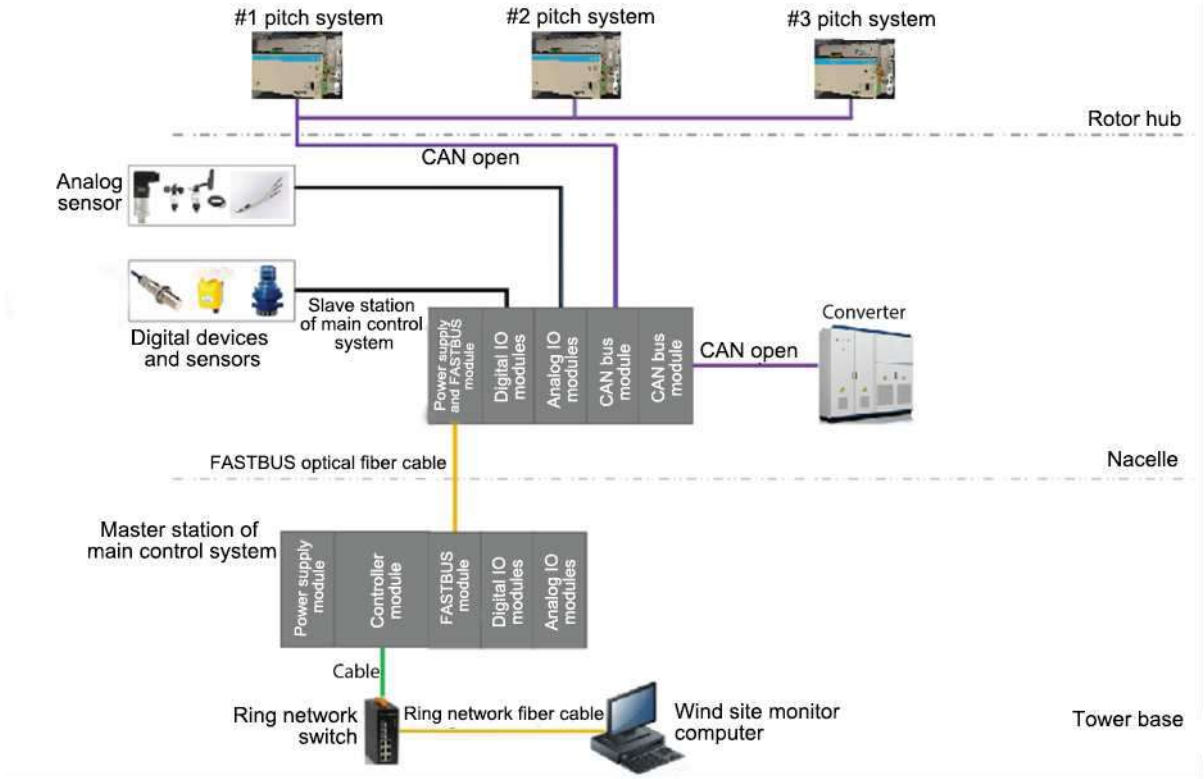


Figure 2-16 Main control system

The functions of the main control system are divided into two categories:

- Operational functions: Functions that are directly related to the operation of the wind turbine and that convert wind energy into electrical energy for output.
- Auxiliary functions: Functions that provide support services for operational functions.

Table 2-1 Functions of the main control system

| No. | Function | Sub-function | Description |
|---|---|---|---|
| 1 | Operational functions | Yaw/untwist control | Send nacelle yaw control commands based on the measured value of the wind vane sensor, and the nacelle actively faces the wind, monitors the cable twist state in the tower, and send cable untwist commands. |
| | | Pitch control | Adjust the operating state of the wind turbine by using different control methods under different wind speeds and different operating conditions together with the pitch system and the converter, to increase power generation and optimize loads. |
| | | Converter control | |
| | | Grid connection and disconnection control | Control the output parameters of the wind turbine to meet grid connection requirements, send grid connection commands, and send grid disconnection commands. |

| No. | Function | Sub-function | Description |
|---|---|---|---|
| 2 | Auxiliary functions | Equipment status and environmental status detection | Send heating or cooling commands based on the measured value of the temperature sensor. Determine the equipment conditions based on the parameters such as the rotation and vibration state of the mechanical parts, gearbox, and motor. Process the measured values of the temperature, pressure, and other sensors and determine whether there is any fault or hidden risk according to the setting and the logic. |
| | | Log, alarm, and troubleshooting | Generate and save logs, generate and save alarms, and implement planned shutdown strategy based on fault codes. |
| | | Hydraulic system | Control the pressure buildup of the hydraulic system and deliver mechanical energy to the brake. |
| | | Remote communication | Exchange data with the remote monitoring system. |
| | | Human-machine interaction | Provide local human-machine interaction, implement parameter setting and query, and provide an environment for maintenance and commissioning. |

## 2.7 Tower system

The main function of the tower is to support the nacelle, rotor, and other components of the wind turbine and bear all the loads from the various components of the wind turbine.

The tower is a steel conical structure, which is composed of multiple sections. Refer to Figure 2-17 for the illustration of tower. The upper end is connected to the yaw bearing of the wind turbine and the lower end is connected to the anchor bolt foundation. The upper and lower ends of each tower section are provided with connecting flanges and connected by using bolts. The tower also has multiple maintenance platforms for the installation and maintenance of the tower connecting bolts, cable twist systems, and other components and for the rest of the personnel. The center of the tower top platform is designed with a square ladder for access to the nacelle. The tower can be provided with auxiliary lifting equipment such as climb auto system and service lift as required and is equipped with fall protection equipment.

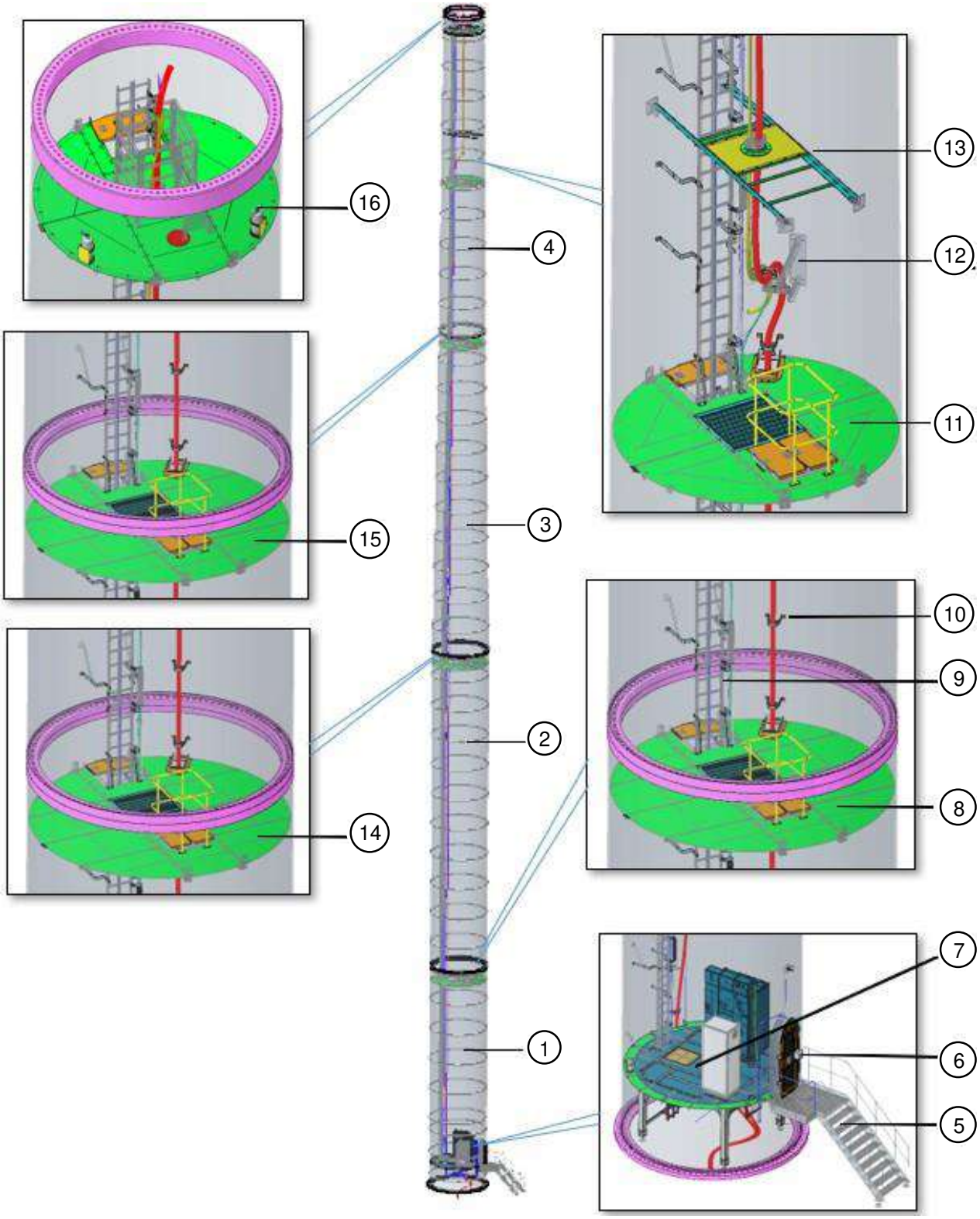


Figure 2-17 Tower

| | | | |
|---|---|---|---|
| 1. Bottom tower section | 2. Second tower section | 3. Third tower section | 4. Fourth tower section |
| 5. External ladder | 6. Tower door | 7. Electrical cabinet platform | 8. First tower section platform |
| 9. Ladder assembly | 10. Cable clamp assembly | 11. Cable twist platform | 12. Saddle |
| 13. Cable twist limit bracket | 14. Second tower section platform | 15. Third tower section platform | 16. Tower top platform |

## 2.8 Auxiliary systems

### 2.8.1 Lubrication system

The lubrication systems include the pitch bearing lubrication system and the main shaft yaw lubrication system. The gearbox and the generator have their own lubrication systems.

Both the pitch bearing lubrication system and the main shaft yaw lubrication system consist of the lubrication pump, distributor, and tubing fittings. The lubrication pump is connected to the distributors at all levels, to supply the grease alternately to each lubricating point. A plunger detector is set on the main distributor to monitor the operating conditions of the entire system.

### 2.8.2 Hydraulic system

The main function of the hydraulic system is to provide braking force for the high-speed shaft brake and braking force and yaw residual pressure for the yaw system. The hydraulic system consists of hydraulic station, oil circuit, control element, and actuator.

The hydraulic unit is used together with the active brake and connected to the yaw brake. The hydraulic system converts the electrical energy into oil pressure and hydraulic oil flow through the motor and pump. When there is no fault in the hydraulic system and the system pressure is lower than the set value for starting the hydraulic pump, the hydraulic pump will get started automatically. When the system pressure is higher than the set value for stopping the hydraulic pump, the hydraulic pump stops working.

### 2.8.3 Cooling system

The cooling systems include the gearbox water cooling system and the converter water cooling system, which guarantee the normal operation of the gearbox and converter and meet the cooling requirements of large wind turbines.
The cooling system consists of water cooling pump station, radiator outside the nacelle, and water cooling tubing. The coolant circulates between the water cooling pump station, the radiator outside the nacelle, and the components to be cooled (gearbox/converter) through the water cooling tubing to continuously remove the heat generated during the operation of the components, thus making sure that the wind turbine operates within a reasonable temperature range.
The centrifugal pump in the water cooling pump station is the power source of the system, which provides the driving force for the coolant. After entering the components to be cooled (gearbox/converter), the coolant takes away the heat generated during the operation of the components through convection and conduction. The heated coolant exchanges heat with the ambient air through the radiator outside the nacelle to cool itself. The cooled coolant enters the components to be cooled again. A complete cooling cycle is finished.
The cooling system has the following features:

- The radiator outside the nacelle is installed on the top of the nacelle, and adopts the natural air cooling technology with low energy consumption, eliminating the need for fans and motors for forced wind, thus effectively reducing the power consumption of the wind turbine.
- Temperature and pressure sensors are provided at the inlet and outlet of the gearbox water cooling system and the converter water cooling system. The temperature and pressure of the water cooling system are monitored in real time through the main control system of the wind turbine for fault alarm and shutdown.

## 2.9 Auxiliary equipment

### 2.9.1 Hoist

A hoist is installed in the nacelle for lifting tools and parts for routine maintenance.

### 2.9.2 Wind sensors

The ultrasonic wind sensor (optional) or mechanical wind sensors are installed on the radiator outside the nacelle. Both the ultrasonic wind sensor and the mechanical wind sensors are freezing resistant. As the pitch and yaw sensor of the main control system, its main function is to measure the wind speed and wind direction.

### 2.9.3 Aviation obstruction light

The wind turbine is equipped with signal equipment and beacon systems that comply with various regulations and flash and operate at night. Refer to Figure 2-18.

Figure 2-18 Aviation obstruction light

# 3. Protection system of the wind turbine

The fault state information of the wind turbine can be monitored remotely or locally via SCADA or HMI.

## 3.1 Safety chain

### 3.1.1 Composition and principle

The safety chain is a series of interlock monitoring equipment that is independent of the main control system. The main function of the safety chain is to achieve emergency shutdown when the main control system cannot work due to an emergency.

The safety chain is made up of a series of effective protective contacts connected in series, which normally form a closed-loop channel. The safety chain consists of hardware such as nacelle emergency switch, vibroswitch contact, overspeed protection switch, relay, and yaw limit protection switch. The disconnection of any link in the chain will immediately activate the safety system and force the braking system to perform the corresponding operations.

### 3.1.2 Triggering of the safety chain

The safety chain is formed by connecting various components according to the sequence of triggering different braking programs. The components connected by the safety chain are:

- Nacelle emergency stop
- Tower base emergency stop
- Rotor/high-speed shaft overspeed
- Vibroswitch
- Twist limit
- Watch dog
- Safety chain actively disconnected by the main control system
- Overpower and converter safety chain
- Pitch safety chain

## 3.2 Braking system

The wind turbine has two braking systems. One is the aerodynamic braking system (implemented through the pitch system), and the other is the high-speed shaft braking system. The aerodynamic braking system is the primary braking system, and the high-speed shaft braking system is the secondary braking system.

During normal braking, the primary braking system is activated, the rotor blades are feathered, and the wind turbine is stopped normally.
When emergency braking is triggered by the manual emergency stop button, the primary braking system is activated first, and the rotor blades are quickly feathered. Then, the secondary braking system is activated, and the wind turbine is stopped in an emergency.

The braking status of the wind turbine can be reset (to release the braking state) by the following methods:

- The status code is set to automatic reset, and the program is automatically run when the conditions are met.
- Reset by the user.
- Reset by the central monitoring system software.

In addition, rotor locking pins are provided at the low-speed shaft. As the rotor locking device, the locking pins can mechanically lock the rotor to make sure that the rotor stops in case of equipment maintenance or failure, thus ensuring the safety of the wind turbine during maintenance.

## 3.3 Lightning protection and earth-termination system

### 3.3.1 General information

The lightning protection and earth-termination system of the wind turbine consists of external and internal lightning protection devices. The design of the lightning protection and earth-termination system must comply with IEC 61400-24:2019. The external lightning protection device transfers the direct lightning current into the ground and discharges it, thereby protecting the exposed equipment in the nacelle. The internal lightning protection device prevents the impact of the instantaneous pulse-induced voltage generated by the lightning on the electrical equipment in the nacelle.

### 3.3.2 External lightning protection device

The rotor blades are provided with lightning receptors, the leads of which are embedded in the blades. The lightning receptors are connected to the lightning protection bracket at the rotor blade root through the leads. The lightning protection bracket at the rotor blade root is connected to the lightning protection bracket at the rotor hub end by using braided flat copper wires. The lightning protection bracket at the rotor hub end is secured to the rotor hub by using bolts. The rotor hub is connected to the nacelle bedplate through the lightning protection carbon brush on the main shaft, and then connected to the earthing ring at the tower base through the earthing cable, the lightning protection carbon brush of the yaw system, and the equipotential bonding cable of the tower. These lightning protection facilities form a complete lightning current discharge channel. This allows lightning currents to be transmitted safely to the ground. Refer to Figure 3-1.

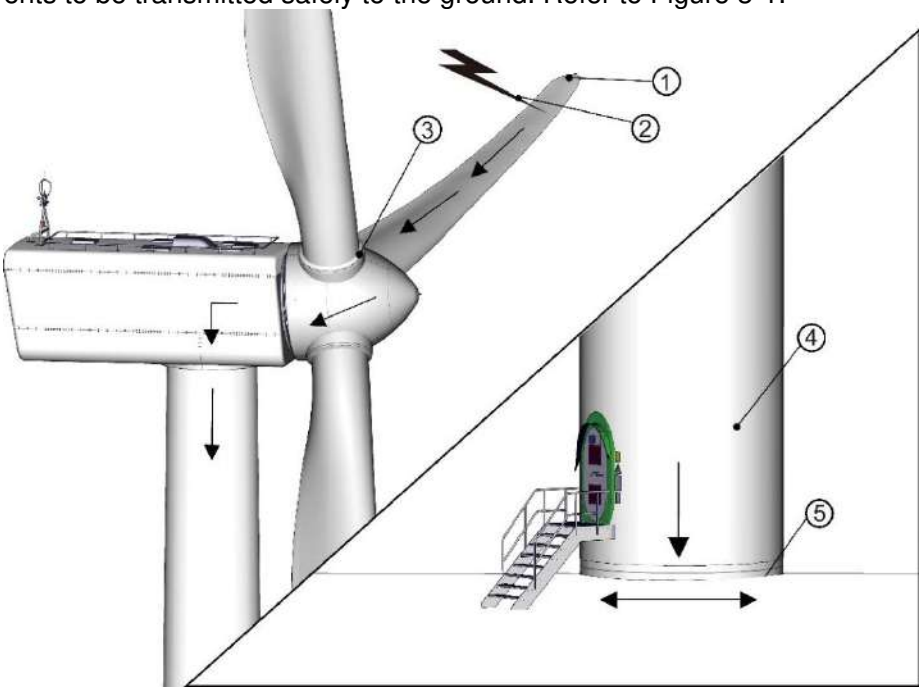


Figure 3-1 External lightning protection channel

1. Lightning protection and earth-termination
2. Cloud thunderbolt
3. Lightning protection carbon brush on the main shaft
4. Tower section
5. Earthing ring at tower base

### 3.3.3 Internal lightning protection device

The electrical equipment used in the system, such as the main control cabinet, yaw motor, and generator, are connected to the nacelle bedplate to achieve equipotential, so as to eliminate the voltage difference between electrical equipment, thereby avoiding equipment damage and electric shock caused by lightning or current leakage or short-circuit to ground of the equipment. This will reduce common mode interference and ensure the performance of electrical equipment. In addition, by installing surge arresters on electrical equipment, the transient pulse-induced voltage is discharged to prevent damage to electronic devices.

### 3.3.4 Earth-termination system

The earth-electrode network of the foundation is installed during construction. At least three joints of reinforcement of the earth-electrode network of the foundation are led out of the ground and welded to the earthing steel strap at the tower base to form a ring earth-termination. Holes are drilled on the earthing steel strap at intervals for crimping the earthing cable connected to the earthing stud of the tower foundation flange, thereby discharging the lightning current on the top of the wind turbine. The earth-terminations of the transformer and the transfer station outside the nacelle are connected to those of the wind turbine.
The earth-termination system of the wind turbine is designed according to the site-specific requirements and local electrical regulations and requirements. The earth-termination below the earthing steel strap (inclusive) at the tower base is designed by the owner in compliance with IEC 61400-24:2019. The lightning protection and earth-termination in the wind turbine above the earthing steel strap at the tower base is designed by Sany RE.

## 3.4 Low-temperature protection

The structural members, drive parts, fasteners, electrical elements, control systems, heating and sealing components in the nacelle, and other components of the wind turbine are designed to operate at a low temperature of up to -30 °C. Hence, the survival environmental temperature of the wind turbine is up to -40 °C.

- The tower sections and flanges are made of low-temperature resistant steel plates, and the performance of welds and heat-affected zones meets the requirements of base metal.
- The rotor blades are added with low-temperature adhesives.
- Key components such as the main shaft, rotor hub, and main frame are all made of low-temperature resistant materials.
- To prevent condensation at low temperature, generators are equipped with winding heaters.
- All greases of the wind turbine have low-temperature properties (the low-temperature resistance after grease exchange depends on the type of grease used by the user).

## 3.5 High-temperature protection

The wind turbine has been designed and tested for high temperature resistance to ensure reliable operation under the dual influence of the long-time high environmental temperature and the high internal temperature caused by heat dissipation during system operation.

- The nacelle and tower are equipped with ventilation systems to ensure their ventilation and heat dissipation performance.
- Key components such as the generator, gearbox, and converter all have their own cooling systems.
- The wind turbine has undergone strict high-temperature test and cooling system test, and is reliable in high-temperature operation.

## 3.6 Corrosion protection

The exterior and interior of the wind turbine meet the requirements of corrosivity category C4 and C2 or C3 respectively according to ISO 12944-2.

# 4. Personal safety design

## 4.1 Personal protective equipment

Generally, the wind farm provides personal protective equipment (PPE) such as full-body harness, protective clothing, and safety helmet to ensure the safety of the personnel climbing the wind turbine and working inside and outside the nacelle. In addition, the wind turbine is equipped with devices to protect the safety of the personnel, so as to reduce safety risks and ensure personal safety.

## 4.2 Safety passage and work platform

The personnel can enter the wind turbine through the tower door at the tower base, enter the nacelle through the ladder or the climb auto system, and enter the top platform of the nacelle through the hatch.

In addition to the above conventional routes, the nacelle is equipped with a high-altitude escape device for use in an emergency, and the device meet the requirements of the applicable standards ANSI/ASSE Z 359.4, CSA/CAN Z 259.2.3, EN 341, and EN 1496.

The passages in the nacelle and tower are free of sharp parts that could cause personal injury. All potentially dangerous places are covered with protective covers, which can only be opened or removed with tools. Make sure that personnel will not be hurt when passing through.

The working space and standing platform in the wind turbine meet the requirements for operation.

The hatch of the nacelle cover meets the requirements of Section 4.2 in EN 50308: "Hatch openings in a wall for entry by a person shall have a minimum free opening of 0.4 m × 0. 6 m. The corners in the passage opening may be rounded off." Dimensions of the two hatches at the top of nacelle are 0.7 m × 0.7 m. There is a hatch at the bottom of the nacelle with dimensions of 0.75 m × 0.75 m. The loads in the standing places and working places near all nacelle hatches meet the requirements of Section 6.4 in GL 2010.

The entrances, escape routes, handrails, and fixing points meet the requirements of Section 4.2 in EN 50308.

The anchor points on the nacelle cover meet the requirements of Section 6.4 in GL 2010 and can bear a load of 20 kN in all directions. In addition, the anchor points are subjected to dynamic and static load tests in the type test to assess whether the design requirements are met.

## 4.3 Lighting facilities

Lighting devices are installed in the tower, nacelle and rotor hub of the wind turbine. When the external power supply of the wind turbine is interrupted, the emergency lighting system in the wind turbine can meet the required lighting conditions.

## 4.4 Fall protection equipment

The fall protection equipment provided in the wind turbine together with the full-body harness can ensure the safety of the personnel climbing up and down the tower of the wind turbine. When the personnel is about to fall off the ladder, the anti-fall slider will be stuck on the guide rail of the ladder to prevent the person from falling.

## 4.5 Fire protection facilities

The wind turbine is equipped with multiple portable fire extinguishers.
In addition to the portable fire extinguisher, the nacelle is also equipped with an automatic fire protection system.
The fire resistance rating of the nacelle, including the entire space and all electrical cabinets, is designed to be 1 hour. The cable outlets of all motors, floors, and platforms in the nacelle must be provided with fireproof sealing compound. The fire resistance rating of the fireproof sealing compound must be at least 1 hour, and fire partition walls must be provided around the transformer in the nacelle to resist fire at least 1 hour.
The wind turbine has two escape routes:

- Escape from the entrance to the nacelle cover and reach the ground through the tower door.
- Leave from the hoist hatch by using escape apparatus. According to EN 50308, the escape routes must maintain their function for a minimum of 30 minutes in case of fire.

## 4.6 Electrical protection

An emergency stop button is set in the wind turbine to shut down and de-energize the wind turbine in an emergency.
The high-voltage electrical equipment and components in the wind turbine are designed to maintain sufficient safety distance during operation and prevent maloperation.

## 4.7 Warnings and signs

Safety warning signs are provided at locations of the wind turbine that can bring danger to the operator.
The functions of all operating elements and buttons are clearly marked to facilitate operation by the personnel and to prevent maloperation.

# Appendix

## A Overall technical parameters

| Item | | Value/description |
|---|---|---|
| Wind turbine type | | SI-16050 |
| Basic parameters | Wind class | IEC S |
| | Rated power | 5000 kW |
| | Rotor diameter | 160 m |
| | Swept area | 20106 $m^2$ |
| | Rated wind speed | 10.6 m/s (static) |
| | Cut-in wind speed | 3 m/s |
| | Cut-out wind speed | 25 m/s |
| | Survival wind speed(3 s average wind speed) | 56 m/s |
| | Noise source | Comply with IEC 61400-11 |
| | Corrosivity category | C4 for exterior and C2 or C3 for interior according to ISO 12944-2 |
| | Operating ambient temperature | -30 °C to +40 °C |
| | Survival environmental temperature | -40 °C to +50 °C |
| | Solar irradiance | 1000 W/$m^2$ |
| | Relative humidity | < 95% |
| | Altitude (for conventional wind turbines) | ≤ 2500 m |
| | Service life | 20 years |
| Rotor | Number of blades | 3 |
| | Blade length | 78 m |
| | Blade material | Fiber reinforced plastic |
| | Pitch system | Three independent electrical pitching |
| Gearbox | Structure type | Two-stage planetary helical gear and one-stage parallel shaft helical gear |
| | Mechanical efficiency | ≥ 97% |
| Generator | Type | Doubly fed asynchronous generator |
| | Number of pole pairs | 2 |
| | Rated power | 5200 kW |
| | Rated voltage | 690 V |
| | Rated frequency | 50 Hz |
| | Rated power factor | 1 |
| | Rated speed | 1723 rpm |
| | Insulation temperature rating | H |
| | Vibration level | Rigid support ≤ 1.8 mm/s |
| | Stator wiring | Δ |
| | Rotor wiring | Y |
| | Degree of protection | IP54 |

| Item | | | Value/description |
|---|---|---|---|
| Converter | Rated power (grid connection point) | | 5000 kW |
| | Rated voltage (grid side) | | 690 V |
| | Degree of protection | | IP54 |
| | Rotor side (two modules in parallel) | Rated power/capacity | 1912 kW/1912 kVA |
| | | Maximum continuous current | 1600 A |
| | Grid side (single module) | Rated power/capacity | 896 kW/896 kVA |
| | | Maximum continuous current | 750 A |
| Main bearing | Type | | Double row self-aligning roller bearing |
| Yaw system | Yaw bearing | | Four-point contact ball bearing |
| | Brake | | Hydraulic brake |
| | Drive mode | | Motor-gear drive |
| | Yaw speed | | < 0.42 °/s |
| Main control system | Rated voltage | | 690 V (AC) ± 10% |
| | Rated frequency | | 50 Hz |
| | Communication mode | Nacelle/tower base | HCS optical fiber |
| | | Wind farm communication | Single mode fiber |
| | Relative humidity of operating environment | | ≤ 95% |
| | Degree of protection of control cabinet | | IP54 |
| Pitch system | Pitch mode | | Electrical pitching |
| | Maximum pitch speed | | 6 °/s |
| | Emergency feathering speed | | Variable speed feathering |
| | Pitch angle | | 0 to 90° |
| | Type of backup power supply | | Supercapacitor |
| | Rated speed of pitch motor | | 2000 rpm |
| | Type of pitch motor | | AC permanent magnet synchronous |
| | Pitch lubrication | | Centralized lubrication |
| | Degree of protection of control cabinet | | IP54 |

# B Design standards

The main design standards of the wind turbine include but are not limited to:

| Standard | Standard name |
|---|---|
| IEC 61400-1 | Wind Energy Generation Systems – Part 1: Design Requirements |
| IEC 61400-4 | Wind Turbines – Part 4: Design Requirements for Wind Turbine Gearboxes |
| IEC 61400-12-1 | Wind Energy Generation Systems – Part 12-1: Power Performance Measurements of Electricity Producing Wind Turbines |
| IEC 61400-23 | Wind Turbines – Part 23: Full-Scale Structural Testing of Rotor Blades |
| IEC 61400-24 | Wind Turbines – Part 24: Lightning Protection |
| IEC 60034-1 | Rotating Electrical Machines – Part 1: Rating and Performance |
| IEC 60204-1 | Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements |
| ISO 13849-1 | Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design |

# C Terms and abbreviations

| Term | Explanation |
|---|---|
| Hub height | Height of the center of the swept area of the wind turbine rotor above the terrain surface |
| Rated power | Output power at the rated wind speed of the wind turbine under standard air conditions |
| Rated wind speed | Minimum wind speed at which the rated power of the wind turbine is achieved, given by the design and manufacturing department |
| Cut-in wind speed | Lowest wind speed at which the wind turbine starts to produce power at the rated load |
| Cut-out wind speed | Wind speed at which the wind turbine stops power output at the rated load due to the action of the regulator |
| Survival wind speed | Also known as extreme wind speed, maximum allowable wind speed at which the wind turbine will not be damaged during manual or automatic protection |
| Swept area | Rotating area of the rotor blade when the rotor rotates |
| Rated speed | Rotational speed of the rotor when the rated power is output |
| Thrust coefficient | Non-dimensionalized value of the force acting on the brake disk due to the pressure drop, denoted by Ct |
| Rotor tilt angle | Angle between the rotor axis of the wind turbine and the horizontal plane |

# D Reference table for unit conversation

## Units of measurement

The units used in this document are mainly international metric units. The following table is for reference when converting from metric units to other units.

| Parameter | International system of units | Other units | Conversations |
|---|---|---|---|
| Length | Meter/m | Inch/in | 1 m ≈ 39.37 in |
| | Meter/m | Foot/ft | 1 m ≈ 3.28 ft |
| Volume | Cubic meter/$m^3$ | US gallon/US gal | 1 $m^3$ ≈ 264.17 US gal |
| | Cubic meter/$m^3$ | Cubic yards/$yd^3$ | 1 $m^3$ ≈ 1.31 $yd^3$ |
| | Liter/L | US quart/US qt | 1 L ≈ 0.91 US qt |
| Mass | Kilogram/kg | Pound/lb | 1 kg ≈ 2.20 lb |
| Force | Newton/N | Kilogram force/kgf | 1 N ≈ 0.10 kgf |
| | Newton/N | Pound force/lbf | 1 N ≈ 0.22 lbf |
| Torque | Newton meter/Nm | Kilogram force meter/kgf·m | 1 Nm ≈ 0.10 kgf·m |
| | Newton meter/Nm | Pound force foot/lbf·ft | 1 Nm ≈ 0.74 lbf·ft |
| Pressure | Megapascal/MPa | Kilogram force per square centimeter/kgf/$cm^2$ | 1 MPa ≈ 10.20 kgf/$cm^2$ |
| | Megapascal/MPa | bar | 1 MPa ≈ 10 bar |
| Power | Kilowatt/kW | Horsepower/PS | 1 kW ≈ 1.36 PS |
| | Kilowatt/kW | British horsepower/HP | 1 kW ≈ 1.34 HP |
| Temperature | Celsius degree/°C | degree Fahrenheit/°F | tF (°F) = 1.8t (°C) + 32 |
| Speed | Kilo meter per hour/km/h | Miles per hour/mph | 1 km/h ≈ 0.62 mph |
| | Revolutions per minute/$min^{-1}$ | Revolutions per minute /rpm | 1 $min^{-1}$=1 rpm |
| Flow | Liters per minute/L/min | US gallon per minute/US gpm | 1 L/min ≈ 0.26 US gpm |
| | Milliliters per revolution/mL/rev | Cubic centimeter per revolution/cc/rev | 1 mL/rev = 1 cc/rev |