

---

# ANEXOS TOMO I

## REPOTENCIACIÓN

## PARQUE EÓLICO “I+D CABEZO NEGRO”

T.M. DE JAULÍN (ZARAGOZA)

Febrero 2024

---

## ÍNDICE

|   |    |
|---|----|
| 1. ANEXO I DOCUMENTACIÓN REQUERIDA POR EL DEPARTAMENTO DE ECONOMÍA, INDUSTRIA Y EMPLEO DEL GOBIERNO DE ARAGÓN DECRETO-LEY 2/2016, DE 30 DE AGOSTO, DE MEDIDAS URGENTES PARA LA EJECUCIÓN DE LAS SENTENCIAS DICTADAS EN RELACIÓN CON LOS CONCURSOS CONVOCADOS EN EL MARCO DEL DECRETO 124/2010, DE 22 DE JUNIO, Y EL IMPULSO DE LA PRODUCCIÓN DE ENERGÍA ELÉCTRICA A PARTIR DE LA ENERGÍA EÓLICA EN ARAGÓN. ARTÍCULO 13 APARTADO C)..... | 4  |
| 1.1. Razones de cualquier índole que justifiquen la implantación o modificación del parque eólico en la zona de que se trate. ....  | 5  |
| 1.2. Criterios técnicos de situación que desde el punto de vista de aprovechamiento del recurso eólico, optimización de la planificación de redes de evacuación y transporte eléctrico, respecto al patrimonio cultural y a los valores medioambientales se han seguido para elegir los terrenos en los que se situarán concretamente las instalaciones. ....   | 6  |
| 1.3. Descripción de los recursos eólicos presentes mediante las mediciones efectuadas o un estudio o modelización que confirme la existencia de recurso suficiente para el funcionamiento del parque. ....  | 7  |
| 1.4. Adecuación del proyecto a la situación de planeamiento urbanístico vigente, en el área de implantación prevista. ....  | 8  |
| 1.5. Descripción y justificación de los datos referidos a la ordenación del parque eólico, tales como superficie, ocupación de la finca por edificaciones, instalaciones y superficies pavimentadas. Se incluirá asimismo, la justificación de los movimientos de tierra a efectuar. ...  | 9  |
| 1.6. Descripción de los servicios existentes y previstos relativos a accesos, abastecimientos, energías, alumbrado y otras instalaciones. ....  | 10 |
| 1.7. Descripción de las características formales y constructivas; uso y destino de las edificaciones, referidas a la superficie construida; altura de las edificaciones y de los elementos singulares, composición, materiales y otras. ....  | 11 |
| 1.8. Plazo de ejecución del proyecto.....   | 12 |
| 1.9. Presupuesto de las instalaciones.....  | 13 |
| 1.10. Descripción detallada de todas las instalaciones de alta y baja tensión con adecuación a la Normativa Vigente.....  | 14 |
| 1.11. Descripción de las instalaciones de evacuación de energía eléctrica hasta el punto de conexión con la red de distribución o transporte.....   | 15 |
| 1.12. Medidas previstas de protección contra incendios. ....  | 16 |
| 1.13. Descripción del aerogenerador a instalar que certifique el cumplimiento de las exigencias del operador del sistema conforme a la normativa estatal vigente y principales características, en especial, el apartado relativo a los huecos de tensión. Declaración de conformidad CE de las máquinas que se pretende instalar, junto con una descripción detallada del aerogenerador a instalar. ....                               | 17 |
| 1.14. Adecuación de las instalaciones a las disposiciones relativas a la seguridad y a la salud para la utilización por los operadores de los equipos de trabajo.....   | 18 |
| 1.15. Estudio de seguridad y salud.....   | 19 |

|         |   |    |
|---------|---|----|
| 1.16.   | Relación de personas físicas y jurídicas propietarios de bienes, instalaciones, obras o servicios afectados por la instalación. ....  | 20 |
| 1.17.   | Partes del proyecto que afectan a bienes, instalaciones, obras o servicios, centros o zonas dependientes de otras Administraciones Públicas, Organismos, Corporaciones, o Departamentos del Gobierno de Aragón, para que estos establezcan, si procede, el condicionado procedente en el trámite de informe.....  | 21 |
| 1.18.   | Documentación acreditativa de la capacidad legal, técnica y económica del solicitante. ....   | 22 |
| 1.19.   | Informe de las servidumbres aeronáuticas afectadas y, en caso de existir, estudio aeronáutico que asegure que las instalaciones no comprometen la seguridad de las operaciones de las aeronaves, de acuerdo con el Real Decreto 1541/2003, por el que se modifica el Decreto 584/1972, de servidumbres aeronáuticas, y el Decreto 1844/1975, de servidumbres aeronáuticas en helipuertos, para regular excepciones a los límites establecidos por las superficies limitadoras de obstáculos alrededor de aeropuertos y helipuertos..... | 23 |
| 1.19.1. | Solicitud enviada a AESA.....   | 23 |
| 1.20.   | Cuantos documentos adicionales relacionados con el expediente y relevantes para su resolución estime oportuno reclamar el órgano competente para la tramitación del expediente administrativo.....  | 31 |
| 2.      | ANEXO II CARACTERÍSTICAS TÉCNICAS DE LOS AEROGENERADORES .....  | 32 |
| 2.1.    | Características y funcionamiento general de la plataforma de aerogeneradores SG 5.0 .....   | 32 |
| 2.2.    | CARACTERÍSTICAS DE VIALES Y PLATAFORMAS APARA AEROGENERADORES SG 6.6 .....  | 33 |
| 2.3.    | CUMPLIMIENTO DE LOS CODIGOS DE RED PARA CONEXIÓN DE PARQUES EÓLICOS.....  | 34 |

---

1. ANEXO I DOCUMENTACIÓN REQUERIDA POR EL DEPARTAMENTO DE ECONOMÍA, INDUSTRIA Y EMPLEO DEL GOBIERNO DE ARAGÓN DECRETO-LEY 2/2016, DE 30 DE AGOSTO, DE MEDIDAS URGENTES PARA LA EJECUCIÓN DE LAS SENTENCIAS DICTADAS EN RELACIÓN CON LOS CONCURSOS CONVOCADOS EN EL MARCO DEL DECRETO 124/2010, DE 22 DE JUNIO, Y EL IMPULSO DE LA PRODUCCIÓN DE ENERGÍA ELÉCTRICA A PARTIR DE LA ENERGÍA EÓLICA EN ARAGÓN. ARTÍCULO 13 APARTADO C)

---

**1.1. Razones de cualquier índole que justifiquen la implantación o modificación del parque eólico en la zona de que se trate.**

1 Obtener energía partiendo de recursos no contaminantes sin emisión de gases que contribuyen a aumentar el efecto invernadero, especialmente CO<sub>2</sub>.

2 Potenciar el uso de energías renovables obteniendo una mejora en el medioambiente y a su vez repercusiones positivas en el ámbito socioeconómico

3 Esta iniciativa privada de aprovechamiento de la energía eólica repercutirá directamente sobre la estructura productiva de la zona y generará unos ingresos por canon de cesión de terrenos, licencia de obras, contratación de personal e ingresos de carácter fiscal y administrativos importantes.

4 Las instalaciones mejorarán las infraestructuras de regionales energéticas.

5 El carácter inagotable de la energía eólica y su utilización que es independiente de cualquier relación comercial, hace que el desarrollo de este parque y sus infraestructuras ofrezcan un aprovechamiento óptimo de uno de los recursos naturales propios de Aragón como es el viento.

6 Contribución en la disminución de la dependencia energética de nuestro país así como de la Unión Europea.

---

**1.2. Criterios técnicos de situación que desde el punto de vista de aprovechamiento del recurso eólico, optimización de la planificación de redes de evacuación y transporte eléctrico, respecto al patrimonio cultural y a los valores medioambientales se han seguido para elegir los terrenos en los que se situarán concretamente las instalaciones.**

El parque es una repotenciación de uno existente y en funcionamiento.

---

**1.3. Descripción de los recursos eólicos presentes mediante las mediciones efectuadas o un estudio o modelización que confirme la existencia de recurso suficiente para el funcionamiento del parque.**

Ver estudio de viento incluido en el volumen ANEXOS TOMO II

---

**1.4. Adecuación del proyecto a la situación de planeamiento urbanístico vigente, en el área de implantación prevista.**

Ya existe un parque eólico en funcionamiento.



**1.5. Descripción y justificación de los datos referidos a la ordenación del parque eólico, tales como superficie, ocupación de la finca por edificaciones, instalaciones y superficies pavimentadas. Se incluirá asimismo, la justificación de los movimientos de tierra a efectuar.**

Tabla resumen de las afecciones del parque eólico “I+D Cabezó Negro”

|  |               |        | Superficie |
|--|---------------|--------|------------|
| Ocupación aerogeneradores                                    |               |        | 524 m2     |
| Ocupación plataformas  |               |        | 5.882 m2   |
| Ocupación caminos  | Existentes    | 90,46% | 31.677 m2  |
|  | Nuevos        | 9,54%  | 3.342 m2   |
|  | Total caminos |        | 35.019 m2  |
| Ocupación total  |               |        | 41.426 m2  |
| Longitud Caminos   | Existentes    | 89,44% | 3.329 m    |
|  | Nuevos        | 10,56% | 393 m      |
|  | Total caminos |        | 3.722 m    |
| Ocupación de las losas de cimentación de los aerogeneradores |               |        |            |
| Ocupación aerogeneradores (Losa de cimentación)              |               |        | 452 m2     |

En el anexo de cálculos de la memoria del proyecto se han colocado las tablas con los movimientos de tierra a realizar en Caminos, Cimentaciones y Plataformas de Montaje.

En los planos 07 de perfiles longitudinales se puede observar cómo se han trazado los caminos para ajustar sus características de diseño a los condicionantes de los transportes y de las grúas de montaje, el resultado de los movimientos de tierras expresado en las tablas es consecuencia de adaptar los caminos a esos condicionantes.

En el Anexo de cálculos se incluye también una tabla con la superficie de los taludes para replantar con tierra vegetal procedente de los desbroces.

---

**1.6. Descripción de los servicios existentes y previstos relativos a accesos, abastecimientos, energías, alumbrado y otras instalaciones.**

Los viales de acceso al parque eólico ya están en uso, se adaptarán a los requisitos de los transportes.

---

**1.7. Descripción de las características formales y constructivas; uso y destino de las edificaciones, referidas a la superficie construida; altura de las edificaciones y de los elementos singulares, composición, materiales y otras.**

El uso y destino tanto de las edificaciones como los elementos singulares de este proyecto, son la generación de energía eléctrica a partir del viento.

En el parque eólico, los elementos singulares a instalar son los aerogeneradores. En la memoria del proyecto y en el ANEXO , se detalla su altura, composición y materiales.

### 1.8. Plazo de ejecución del proyecto.

| Id | ACTIVIDAD                              |   |   |   |   |   |   |   |   |   |    |    |    |
|----|--|---|---|---|---|---|---|---|---|---|----|----|----|
|    | Mes                                    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|    | <b>PARQUE EOLICO</b>                   |   |   |   |   |   |   |   |   |   |    |    |    |
| 1  | Obra Civil                             |   |   |   |   |   |   |   |   |   |    |    |    |
| 2  | Camino de Acceso                       |   |   |   |   |   |   |   |   |   |    |    |    |
| 3  | Cimentaciones                          |   |   |   |   |   |   |   |   |   |    |    |    |
| 4  | Desmantelamiento aerogeneradores       |   |   |   |   |   |   |   |   |   |    |    |    |
| 5  | Plataformas                            |   |   |   |   |   |   |   |   |   |    |    |    |
| 6  | Hidrosiembra                           |   |   |   |   |   |   |   |   |   |    |    |    |
| 7  | Red de media tensión                   |   |   |   |   |   |   |   |   |   |    |    |    |
| 8  | Apertura de zanjas                     |   |   |   |   |   |   |   |   |   |    |    |    |
| 9  | Tendido de conductores y cierre zanjas |   |   |   |   |   |   |   |   |   |    |    |    |
| 10 | Aerogeneradores                        |   |   |   |   |   |   |   |   |   |    |    |    |
| 11 | Montaje de aerogeneradores             |   |   |   |   |   |   |   |   |   |    |    |    |
| 12 | Conexión de aerogeneradores            |   |   |   |   |   |   |   |   |   |    |    |    |
| 13 | Puesta en marcha                       |   |   |   |   |   |   |   |   |   |    |    |    |
| 14 | <b>SUBESTACION DE TRANSFORMACION</b>   |   |   |   |   |   |   |   |   |   |    |    |    |
| 15 | Instalacion de aparamenta              |   |   |   |   |   |   |   |   |   |    |    |    |
| 16 | Pruebas                                |   |   |   |   |   |   |   |   |   |    |    |    |

---

### 1.9. Presupuesto de las instalaciones.

Ver presupuesto en los documentos de Proyecto

---

#### **1.10. Descripción detallada de todas las instalaciones de alta y baja tensión con adecuación a la Normativa Vigente.**

El proyecto presentado visado por técnico competente y visado por el colegio oficial, cumple con los requisitos establecidos en el artículo 12 e Instrucción Técnica Complementaria ITC-RAT20, del vigente Reglamento sobre Condiciones Técnicas y Garantías de Seguridad en Centrales Eléctricas, Subestaciones y Centros de Transformación (aprobadas mediante Real Decreto 337/2014, de 9 de mayo, por el que se aprueban el Reglamento sobre condiciones técnicas y garantías de seguridad en instalaciones eléctricas de alta tensión y sus Instrucciones Técnicas Complementarias ITC-RAT 01 a 23.)

Ver Capítulo 1.3 de la memoria del proyecto

---

#### **1.11. Descripción de las instalaciones de evacuación de energía eléctrica hasta el punto de conexión con la red de distribución o transporte.**

El parque actual ya tiene evacuación en SET Muel y no está previsto modificar las instalaciones de enlace y evacuación.

## **1.12. Medidas previstas de protección contra incendios.**

### **AEROGENERADORES**

Esta instalación no está incluida dentro del ámbito de aplicación del real Decreto 2267/2004 de 3 de Diciembre por el que se aprueba el reglamento de seguridad contra incendios en los establecimientos industriales. Según se deduce del artículo 2 del citado Real Decreto y del artículo 3.1 de la Ley 21/1992 de 16 de Julio de Industria.

En la memoria se ha especificado que cada aerogenerador dispondrá de un extintor contra incendios, clase B29 en la zona de celdas. Esos extintores cumplirán con lo indicado en la MIE RAT 14 capítulo 4, por ser los transformadores de aislamiento seco, no es necesario un sistema de extinción fijo.

Como en cualquier instalación existe un riesgo de incendio (calentamiento excesivo de la multiplicadora, de los sistemas hidráulicos etc). Los sistemas de detección de incendios instalados en el aerogenerador están conectados al SCADA del parque, por lo que garantiza la rápida actuación ante cualquier incidente.

El hecho que el sistema de generación se encuentre situado a una considerable altura del suelo permite que el incendio quede bastante aislado, con lo que se minimiza el riesgo de propagación del mismo a otras partes de la instalación.

Existe el riesgo de que se produzca un incendio cuando el personal de mantenimiento se encuentre dentro de la nacelle por lo que cada operado deberá de disponer de un sistema paracaídas que permita una rápida evacuación del aerogenerador en el caso de que se produzca un incendio incontrolado que bloquee el acceso a la escalera de la torre y sea necesario escapar por las otras salidas que dispone el aerogenerador.

El personal Operación Mantenimiento y Servicio de SIEMENS GAMESA, está entrenado para realizar esta evacuación de emergencia.

Queda totalmente prohibido el acceso de ninguna persona a la zona de altura del aerogenerador, si no va acompañado de un técnico cualificado de la compañía y deberá contar con los mismos equipos de protección y evacuación que el personal de la compañía, así como estar en posesión y en vigor, de la certificación necesaria para acceder a lo alto de un aerogenerador.



---

1.13. Descripción del aerogenerador a instalar que certifique el cumplimiento de las exigencias del operador del sistema conforme a la normativa estatal vigente y principales características, en especial, el apartado relativo a los huecos de tensión. Declaración de conformidad CE de las máquinas que se pretende instalar, junto con una descripción detallada del aerogenerador a instalar.

VER MEMORIA DEL PROYECTO Y ANEXO II

---

#### **1.14. Adecuación de las instalaciones a las disposiciones relativas a la seguridad y a la salud para la utilización por los operadores de los equipos de trabajo.**

A partir del estudio de seguridad y salud del proyecto, el contratista de la obra elaborará un Plan de Seguridad, previo al inicio de los trabajos. Este plan será supervisado y aprobado por el coordinador de seguridad y salud que asuma los trabajos.

---

### 1.15. Estudio de seguridad y salud

Ver Estudio de Seguridad y Salud en los documentos de proyecto.

## 1.16. Relación de personas físicas y jurídicas propietarios de bienes, instalaciones, obras o servicios afectados por la instalación.

| DATOS DE LA FINCA |     |      |                | AFECCION          |                         |               |              |            |             |                   |              |                            |                          | SET          |                 |
|-------------------|-----|------|----------------|-------------------|-------------------------|---------------|--------------|------------|-------------|-------------------|--------------|----------------------------|--------------------------|--------------|-----------------|
| Nº FINCA PROYECTO | PGR | PARC | REF CATASTRAL  | TERMINO MUNICIPAL | SUPERFICIE PARCELA (m2) | AEROGENERADOR |              |            |             | LINEA SUBTERRÁNEA |              |                            |                          | CAMINOS      |                 |
|                   |     |      |                |                   |                         | Uds           | DENOMINACIÓN | VUELO (m2) | ZAPATA (m2) | Plataforma (m2)   | Longitud (m) | Superficie Permanente (m2) | Superficie Temporal (m2) | Longitud (m) | Superficie (m2) |
| 46                | 1   | 1    | 50132A0100001  | Jaulín            | 850,225.88              |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 113.13       | 1,014.10        |
| 15                | 1   | 6    | 50132A0100006  | Jaulín            | 125,927.99              |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 31.88        | 601.24          |
| 25                | 1   | 23   | 50132A0100023  | Jaulín            | 154,649.61              |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 70.40           |
| 19                | 1   | 26   | 50132A0100026  | Jaulín            | 7,284.39                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 179.29       | 1,502.30        |
| 29                | 1   | 38   | 50132A0100029  | Jaulín            | 16,341.98               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 281.23       | 0.00            |
| 31                | 1   | 31   | 50132A0100031  | Jaulín            | 26,089.67               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 114.42          |
| 32                | 1   | 32   | 50132A0100032  | Jaulín            | 11,212.45               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 52.38           |
| 34                | 1   | 34   | 50132A0100034  | Jaulín            | 7,749.18                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 98.10           |
| 36                | 1   | 36   | 50132A0100036  | Jaulín            | 8,745.37                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 395.41          |
| 37                | 1   | 37   | 50132A0100037  | Jaulín            | 2,766.16                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 191.11       | 1,171.85        |
| 27                | 1   | 38   | 50132A0100038  | Jaulín            | 21,006.91               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 105.59          |
| 14                | 15  | 1    | 50132A0150001  | Jaulín            | 1,842.71                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 4.18            |
| 17                | 15  | 170  | 50132A01500170 | Jaulín            | 32,906.72               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 74.59           |
| 44                | 17  | 2    | 50132A0170002  | Jaulín            | 3,251.90                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 28.90        | 337.25          |
| 42                | 17  | 3    | 50132A0170003  | Jaulín            | 9,189.25                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 47.40           |
| 41                | 17  | 4    | 50132A0170004  | Jaulín            | 24,942.10               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 32.50        | 444.12          |
| 40                | 17  | 6    | 50132A0170006  | Jaulín            | 14,971.57               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 5.87         | 289.07          |
| 39                | 17  | 13   | 50132A0170013  | Jaulín            | 19,745.39               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 227.50          |
| 38                | 17  | 14   | 50132A0170014  | Jaulín            | 11,911.27               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 152.24       | 1,052.67        |
| 45                | 17  | 24   | 50132A0170024  | Jaulín            | 544,721.61              | 1             | CN1          | 16,512.89  | 400.01      | 5,444.21          | 665.03       | 3,075.65                   | 1,998.39                 | 1,023.83     | 11,410.67       |
| 30                | 17  | 53   | 50132A0170053  | Jaulín            | 31,077.99               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 6.25         | 486.71          |
| 33                | 17  | 56   | 50132A0170056  | Jaulín            | 217,384.70              |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 272.33       | 1,318.44        |
| 28                | 17  | 60   | 50132A0170060  | Jaulín            | 7,239.47                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 79.92        | 332.39          |
| 24                | 17  | 65   | 50132A0170065  | Jaulín            | 35,431.27               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 580.73       | 4,330.85        |
| 26                | 17  | 73   | 50132A0170073  | Jaulín            | 8,734.17                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 1.51            |
| 2                 | 18  | 9    | 50132A0180009  | Jaulín            | 6,060.01                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.22         | 314.59          |
| 1                 | 18  | 10   | 50132A0180010  | Jaulín            | 10,516.36               |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 6.27         | 200.27          |
| 11                | 18  | 134  | 50132A01800134 | Jaulín            | 4,367.03                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 3.40         | 215.69          |
| 3                 | 19  | 3    | 50132A0190003  | Jaulín            | 3,209.06                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 0.00         | 96.34           |
| 4                 | 19  | 5    | 50132A0190004  | Jaulín            | 3,069.96                |               |              | 0.00       | 0.00        | 0.00              | 0.00         | 0.00                       | 0.00                     | 49.00        | 811.96          |

1.17. Partes del proyecto que afectan a bienes, instalaciones, obras o servicios, centros o zonas dependientes de otras Administraciones Públicas, Organismos, Corporaciones, o Departamentos del Gobierno de Aragón, para que estos establezcan, si procede, el condicionado procedente en el trámite de informe.

| DATOS DE LA FINCA |               |      |                |                   |                         | AFECCIÓN |              |            |      |             |                 |              | SET                        |                          |              |
|-------------------|---------------|------|----------------|-------------------|-------------------------|----------|--------------|------------|------|-------------|-----------------|--------------|----------------------------|--------------------------|--------------|
| Nº FINCA PROYECTO | AEROGENERADOR |      |                | LINEA SUBTERRÁNEA |                         |          | CAMINOS      |            | SET  |             |                 |              |                            |                          |              |
|                   | PGNO          | PARC | REF CATASTRAL  | TERMINO MUNICIPAL | SUPERFICIE PARCELA (m2) | UDs      | DENOMINACIÓN | VUELO (m2) |      | ZAPATA (m2) | Plataforma (m2) | Longitud (m) | Superficie Permanente (m2) | Superficie Temporal (m2) | Longitud (m) |
| 18                | 1             | 9002 | 50132A00109002 | Jaulin            | 4.162,61                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 11,81                    | 0,00         |
| 16                | 1             | 9003 | 50132A00109003 | Jaulin            | 1.103,03                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 270,87                   | 1.053,48     |
| 21                | 1             | 9004 | 50132A00109004 | Jaulin            | 3.419,05                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 117,10                   | 1.720,12     |
| 35                | 1             | 9005 | 50132A00109005 | Jaulin            | 171,00                  |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 0,00                     | 0,25         |
| 13                | 15            | 9001 | 50132A00159001 | Jaulin            | 5.024,33                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 97,06                    | 993,74       |
| 22                | 17            | 9001 | 50132A00179001 | Jaulin            | 3.662,48                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 332,49                   | 1.965,85     |
| 23                | 17            | 9002 | 50132A00179002 | Jaulin            | 5.534,85                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 4,48                     | 52,23        |
| 43                | 17            | 9003 | 50132A00179003 | Jaulin            | 773,70                  |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 6,25                     | 308,76       |
| 12                | 18            | 9002 | 50132A00189002 | Jaulin            | 2.259,00                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 60,09                    | 289,16       |
| 10                | 18            | 9007 | 50132A00189007 | Jaulin            | 14.612,01               |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 10,71                    | 0,00         |
| 7                 | 19            | 9011 | 50132A00190005 | Jaulin            | 219,95                  |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 0,22                     | 22,22        |
| 9                 | 19            | 9009 | 50132A00190009 | Jaulin            | 9.112,11                |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 0,09                     | 0,00         |
| 5                 | 19            | 9010 | 50132A00190010 | Jaulin            | 85,88                   |          |              | 0,00       | 0,00 | 0,00        | 0,00            | 0,00         | 0,00                       | 2,78                     | 21,43        |

---

**1.18. Documentación acreditativa de la capacidad legal, técnica y económica del solicitante.**

SE HA INCLUIDO EN EL ANEXO II

---

1.19. Informe de las servidumbres aeronáuticas afectadas y, en caso de existir, estudio aeronáutico que asegure que las instalaciones no comprometen la seguridad de las operaciones de las aeronaves, de acuerdo con el Real Decreto 1541/2003, por el que se modifica el Decreto 584/1972, de servidumbres aeronáuticas, y el Decreto 1844/1975, de servidumbres aeronáuticas en helipuertos, para regular excepciones a los límites establecidos por las superficies limitadoras de obstáculos alrededor de aeropuertos y helipuertos.

Solicitud enviada a AESA.



ENTRADA  
Registro General AESA  
Número: 2024020234  
Fecha: 30/01/2024 10:13

## JUSTIFICANTE DE PRESENTACIÓN DE REGISTRO

### 1. DATOS DE LOS SOLICITANTES

SISTEMAS ENERGÉTICOS CABEZO NEGRO, SAU (A99141913) representado por MICHAEL MATROSS NOBANDIAN (X9637577W)

### 2. ASUNTO

SOLICITUD DE EVALUACION DE SSAA  
SOLICITUD DE EVALUACION DE ACTUACION EN CERCANIAS AFECTADAS POR ZONAS DE SERVIDUMBRES  
AERONAUTICAS CON ORIGEN O DESTINO EN ESPAÑA

PASEO DE LA CASTELLANA, 112  
28046, MADRID  
TEL: 91 396 80 00





MINISTERIO  
DE TRANSPORTES  
Y MOVILIDAD SOSTENIBLE

## SOLICITUD PARA LA TRAMITACIÓN DE SERVIDUMBRES AERONÁUTICAS



AGENCIA ESTATAL  
DE SEGURIDAD AÉREA

DIRECCIÓN DE SEGURIDAD DE AEROPUERTOS  
Y NAVEGACIÓN AÉREA

SERVIDUMBRES AERONÁUTICAS

| 1. PETICIONARIO           |  |  |                 |  |         |           |                           |
|---------------------------|--|--|-----------------|--|---------|-----------|---------------------------|
| 1. CIF<br>A99141913       |  |  |                 | 2. Razón Social<br>SISTEMAS ENERGÉTICOS CABEZO NEGRO, SAU    |         |           |                           |
| 3. Tipo Vía<br>Calle      | 4. Domicilio Social<br>Ramírez de Arellano |  | 5. Número<br>37 | 6. Escalera  | 7. Piso | 8. Puerta | 9. Código Postal<br>28043 |
| 10. Municipio<br>Madrid   |  |  |                 | 11. Provincia<br>Madrid                                      |         |           |                           |
| 12. Teléfono<br>664032997 |  |  |                 | 13. Correo Electrónico<br>alejandro.ribera@siemensgamesa.com |         |           |                           |

| 2. REPRESENTANTE DEL PETICIONARIO |   |
|-----------------------------------|---|
| 14. NIF<br>X9637577W              | 15. Apellidos y Nombre<br>MATROSS NOBANDIANS MICHAEL        |
| 16. Teléfono                      | 17. Correo Electrónico<br>michael.matross@siemensgamesa.com |

| 3. DATOS DE LA SOLICITUD                 |  |
|--|--|
| 18. Tipo de la Solicitud<br>Autorización | 19. Código de la solicitud<br>S24-1045 |

| 4. TIPOS DE ACTUACIÓN   |               |                            |            |                         |            |
|---|---------------|----------------------------|------------|-------------------------|------------|
| 20. Id.   | 1             |                            |            |                         |            |
| 21. Municipio   | Jaulín        | 22. Provincia              | Zaragoza   | 23. Datum               | ETRS89     |
| 24. Huso  | 30            | 25. UTM X                  | 665230,00  | 26. UTM Y               | 4590692,00 |
| 27. Altura solicitada (m.)  | 200,00        | 28. Cota terreno (m.s.n.m) | 651,00     | 29. Altura cubierta (m) |            |
| 30. Uso   | Parque eólico | 31. Carácter de uso        | Permanente |                         |            |
| 32. Descripción<br>Modificación de las coordenadas de las turbinas con Autorización |               |                            |            |                         |            |
| 20. Id.   | 2             |                            |            |                         |            |
| 21. Municipio   | Jaulín        | 22. Provincia              | Zaragoza   | 23. Datum               | ETRS89     |
| 24. Huso  | 30            | 25. UTM X                  | 664987,00  | 26. UTM Y               | 4590052,00 |
| 27. Altura solicitada (m.)  | 200,00        | 28. Cota terreno (m.s.n.m) | 648,00     | 29. Altura cubierta (m) |            |
| 30. Uso   | Parque eólico | 31. Carácter de uso        | Permanente |                         |            |
| 32. Descripción<br>Modificación de las coordenadas de las turbinas con Autorización |               |                            |            |                         |            |

| 5. MEDIOS AUXILIARES       |            |                            |           |                     |            |
|----------------------------|------------|----------------------------|-----------|---------------------|------------|
| 33. Id.                    | 1Aux       |                            |           |                     |            |
| 34. Municipio              | Jaulín     | 35. Provincia              | Zaragoza  | 36. Datum           | ETRS89     |
| 37. Huso                   | 30         | 38. UTM X                  | 664987,00 | 39. UTM Y           | 4590052,00 |
| 40. Altura solicitada (m.) | 140,00     | 41. Cota terreno (m.s.n.m) | 648,00    | 42. Tiempo estimado | 3 meses    |
| 43. Tipo medio             | Grúa móvil | 44. Carácter de uso        | 40        |                     |            |

Ejemplar para el interesado.

CORREO ELECTRONICO:  
servidumbres.aesa@seguridadaerea.es

www.seguridadaerea.gob.es

PASEO DE LA CASTELLANA, 112  
28046 MADRID  
TEL: +34 91 396 8320  
FAX: +34 91 770 5459



|                 |      |
|-----------------|------|
| 45. Descripción | Grúa |
|-----------------|------|

## 6. OBSERVACIONES

46. Observaciones

## 7. DOCUMENTACIÓN ADICIONAL

| 47. Descripción   | 48. Nombre del documento           | 49. Huella                       |
|---|------------------------------------|----------------------------------|
| Plano(s) de situación a escala                                      | 20240130101156-Plano situacion.pdf | 54fa8c7a18b427c689a970460d8e2969 |
| Plano(s) de situación a escala                                      | 20240130101201-Plano situacion.pdf | 6028d9a541ee76d7046df70ff860a10  |
| Plano(s) acotado(s) de la planta y el alzado                        | 20240130101208-Plano planta.pdf    | 3d5933cbbc457c8c1b2ad034472877f8 |
| Plano(s) acotado(s) de la planta y el alzado                        | 20240130101214-Plano planta.pdf    | 36d9d3bed120fc4e133150c51096ab56 |
| En caso de representante, poder notarial o similar que lo acredite. | 20240130101240-Poder notarial.pdf  | 4dfc3acb2240b379bdd53c84009181ad |

## 8. FECHA Y FIRMA

En Madrid  
a 30 de enero de 2024

Firma:

Firmado electrónicamente por  
30/01/2024 10:12:44

Ejemplar para el interesado.

MINISTERIO  
DE TRANSPORTES  
Y MOVILIDAD SOSTENIBLE  
AGENCIA ESTATAL  
DE SEGURIDAD AÉREA



La Agencia Estatal de Seguridad Aérea (En adelante AESA), como Responsable del Tratamiento de sus datos personales en cumplimiento de la Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales y el Reglamento (UE) 2016/679 del Parlamento Europeo y del Consejo, de 27 de abril de 2016, relativo a la protección de las personas físicas en lo que respecta al tratamiento de datos personales y a la libre circulación de estos datos (Reglamento General de Protección de Datos), le informa, de manera explícita e inequívoca, que se va a proceder al tratamiento de sus datos de carácter personal obtenidos del "Formulario de solicitud para la tramitación de servidumbres aeronáuticas y obstáculos mayores de 100 m", para el tratamiento "**Autorización en materia de servidumbres aeronáuticas**" y con la finalidad:

- De "**Gestionar autorizaciones**". El usuario no podrá negar su consentimiento por ser este una obligación legal, definida por la "**Ley 48/1960, de 21 de Julio, sobre Navegación Aérea.**"

Este tratamiento de datos de carácter personal se encuentra incluido en el Registro de Datos Personales de AESA.

La legalidad del tratamiento está basada en una obligación legal.

La información de carácter personal será conservada mientras sea necesaria o no se ejerza su derecho de cancelación o supresión.

La información puede ser cedida a terceros para colaborar en la gestión de los datos de carácter personal, únicamente para la finalidad descrita anteriormente.

La categoría de los datos de carácter personal que se tratan son únicamente "**Datos identificativos (nombre, DNI, dirección, correo-e...)**".

De acuerdo con lo previsto en la citada Ley Orgánica de Protección de Datos y Garantías de Derechos Digitales y el también citado Reglamento General de Protección de Datos, puede ejercitar sus derechos de Acceso, Rectificación, Supresión, Portabilidad de sus datos, la Limitación u Oposición a su tratamiento ante el Delegado de Protección de Datos, dirigiendo una comunicación al correo [dpd.aesa@seguridadaerea.es](mailto:dpd.aesa@seguridadaerea.es)

Para más información sobre el tratamiento de los datos de carácter personal pulse el siguiente enlace:

<https://www.seguridadaerea.gob.es/es/quienes-somos/normativa-aesa/proteccion-de-datos>

Ejemplar para el interesado.

MINISTERIO  
DE TRANSPORTES  
Y MOVILIDAD SOSTENIBLE  
AGENCIA ESTATAL  
DE SEGURIDAD AÉREA



MINISTERIO  
DE TRANSPORTES  
Y MOVILIDAD SOSTENIBLE

**SOLICITUD PARA LA TRAMITACIÓN  
DE SERVIDUMBRES  
AERONÁUTICAS**



**AGENCIA ESTATAL  
DE SEGURIDAD AÉREA**

DIRECCIÓN DE SEGURIDAD DE AEROPUERTOS  
Y NAVEGACIÓN AÉREA

SERVIDUMBRES AERONÁUTICAS

| 1. PETICIONARIO           |  |  |             |   |           |                           |  |
|---------------------------|--|--|-------------|---|-----------|---------------------------|--|
| 1. CIF<br>A99141913       |  |  |             | 2. Razón Social<br>SISTEMAS ENERGÉTICOS CABEZO NEGRO, SAU |           |                           |  |
| 3. Tipo Vía<br>Calle      | 4. Domicilio Social<br>Ramírez de Arellano | 5. Número<br>37  | 6. Escalera | 7. Piso   | 8. Puerta | 9. Código Postal<br>28043 |  |
| 10. Municipio<br>Madrid   |  | 11. Provincia<br>Madrid                                      |             |   |           |                           |  |
| 12. Teléfono<br>664032997 |  | 13. Correo Electrónico<br>alejandro.ribera@siemensgamesa.com |             |   |           |                           |  |

| 2. REPRESENTANTE DEL PETICIONARIO |   |
|-----------------------------------|---|
| 14. NIF<br>X9637577W              | 15. Apellidos y Nombre<br>MATROSS NOBANDIANS MICHAEL        |
| 16. Teléfono                      | 17. Correo Electrónico<br>michael.matross@siemensgamesa.com |

| 3. DATOS DE LA SOLICITUD                 |  |
|--|--|
| 18. Tipo de la Solicitud<br>Autorización | 19. Código de la solicitud<br>S24-1045 |

| 4. TIPOS DE ACTUACIÓN      |  |                            |            |                         |            |
|----------------------------|--|----------------------------|------------|-------------------------|------------|
| 20. Id.                    | 1  |                            |            |                         |            |
| 21. Municipio              | Jaulín   | 22. Provincia              | Zaragoza   | 23. Datum               | ETRS89     |
| 24. Huso                   | 30   | 25. UTM X                  | 665230,00  | 26. UTM Y               | 4590692,00 |
| 27. Altura solicitada (m.) | 200,00   | 28. Cota terreno (m.s.n.m) | 651,00     | 29. Altura cubierta (m) |            |
| 30. Uso                    | Parque eólico  | 31. Carácter de uso        | Permanente |                         |            |
| 32. Descripción            | Modificación de las coordenadas de las turbinas con Autorización |                            |            |                         |            |
| 20. Id.                    | 2  |                            |            |                         |            |
| 21. Municipio              | Jaulín   | 22. Provincia              | Zaragoza   | 23. Datum               | ETRS89     |
| 24. Huso                   | 30   | 25. UTM X                  | 664987,00  | 26. UTM Y               | 4590052,00 |
| 27. Altura solicitada (m.) | 200,00   | 28. Cota terreno (m.s.n.m) | 648,00     | 29. Altura cubierta (m) |            |
| 30. Uso                    | Parque eólico  | 31. Carácter de uso        | Permanente |                         |            |
| 32. Descripción            | Modificación de las coordenadas de las turbinas con Autorización |                            |            |                         |            |

| 5. MEDIOS AUXILIARES       |            |                            |           |                     |            |
|----------------------------|------------|----------------------------|-----------|---------------------|------------|
| 33. Id.                    | 1Aux       |                            |           |                     |            |
| 34. Municipio              | Jaulín     | 35. Provincia              | Zaragoza  | 36. Datum           | ETRS89     |
| 37. Huso                   | 30         | 38. UTM X                  | 664987,00 | 39. UTM Y           | 4590052,00 |
| 40. Altura solicitada (m.) | 140,00     | 41. Cota terreno (m.s.n.m) | 648,00    | 42. Tiempo estimado | 3 meses    |
| 43. Tipo medio             | Grúa móvil | 44. Carácter de uso        | 40        |                     |            |

Ejemplar para el interesado.

CORREO ELECTRÓNICO  
servidumbres.aesa@seguridadaerea.es

www.seguridadaerea.gob.es

PASEO DE LA CASTELLANA, 112  
28045 MADRID  
TEL: +34 91 396 8320  
FAX: +34 91 770 5459





|                 |      |
|-----------------|------|
| 45. Descripción | Grúa |
|-----------------|------|

## 6. OBSERVACIONES

|                   |
|-------------------|
| 46. Observaciones |
|-------------------|

## 7. DOCUMENTACIÓN ADICIONAL

| 47. Descripción   | 48. Nombre del documento           | 49. Huella                       |
|---|------------------------------------|----------------------------------|
| Plano(s) de situación a escala                                      | 20240130101156-Plano situacion.pdf | 54fa8c7a18b427c689a970460d8e2969 |
| Plano(s) de situación a escala                                      | 20240130101201-Plano situacion.pdf | 6028d9a541ee76d7046df70fff860a10 |
| Plano(s) acotado(s) de la planta y el alzado                        | 20240130101208-Plano planta.pdf    | 3d5933cbbc457c8c1b2ad034472877f8 |
| Plano(s) acotado(s) de la planta y el alzado                        | 20240130101214-Plano planta.pdf    | 36d9d3bed120fc4e133150c51096ab56 |
| En caso de representante, poder notarial o similar que lo acredite. | 20240130101240-Poder notarial.pdf  | 4dfc3acb2240b379bdd53c84009181ad |

## 8. FECHA Y FIRMA

En Madrid  
a 30 de enero de 2024

Firma:

Firmado electrónicamente por

30/01/2024 10:12:44

Ejemplar para el interesado.

MINISTERIO  
DE TRANSPORTES  
Y MOVILIDAD SOSTENIBLE  
AGENCIA ESTATAL  
DE SEGURIDAD AÉREA



La Agencia Estatal de Seguridad Aérea (En adelante AESA), como Responsable del Tratamiento de sus datos personales en cumplimiento de la *Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales* y el *Reglamento (UE) 2016/679 del Parlamento Europeo y del Consejo, de 27 de abril de 2016, relativo a la protección de las personas físicas en lo que respecta al tratamiento de datos personales y a la libre circulación de estos datos (Reglamento General de Protección de Datos)*, le informa, de manera explícita e inequívoca, que se va a proceder al tratamiento de sus datos de carácter personal obtenidos del "Formulario de solicitud para la tramitación de servidumbres aeronáuticas y obstáculos mayores de 100 m", para el tratamiento "*Autorización en materia de servidumbres aeronáuticas*" y con la finalidad:

- De "*Gestionar autorizaciones*". El usuario no podrá negar su consentimiento por ser este una obligación legal, definida por la "*Ley 48/1960, de 21 de julio, sobre Navegación Aérea.*"

Este tratamiento de datos de carácter personal se encuentra incluido en el Registro de Datos Personales de AESA.

La legalidad del tratamiento está basada en una obligación legal.

La información de carácter personal será conservada mientras sea necesaria o no se ejerza su derecho de cancelación o supresión.

La información puede ser cedida a terceros para colaborar en la gestión de los datos de carácter personal, únicamente para la finalidad descrita anteriormente.

La categoría de los datos de carácter personal que se tratan son únicamente "*Datos identificativos (nombre, DNI, dirección, correo-e...)*".

De acuerdo con lo previsto en la citada *Ley Orgánica de Protección de Datos y Garantías de Derechos Digitales* y el también citado *Reglamento General de Protección de Datos*, puede ejercitar sus derechos de Acceso, Rectificación, Supresión, Portabilidad de sus datos, la Limitación u Oposición a su tratamiento ante el Delegado de Protección de Datos, dirigiendo una comunicación al correo [dpd.aesa@seguridadaerea.es](mailto:dpd.aesa@seguridadaerea.es)

Para más información sobre el tratamiento de los datos de carácter personal pulse el siguiente enlace:

<https://www.seguridadaerea.gob.es/es/quienes-somos/normativa-aesa/proteccion-de-datos>

Ejemplar para el interesado.

MINISTERIO  
DE TRANSPORTES  
Y MOVILIDAD SOSTENIBLE  
AGENCIA ESTATAL  
DE SEGURIDAD AÉREA

---

**1.20. Cuantos documentos adicionales relacionados con el expediente y relevantes para su resolución estime oportuno reclamar el órgano competente para la tramitación del expediente administrativo.**

---

## **2. ANEXO II CARACTERISTICAS TÉCNICAS DE LOS AEROGENERADORES**

### **2.1. Características y funcionamiento general de la plataforma de aerogeneradores SG 5.0** **145**



## Developer package SG 5.0-145



| Document ID and revision | Status   | Status date (yyyy-mm-dd) | Language |
|--------------------------|----------|--------------------------|----------|
| GD477725 R7              | Released | 2023-08-01               | en-US    |

| Original or translation of |
|----------------------------|
| Original                   |

| File name        |
|------------------|
| GD477725 R7.docx |

Siemens Gamesa Renewable Energy S.A. Parque Tecnológico de Bizkaia, Edificio 222, 48170, Zamudio, Vizcaya, Spain  
+34 944 03 73 52 – [info@siemensgamesa.com](mailto:info@siemensgamesa.com) – [www.siemensgamesa.com](http://www.siemensgamesa.com)

## Disclaimer of liability and conditions of use.

To the extent permitted by law, neither Siemens Gamesa Renewable Energy A/S nor any of its affiliates in the Siemens Gamesa group including Siemens Gamesa Renewable Energy S.A. and its subsidiaries (hereinafter “SGRE”) gives any warranty of any type, either express or implied, with respect to the use of this document or parts thereof other than the use of the document for its intended purpose. In no event will SGRE be liable for damages, including any general, special, incidental or consequential damages, arising out of the use of the document, the inability to use the document, the use of data embodied in, or obtained from, the document or the use of any documentation or other material accompanying the document except where the documents or other material accompanying the documents becomes part of an agreement between you and SGRE in which case the liability of SGRE will be regulated by the said agreement. SGRE reviews this document at regular intervals and includes appropriate amendments in subsequent issues. The intellectual property rights of this document are and remain the property of SGRE. SGRE reserves the right to update this documentation from time to time, or to change it without prior notice.

## Application of the Developer Package

The Developer Package serves the purpose of informing customers about the latest planned product development from Siemens Gamesa Renewable Energy (SGRE). By sharing information about coming developments, SGRE can ensure that customers are provided with necessary information to make decisions.

Furthermore, the Developer Package can assist in guiding prospective customers with the indicated technical footprint of the SG 5.0-145 in cases where financial institutes, governing bodies, or permitting entities require product specific information in their decision processes.

All technical data contained in the Developer Package is subject to change owing to ongoing technical developments. Information contained within the Developer Package may not be treated separately or out of the context of the Developer Package.

The information contained in the Developer Package may not be used as legally binding documentation and cannot be used in contracts between SGRE and any other parties. This Developer Package contains preliminary technical data on SGRE turbines currently under development and can be used in an indicative capacity only.

All technical data is subject to change according to the technical development of the wind turbine.

# Developer Package

## SG 5.0-145

### Table of contents

|  |    |
|--|----|
| Introduction .....   | 5  |
| Technical Description .....                                    | 6  |
| Nacelle Arrangement .....                                      | 9  |
| Nacelle Dimensions .....                                       | 10 |
| Elevation Drawing .....  | 11 |
| Blade Drawing.....   | 12 |
| Design Climatic Conditions .....                               | 13 |
| Standard Power Curve, Standard power operational mode .....    | 15 |
| Standard Ct Curve, Standard power operational mode .....       | 17 |
| Power Curve, Air density, Standard power operational mode..... | 18 |
| Ct Curve, Air Density, Standard power operational mode.....    | 20 |
| Standard Acoustic Emission .....                               | 21 |
| Noise Reduction System (NRS) operational modes.....            | 22 |
| Electrical Specifications .....                                | 28 |
| Simplified Single Line Diagram .....                           | 29 |
| Transformer Specifications ECO 20 kV* .....                    | 30 |
| Transformer Specifications 34.5 kV* .....                      | 30 |
| Switchgear Specification.....                                  | 31 |
| Preliminary Foundation Loads .....                             | 32 |
| Tower Dimensions .....   | 33 |
| Estimated Foundation Design.....                               | 37 |
| Preliminary Grid Performance Specification, 50 Hz .....        | 44 |
| Preliminary Grid Performance Specification, 60 Hz .....        | 47 |
| Reactive Power Capability, 50 Hz .....                         | 50 |
| Reactive Power Capability, 60 Hz .....                         | 53 |
| SCADA, System Description .....                                | 56 |
| Codes and Standards .....                                      | 58 |
| Other Performance Features .....                               | 59 |

## Introduction

The SG 5.0-145 is the second generation product series of the Siemens Gamesa 4.X Platform, which builds on the SG 4.5-145 design features and the Siemens Gamesa technological expertise and operational experience in the wind energy market.

With a 71m blade, a 5.0 MW generator and a tower portfolio with hub heights ranging from 79.5m to 165m, the SG 5.0-145 aims at becoming a new benchmark in the market for efficiency and profitability.

This Developer Package describes the turbine technical specifications and provides preliminary information for the main components and subsystems.

Information included in the present document is specific of the MY21 product configuration and must always be considered together.

For further information, please contact your regional SGRE Sales Manager.

## Technical Description

### Rotor-Nacelle

The rotor is a three-bladed construction, mounted upwind of the tower. The power output is controlled by pitch and torque demand regulation. The rotor speed is variable and is designed to maximize the power output while maintaining loads and noise level.

The nacelle has been designed for safe access to all service points during scheduled service. This allows a high quality service of the wind turbine and provides optimum troubleshooting conditions.

### Blades

The SG 5.0-145 Siemens Gamesa blade is made up of fiberglass infusion-molded components. The blade structure uses aerodynamic shells containing embedded spar-caps, bonded to two main epoxy-fiberglass-balsa/foam-core shear webs. The SG 5.0-145 SGRE blade uses a blade design based on SGRE proprietary airfoils.

### Rotor Hub

The rotor hub is cast in nodular cast iron and is fitted to the drive train low speed shaft with a flange connection. The hub is sufficiently large to provide room for service technicians during maintenance of blade roots and pitch bearings from inside the structure.

### Drive train

The drive train is a 4-points suspension concept: main shaft with two main bearings and the gearbox with two torque arms assembled to the main frame.

The gearbox is in cantilever position; the gearbox planet carrier is assembled to the main shaft by means of a flange bolted joint and supports the gearbox.

### Main Shaft

A forged main shaft ensures a comfortable access from the nacelle cover to the hub.

### Main Bearings

The low speed shaft of the wind turbine is supported by two spherical roller bearings. The bearings are grease lubricated.

### Gearbox

The gearbox is 3 stages high speed type (2 planetary + 1 parallel).

### Generator

The generator is a doubly-fed asynchronous three phase generator with a wound rotor, connected to a frequency PWM converter. Generator stator and rotor are both made of stacked magnetic laminations and formed windings. Generator is cooled by air which is cooled with a liquid/air cooling system.

### Mechanical Brake

The mechanical brake is fitted to the non-drive end of the gearbox.

### Yaw System

A cast bed frame connects the drive train to the tower. The yaw bearing is an externally geared ring with a friction and sliding plain bearing. A series of electric planetary gear motors drives the yawing.

### Nacelle Cover

The weather screen and housing around the machinery in the nacelle is made of fiberglass-reinforced laminated panels.

## **Tower**

The wind turbine is as standard mounted on a tapered tubular steel tower. Other tower technologies are available for higher hub heights. The tower has internal ascent and direct access to the yaw system and nacelle. It is equipped with platforms and internal electric lighting.

## **Controller**

The wind turbine controller is a microprocessor-based industrial controller. The controller is complete with switchgear and protection devices. It is self-diagnosing and has a touch panel and display for easy readout of status and for adjustment of settings.

## **Converter**

Connected directly with the Rotor, the Frequency Converter is a back to back 4Q conversion system with 2 VSC in a common DC-link. The Frequency Converter allows generator operation at variable speed and voltage, while supplying power at constant frequency and voltage to the MV transformer. The power conversion system is water cooled and has a modular arrangement for easy maintenance.

## **SCADA**

The wind turbine provides connection to the SGRE SCADA system. This system offers remote control and a variety of status views and useful reports from a standard internet web browser. The status views present information including electrical and mechanical data, operation and fault status, meteorological data and grid station data.

## **Turbine Condition Monitoring**

In addition to the SGRE SCADA system, the wind turbine is equipped with the unique SGRE condition monitoring setup. This system monitors the vibration level of the main components and compares the actual vibration spectra with a set of established reference spectra. Review of results, detailed analysis and reprogramming can all be carried out using a standard web browser.

## **Operation Systems**

The wind turbine operates automatically. It is self-starting when the aerodynamic torque is enough. Below rated wind speed, the wind turbine controller fixes the pitch and torque references for operating in the optimum aerodynamic point (maximum production) taking into account the generator capability. Once rated wind speed is surpassed, the pitch position demand is adjusted to keep a stable power production equal to the nominal value. If high wind derated mode is enabled, the power production is limited once the wind speed exceeds a threshold value defined by design, until cut-out wind speed is reached and the wind turbine stops producing power. If the average wind speed exceeds the maximum operational limit, the wind turbine is shut down by pitching of the blades. When the average wind speed drops back below the restart average wind speed, the systems reset automatically.

# Technical Specifications

## Rotor

|                        |  |
|------------------------|--|
| Type .....             | 3-bladed, horizontal axis                        |
| Position .....         | Upwind   |
| Diameter .....         | 145 m  |
| Swept area .....       | 16,513 m <sup>2</sup>                            |
| Power regulation ..... | Pitch & torque regulation<br>with variable speed |
| Rotor tilt .....       | 6 degrees  |

## Blade

|                           |  |
|---------------------------|--|
| Type .....                | Self-supporting                                    |
| Blade length .....        | 71.0 m   |
| Root chord .....          | 2.856 m  |
| Aerodynamic profile ..... | Siemens Gamesa<br>proprietary airfoils             |
| Material .....            | GRE (Glassfiber Reinforced<br>Epoxy)               |
| Surface gloss .....       | Semi-gloss, < 30 / ISO2813                         |
| Surface color .....       | Light grey, RAL 7035 or<br>Papyrus White, RAL 9018 |

## Aerodynamic Brake

|                  |                    |
|------------------|--------------------|
| Type .....       | Full span pitching |
| Activation ..... | Active, hydraulic  |

## Load-Supporting Parts

|                         |                   |
|-------------------------|-------------------|
| Hub .....               | Nodular cast iron |
| Main shaft .....        | Forged steel      |
| Nacelle bed frame ..... | Nodular cast iron |

## Mechanical Brake

|                |                      |
|----------------|----------------------|
| Type .....     | Hydraulic disc brake |
| Position ..... | Gearbox rear end     |

## Nacelle Cover

|                     |                           |
|---------------------|---------------------------|
| Type .....          | Totally enclosed          |
| Surface gloss ..... | Semi-gloss, <30 / ISO2813 |
| Color .....         | Papyrus White, RAL 9018   |

## Generator

|            |                    |
|------------|--------------------|
| Type ..... | Asynchronous, DFIG |
|------------|--------------------|

## Grid Terminals (LV)

|                           |                |
|---------------------------|----------------|
| Baseline nominal power .. | 5.0 MW         |
| Voltage .....             | 690 V          |
| Frequency .....           | 50 Hz or 60 Hz |

## Yaw System

|                   |                       |
|-------------------|-----------------------|
| Type .....        | Active                |
| Yaw bearing ..... | Externally geared     |
| Yaw drive .....   | Electric gear motors  |
| Yaw brake .....   | Active friction brake |

## Controller

|                    |   |
|--------------------|---|
| Type .....         | SGRE Wind Turbine Control<br>architecture |
| SCADA system ..... | SGRE SCADA System                         |

## Tower

|                  |                             |
|------------------|-----------------------------|
| Type .....       | Tubular steel / Hybrid      |
| Hub height ..... | 79.5 - 165 m, site-specific |

|                            |                            |
|----------------------------|----------------------------|
| Corrosion protection ..... | Painted                    |
| Surface gloss .....        | Semi-gloss, <30 / ISO-2813 |

|             |                         |
|-------------|-------------------------|
| Color ..... | Papyrus White, RAL 9018 |
|-------------|-------------------------|

## Operational Data

|                          |   |
|--------------------------|---|
| Cut-in wind speed .....  | 3 m/s   |
| Rated wind speed .....   | 11.2 m/s (steady wind<br>without turbulence, as<br>defined by IEC61400-1) |
| Cut-out wind speed ..... | 27 m/s  |
| Restart wind speed ..... | 24 m/s  |

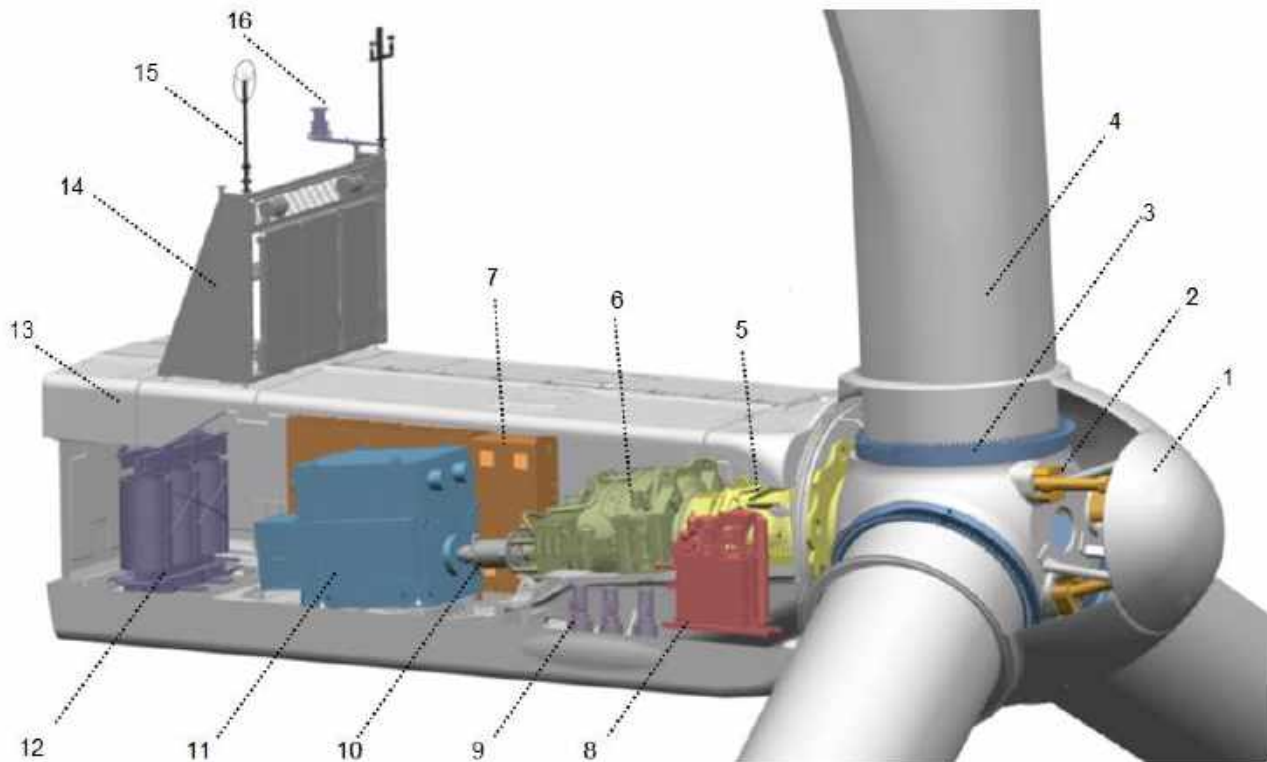
## Weight

|                        |   |
|------------------------|---|
| Modular approach ..... | All modules weight lower<br>than 95 t for transport |
|------------------------|---|



## Nacelle Arrangement

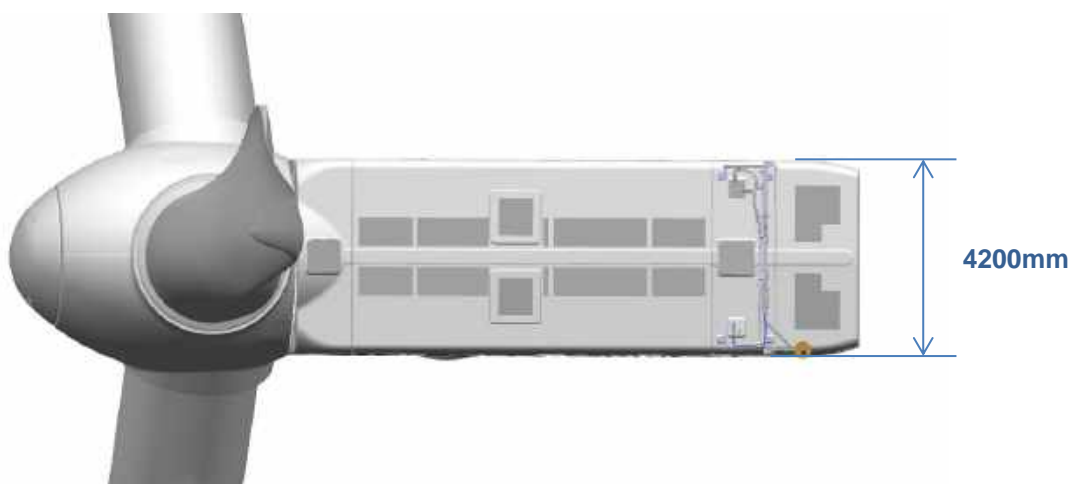
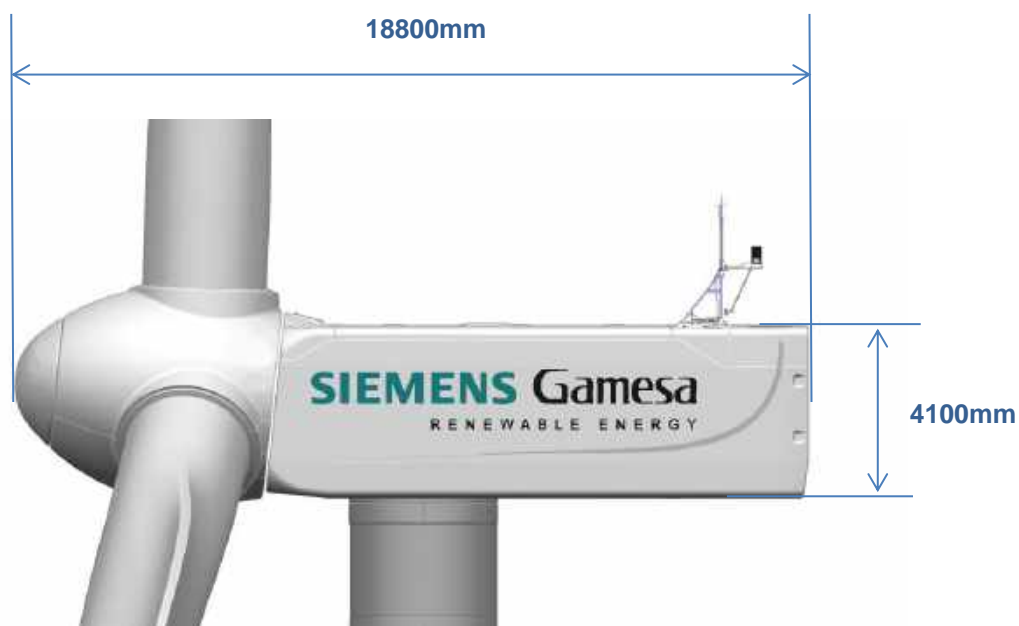
The design and layout of the nacelle are preliminary and may be subject to changes during the development of the product.



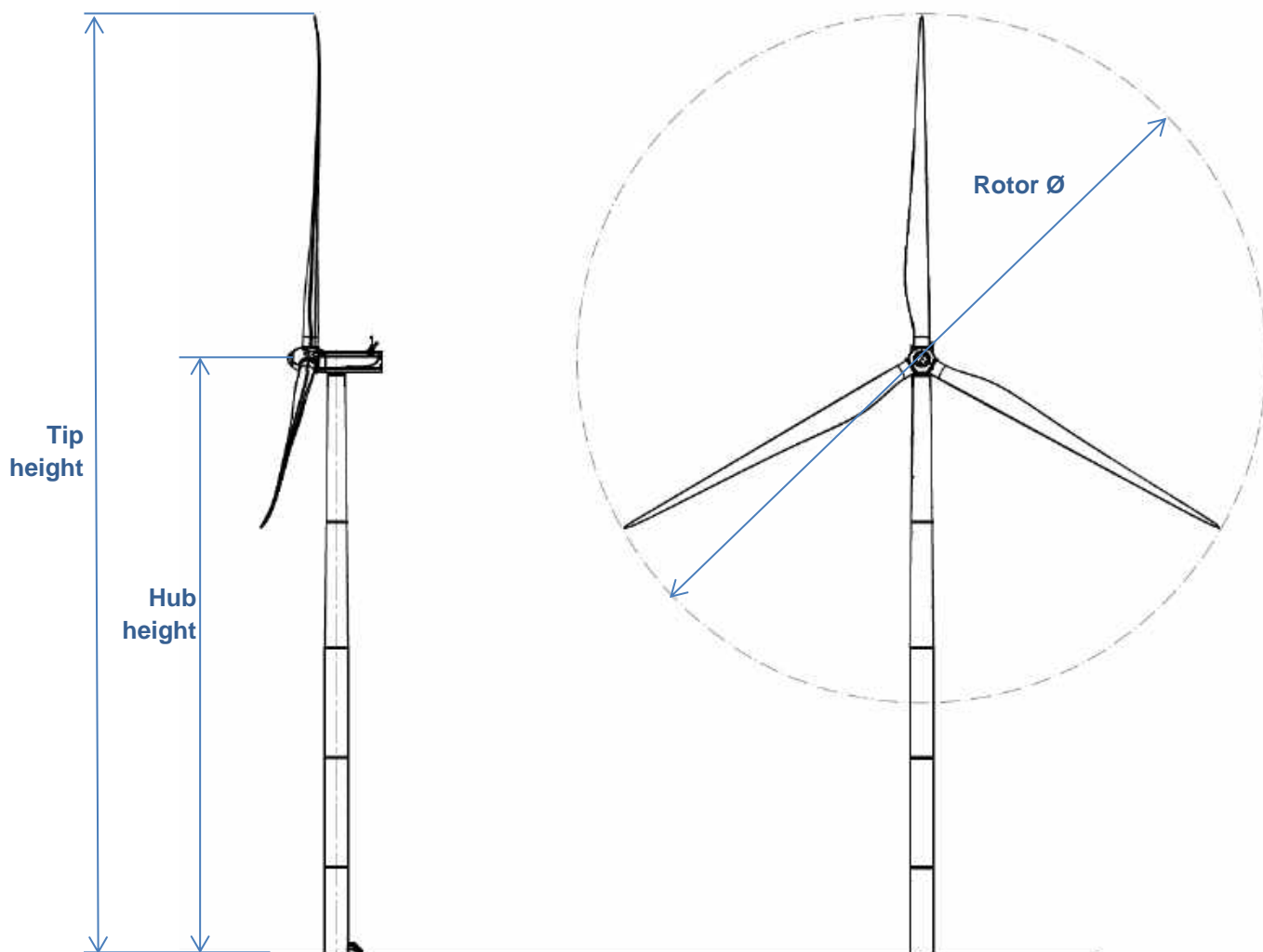
- |                              |                            |
|------------------------------|----------------------------|
| <b>1</b> Rotor cover         | <b>9</b> Yaw system        |
| <b>2</b> Pitch system        | <b>10</b> High speed shaft |
| <b>3</b> Blade bearings      | <b>11</b> Generator        |
| <b>4</b> Blades              | <b>12</b> Transformer      |
| <b>5</b> Low speed shaft     | <b>13</b> Nacelle cover    |
| <b>6</b> Gearbox             | <b>14</b> Cooling system   |
| <b>7</b> Electrical cabinets | <b>15</b> Wind sensors     |
| <b>8</b> Hydraulic group     | <b>16</b> Beacon system    |

## Nacelle Dimensions

The design and dimensions of the nacelle are preliminary and may be subject to changes during the development phases of the product.

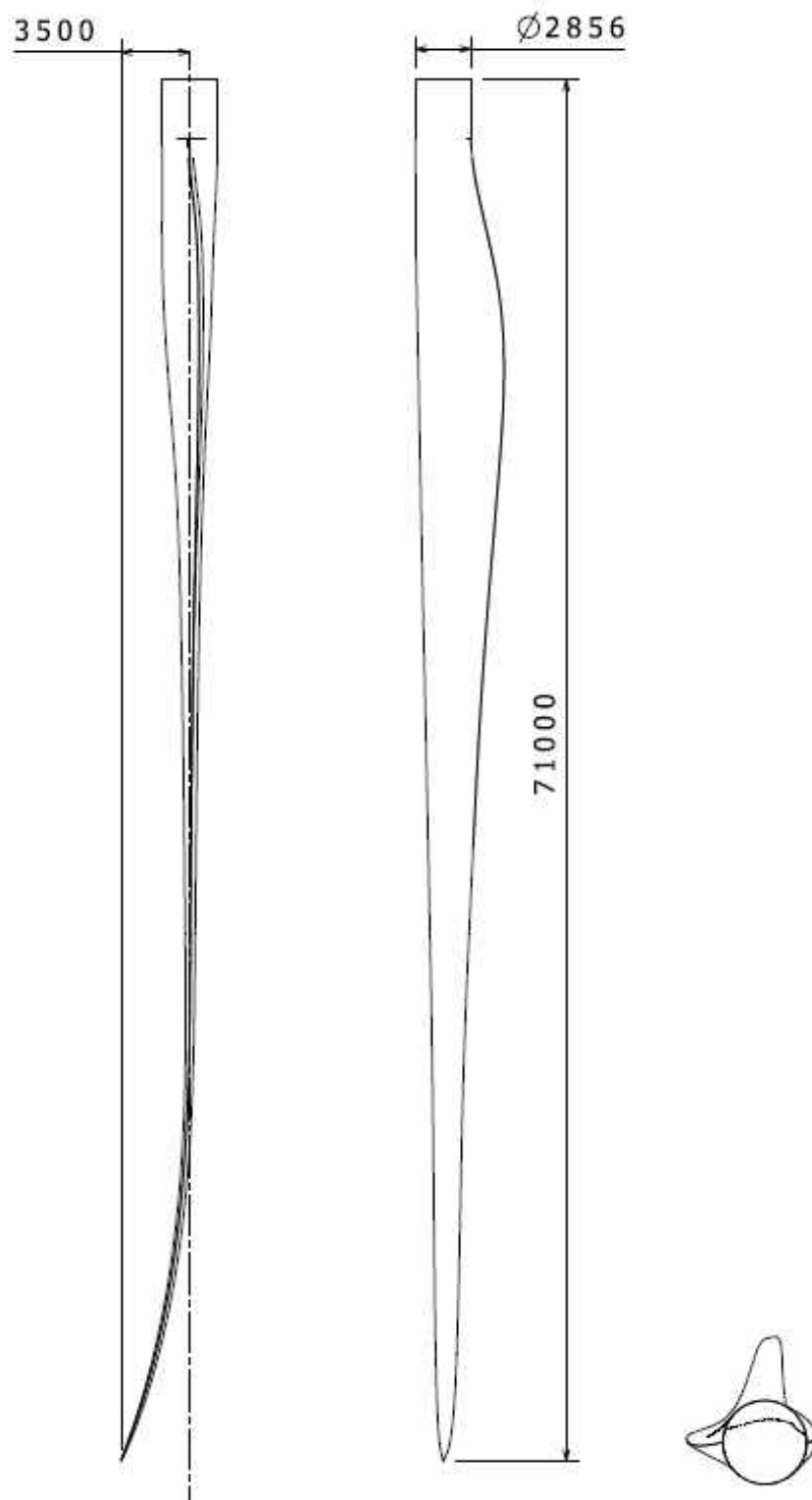


## Elevation Drawing



|                |         |        |        |         |        |
|----------------|---------|--------|--------|---------|--------|
| Tip height     | 163.5m, | 168m,  | 170m,  | 175m,   | 200m   |
| Hub height     | 91m,    | 95.5m, | 97.5m, | 102.5m, | 127.5m |
| Rotor diameter | 145m    |        |        |         |        |

## Blade Drawing



Dimensions in millimeters.

## Design Climatic Conditions

The design climatic conditions are the boundary conditions at which the turbine can be applied without supplementary design review. Applications of the wind turbine in more severe conditions may be possible, depending upon the overall circumstances. A project site-specific review requires the completion by the Client of the “Project Climatic Conditions” form.

| Subject         | ID   | Issue  | Unit              | Value   |
|-----------------|------|--|-------------------|---|
| Design Lifetime | 0.1  | Design lifetime definition   | -                 | IEC 61400-1 <sup>1</sup>  |
|                 | 0.2  | Design lifetime  | years             | 20  |
| Wind, operation | 1.1  | Wind definitions   | -                 | IEC 61400-1 <sup>1</sup>  |
|                 | 1.2  | IEC class  | -                 | IIB   |
|                 | 1.3  | Mean air density, $\rho$   | kg/m <sup>3</sup> | 1.225   |
|                 | 1.4  | Mean wind speed, $V_{ave}$   | m/s               | 8.5   |
|                 | 1.5  | Weibull scale parameter, A   | m/s               | 9.59  |
|                 | 1.6  | Weibull shape parameter, k   | -                 | 2   |
|                 | 1.7  | Wind shear exponent, $\alpha$  | -                 | 0.20  |
|                 | 1.8  | Reference turbulence intensity at 15 m/s, $I_{ref}$                        | -                 | 0.14  |
|                 | 1.9  | Standard deviation of wind direction                                       | Deg               | 8   |
|                 | 1.10 | Maximum flow inclination   | Deg               | 8   |
|                 | 1.11 | Minimum turbine spacing, in rows   | D                 | 3   |
|                 | 1.12 | Minimum turbine spacing, between rows                                      | D                 | 5   |
| Wind, extreme   | 2.1  | Wind definitions   |                   | IEC 61400-1   |
|                 | 2.2  | Air density, $\rho$  | kg/m <sup>3</sup> | 1.225   |
|                 | 2.3  | Reference wind speed average over 10 min at hub height, $V_{ref}$          | m/s               | 42.5  |
|                 | 2.4  | Maximum 3 s gust in hub height, $V_{e50}$                                  | m/s               | 59.5  |
|                 | 2.5  | Maximum hub height power law index, $\alpha$                               | -                 | 0.11  |
| Temperature     | 3.1  | Temperature definitions  | -                 | IEC 61400-1   |
|                 | 3.2  | Minimum temperature, stand-still, $T_{min, s}$                             | Deg.C             | -30   |
|                 | 3.3  | Minimum temperature, operation, $T_{min, o}$                               | Deg.C             | -20   |
|                 | 3.4  | Maximum temperature, nominal operation, altitude below 1000m, $T_{max, o}$ | Deg.C             | +25 (Full Power)<br>+45 (Power Derating) <sup>2</sup>             |
|                 | 3.5  | Maximum temperature, stand-still, $T_{max, s}$                             | Deg.C             | +50   |
| Corrosion       | 4.1  | Atmospheric-corrosivity category definitions                               | -                 | ISO 12944-2   |
|                 | 4.2  | Internal nacelle environment (corrosivity category)                        | -                 | C3  |
|                 | 4.3  | Exterior environment (corrosivity category)                                | -                 | C5-M  |
| Lightning       | 5.1  | Lightning definitions  | -                 | IEC61400-24:2010  |
|                 | 5.2  | Lightning protection level (LPL)   | -                 | LPL 1   |
| Dust            | 6.1  | Dust definitions   | -                 | IEC 60721-3-4:1995  |
|                 | 6.2  | Working environmental conditions   | mg/m <sup>3</sup> | Average Dust Concentration (95% time)<br>→ 0.05 mg/m <sup>3</sup> |

<sup>1</sup> All mentioning of IEC 61400-1 refers to IEC 61400-1 Ed3.0 2005/A1:2010.

<sup>2</sup> Operation maximum temperature is extended up to +45°C including “Power Derating due to external ambient temperature and altitude” feature. See section “Other Performance Features” for further information.

| Subject         | ID   | Issue  | Unit              | Value   |
|-----------------|------|--|-------------------|---|
| Design Lifetime | 0.1  | Design lifetime definition   | -                 | IEC 61400-1 <sup>1</sup>                                      |
|                 | 0.2  | Design lifetime  | years             | 20  |
|                 | 6.3  | Concentration of particles   | mg/m <sup>3</sup> | Peak Dust Concentration (95% time)<br>→ 0.5 mg/m <sup>3</sup> |
| Hail            | 7.1  | Maximum hail diameter  | mm                | 20  |
|                 | 7.2  | Maximum hail falling speed   | m/s               | 20  |
| Ice             | 8.1  | Ice definitions  | -                 | -   |
|                 | 8.2  | Ice conditions   | Days/yr           | 7   |
| Solar radiation | 9.1  | Solar radiation definitions  | -                 | IEC 61400-1   |
|                 | 9.2  | Solar radiation intensity  | W/m <sup>2</sup>  | 1000  |
| Humidity        | 10.1 | Humidity definition  | -                 | IEC 61400-1   |
|                 | 10.2 | Relative humidity  | %                 | Up to 95  |
| Obstacles       | 11.1 | If the height of obstacles within 500m of any turbine location height exceeds 1/3 of (H – D/2) where H is the hub height and D is the rotor diameter then restrictions may apply. Please contact Siemens Gamesa Renewable Energy for information on the maximum allowable obstacle height with respect to the site and the turbine type. |                   |   |

## Standard Power Curve, Standard power operational mode

Air density 1.225 kg/m<sup>3</sup>

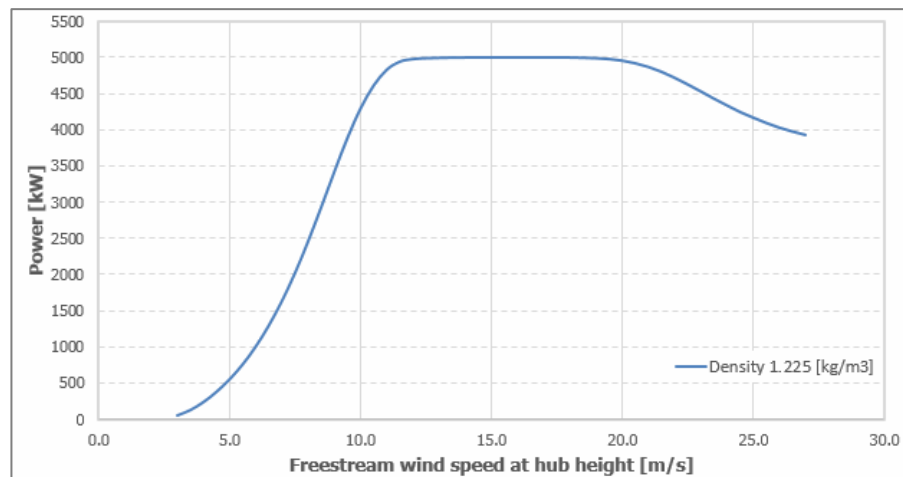
Validity range:

|                                       |   |
|---------------------------------------|---|
| Wind Shear (10min average)            | $\leq 0.3$  |
| Turbulence intensity TI [%] for bin i | $5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$ |
| Terrain                               | Not complex according to IEC 61400-12-1                                     |
| Upflow $\beta$ [°]                    | $-2^\circ \leq \beta \leq +2^\circ$   |
| Grid frequency [Hz]                   | $\pm 0.5$ Hz  |

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

Next table shows the electrical power [kW] as a function of the wind speed [m/s] horizontal referred to the hub height, averaged in ten minutes, for air density = 1.225 kg/m<sup>3</sup>. The power curve does not include losses in the transformer and high voltage cables. The power curve is for the standard version of the turbine.

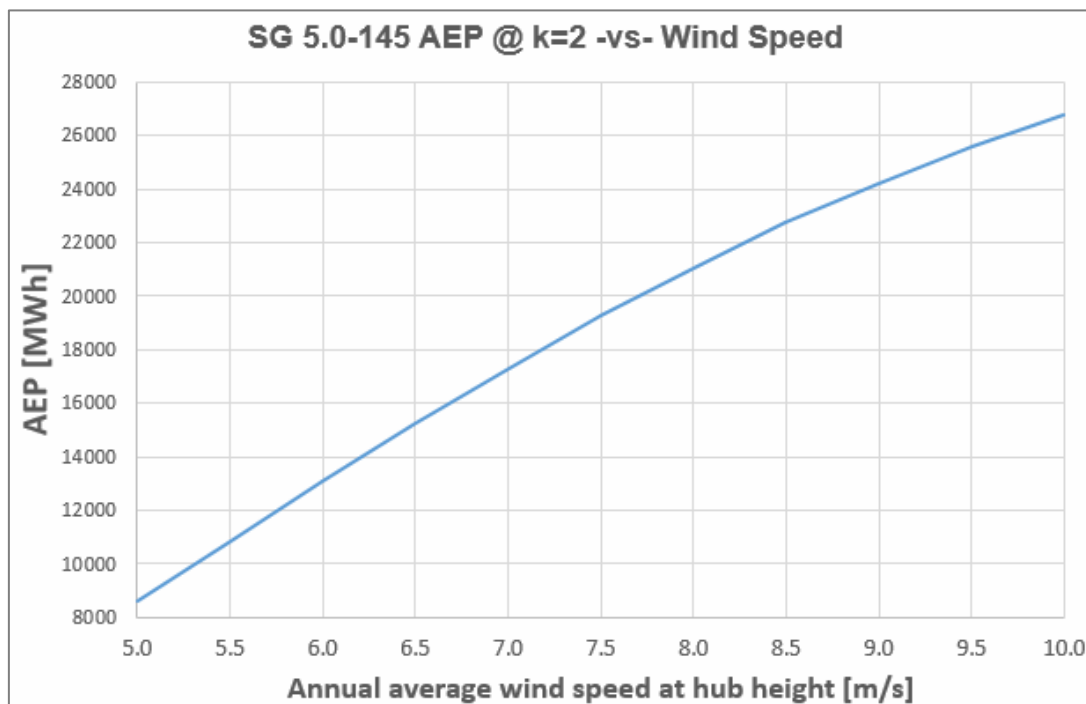
| SG 5.0-145       |            |
|------------------|------------|
| Wind Speed [m/s] | Power [kW] |
| 3                | 56         |
| 4                | 241        |
| 5                | 555        |
| 6                | 1009       |
| 7                | 1638       |
| 8                | 2462       |
| 9                | 3421       |
| 10               | 4294       |
| 11               | 4829       |
| 12               | 4978       |
| 13               | 4995       |
| 14               | 4999       |
| 15               | 5000       |
| 16               | 5000       |
| 17               | 5000       |
| 18               | 4999       |
| 19               | 4990       |
| 20               | 4956       |
| 21               | 4869       |
| 22               | 4720       |
| 23               | 4531       |
| 24               | 4338       |
| 25               | 4169       |
| 26               | 4031       |
| 27               | 3930       |



The annual energy production data for different annual mean wind speeds in hub height are calculated from the above power curve assuming a Weibull wind speed distribution, 100 percent availability, and no reductions due to array losses, grid losses, or other external factors affecting the production.

| AEP [MWh] |     | Annual Average Wind Speed [m/s] at Hub Height |       |       |       |       |       |       |       |       |       |       |
|-----------|-----|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           |     | 5   | 5.5   | 6     | 6.5   | 7     | 7.5   | 8     | 8.5   | 9     | 9.5   | 10    |
| Weibull K | 1.5 | 9611  | 11492 | 13305 | 15018 | 16610 | 18068 | 19385 | 20560 | 21594 | 22490 | 23256 |
|           | 2   | 8622  | 10836 | 13064 | 15241 | 17320 | 19272 | 21079 | 22734 | 24232 | 25573 | 26756 |
|           | 2.5 | 7675  | 10014 | 12483 | 14979 | 17417 | 19737 | 21901 | 23890 | 25698 | 27328 | 28784 |

Annual Production [MWh] SG 5.0-145 wind turbine for the standard version, as a function of the annual mean wind speed at hub height, and for different Weibull parameters. Air density 1.225 kg/m<sup>3</sup>.





## Standard Ct Curve, Standard power operational mode

Air density 1.225 kg/m3

Validity range:

|                                       |   |
|---------------------------------------|---|
| Wind Shear (10min average)            | $\leq 0.3$  |
| Turbulence intensity TI [%] for bin i | $5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$ |
| Terrain                               | Not complex according to IEC 61400-12-1                                     |
| Upflow $\beta$ [°]                    | $-2^\circ \leq \beta \leq +2^\circ$   |
| Grid frequency [Hz]                   | $\pm 0.5$ Hz  |

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

The thrust coefficient  $C_t$  is used for the calculation of the wind speed deficit in the wake of a wind turbine.

$C_t$  is defined by the following expression:

$$C_t = F / (0.5 \cdot ad \cdot w^2 \cdot A)$$

where

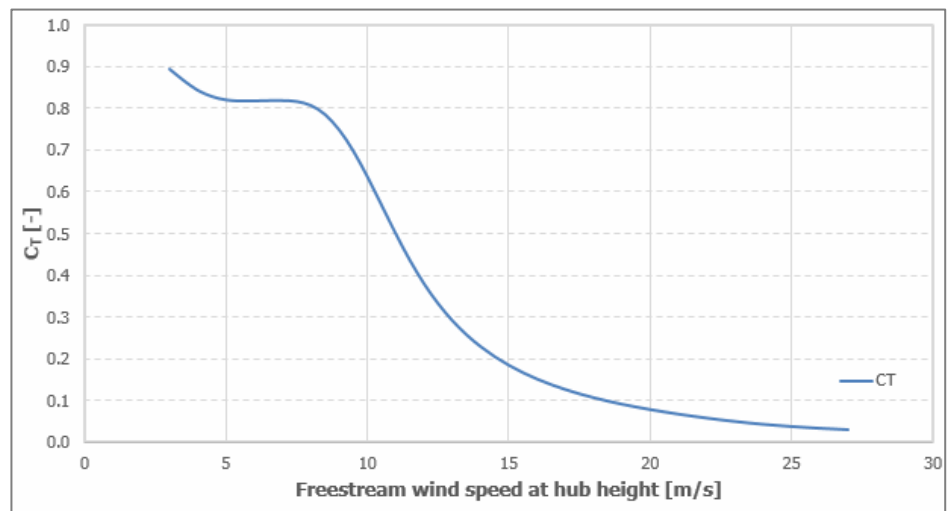
F = Rotor force [N]

ad = Air density [kg/m3]

w = Wind speed [m/s]

A = Swept area of rotor [m2]

| SG 5.0-145       |           |
|------------------|-----------|
| Wind Speed [m/s] | $C_T$ [-] |
| 3                | 0.8948    |
| 4                | 0.8438    |
| 5                | 0.8207    |
| 6                | 0.8185    |
| 7                | 0.8192    |
| 8                | 0.8075    |
| 9                | 0.7488    |
| 10               | 0.6360    |
| 11               | 0.4994    |
| 12               | 0.3794    |
| 13               | 0.2909    |
| 14               | 0.2283    |
| 15               | 0.1834    |
| 16               | 0.1502    |
| 17               | 0.1250    |
| 18               | 0.1054    |
| 19               | 0.0898    |
| 20               | 0.0769    |
| 21               | 0.0659    |
| 22               | 0.0564    |
| 23               | 0.0482    |
| 24               | 0.0415    |
| 25               | 0.0362    |
| 26               | 0.0319    |
| 27               | 0.0286    |



## Power Curve, Air density, Standard power operational mode

Air density 1.225 kg/m<sup>3</sup>

Validity range:

|                                       |   |
|---------------------------------------|---|
| Wind Shear (10min average)            | $\leq 0.3$  |
| Turbulence intensity TI [%] for bin i | $5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$ |
| Terrain                               | Not complex according to IEC 61400-12-1                                     |
| Upflow $\beta$ [°]                    | $-2^\circ \leq \beta \leq +2^\circ$   |
| Grid frequency [Hz]                   | $\pm 0.5$ Hz  |

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

Next table shows the electrical power [kW] as a function of the wind speed [m/s] horizontal referred to the hub height, averaged in ten minutes, for different air densities [kg/m<sup>3</sup>]. The power curve does not include losses in the transformer and high voltage cables. The power curve is for the standard version of the turbine.

| <i>P [kW]</i>           | <i>Air Density [kg/m<sup>3</sup>]</i> |      |      |      |      |      |      |      |      |
|-------------------------|---------------------------------------|------|------|------|------|------|------|------|------|
| <i>Wind Speed [m/s]</i> | 1.225                                 | 1.06 | 1.09 | 1.12 | 1.15 | 1.18 | 1.21 | 1.24 | 1.27 |
| 3                       | 56                                    | 41   | 44   | 46   | 49   | 52   | 54   | 57   | 60   |
| 4                       | 241                                   | 200  | 207  | 215  | 222  | 230  | 237  | 245  | 252  |
| 5                       | 555                                   | 471  | 486  | 502  | 517  | 532  | 547  | 563  | 578  |
| 6                       | 1009                                  | 864  | 891  | 917  | 943  | 969  | 996  | 1022 | 1048 |
| 7                       | 1638                                  | 1409 | 1451 | 1492 | 1534 | 1576 | 1617 | 1659 | 1700 |
| 8                       | 2462                                  | 2123 | 2185 | 2246 | 2308 | 2370 | 2431 | 2493 | 2554 |
| 9                       | 3421                                  | 2961 | 3046 | 3130 | 3214 | 3297 | 3380 | 3461 | 3541 |
| 10                      | 4294                                  | 3799 | 3898 | 3994 | 4085 | 4173 | 4255 | 4332 | 4403 |
| 11                      | 4829                                  | 4484 | 4565 | 4638 | 4702 | 4759 | 4808 | 4848 | 4881 |
| 12                      | 4978                                  | 4882 | 4918 | 4942 | 4958 | 4969 | 4975 | 4980 | 4984 |
| 13                      | 4995                                  | 4982 | 4986 | 4989 | 4991 | 4993 | 4994 | 4995 | 4996 |
| 14                      | 4999                                  | 4995 | 4996 | 4997 | 4998 | 4998 | 4999 | 4999 | 4999 |
| 15                      | 5000                                  | 4999 | 4999 | 4999 | 4999 | 5000 | 5000 | 5000 | 5000 |
| 16                      | 5000                                  | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 |
| 17                      | 5000                                  | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 |
| 18                      | 4999                                  | 4999 | 4999 | 4999 | 4999 | 4999 | 4999 | 4999 | 4999 |
| 19                      | 4990                                  | 4990 | 4990 | 4990 | 4990 | 4990 | 4990 | 4990 | 4990 |
| 20                      | 4956                                  | 4956 | 4956 | 4956 | 4956 | 4956 | 4956 | 4956 | 4956 |
| 21                      | 4869                                  | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 |
| 22                      | 4720                                  | 4720 | 4720 | 4720 | 4720 | 4720 | 4720 | 4720 | 4720 |
| 23                      | 4531                                  | 4531 | 4531 | 4531 | 4531 | 4531 | 4531 | 4531 | 4531 |
| 24                      | 4338                                  | 4338 | 4338 | 4338 | 4337 | 4338 | 4338 | 4338 | 4338 |
| 25                      | 4169                                  | 4168 | 4169 | 4168 | 4168 | 4168 | 4168 | 4168 | 4168 |
| 26                      | 4031                                  | 4031 | 4031 | 4031 | 4031 | 4031 | 4031 | 4031 | 4031 |
| 27                      | 3930                                  | 3930 | 3930 | 3930 | 3930 | 3930 | 3930 | 3930 | 3930 |

The annual energy production data for different annual mean wind speeds in hub height are calculated from the above power curve assuming a Rayleigh wind speed distribution, 100 percent availability, and no reductions due to array losses, grid losses, or other external factors affecting the production.

| <b>AEP [MWh] @ <math>k=2</math></b>   |              | <b>Annual Average Wind Speed [m/s] at Hub Height</b> |            |            |            |            |            |            |            |            |            |             |
|---------------------------------------|--------------|--|------------|------------|------------|------------|------------|------------|------------|------------|------------|-------------|
|                                       |              | <b>5.0</b>   | <b>5.5</b> | <b>6.0</b> | <b>6.5</b> | <b>7.0</b> | <b>7.5</b> | <b>8.0</b> | <b>8.5</b> | <b>9.0</b> | <b>9.5</b> | <b>10.0</b> |
| <b>Density<br/>[kg/m<sup>3</sup>]</b> | <b>1.06</b>  | 7557   | 9597       | 11692      | 13775      | 15797      | 17723      | 19529      | 21202      | 22732      | 24114      | 25345       |
|                                       | <b>1.09</b>  | 7757   | 9833       | 11955      | 14059      | 16095      | 18027      | 19836      | 21507      | 23032      | 24407      | 25629       |
|                                       | <b>1.12</b>  | 7955   | 10063      | 12213      | 14335      | 16383      | 18322      | 20131      | 21799      | 23319      | 24686      | 25900       |
|                                       | <b>1.15</b>  | 8149   | 10290      | 12464      | 14604      | 16662      | 18605      | 20415      | 22080      | 23594      | 24954      | 26159       |
|                                       | <b>1.18</b>  | 8341   | 10512      | 12709      | 14865      | 16932      | 18879      | 20689      | 22350      | 23858      | 25210      | 26406       |
|                                       | <b>1.21</b>  | 8529   | 10729      | 12947      | 15118      | 17193      | 19143      | 20952      | 22609      | 24110      | 25454      | 26642       |
|                                       | <b>1.225</b> | 8622   | 10836      | 13064      | 15241      | 17320      | 19272      | 21079      | 22734      | 24232      | 25573      | 26756       |
|                                       | <b>1.24</b>  | 8715   | 10941      | 13180      | 15363      | 17446      | 19398      | 21205      | 22857      | 24352      | 25688      | 26867       |
|                                       | <b>1.27</b>  | 8897   | 11150      | 13407      | 15602      | 17690      | 19644      | 21448      | 23096      | 24584      | 25912      | 27083       |

Annual Production [MWh] SG 5.0-145 wind turbine for the standard version, as a function of the annual mean wind speed at hub height and for different air densities considering a Rayleigh wind speed distribution.

## Ct Curve, Air Density, Standard power operational mode

Air density 1.225 kg/m<sup>3</sup>

Validity range:

|                                       |   |
|---------------------------------------|---|
| Wind Shear (10min average)            | $\leq 0.3$  |
| Turbulence intensity TI [%] for bin i | $5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$ |
| Terrain                               | Not complex according to IEC 61400-12-1                                     |
| Upflow $\beta$ [°]                    | $-2^\circ \leq \beta \leq +2^\circ$   |
| Grid frequency [Hz]                   | $\pm 0.5$ Hz  |

Other considerations: Clean rotor blades, undisturbed air flow, turbine operated within nominal limits according to the Electrical Specification.

The calculated Ct curve data are valid for air densities as stated below, clean rotor blades, substantially horizontal, undisturbed air flow, normal turbulence intensity and normal wind shear.

| CT [-]           | Air Density [kg/m <sup>3</sup> ] |        |        |        |        |        |        |        |        |
|------------------|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Wind Speed [m/s] | 1.225                            | 1.06   | 1.09   | 1.12   | 1.15   | 1.18   | 1.21   | 1.24   | 1.27   |
| 3                | 0.8948                           | 0.8948 | 0.8948 | 0.8948 | 0.8948 | 0.8948 | 0.8948 | 0.8948 | 0.8948 |
| 4                | 0.8438                           | 0.8438 | 0.8438 | 0.8438 | 0.8438 | 0.8438 | 0.8438 | 0.8438 | 0.8438 |
| 5                | 0.8207                           | 0.8194 | 0.8197 | 0.8199 | 0.8202 | 0.8204 | 0.8206 | 0.8207 | 0.8209 |
| 6                | 0.8185                           | 0.8176 | 0.8178 | 0.8180 | 0.8181 | 0.8183 | 0.8184 | 0.8185 | 0.8186 |
| 7                | 0.8192                           | 0.8189 | 0.8189 | 0.8190 | 0.8191 | 0.8191 | 0.8192 | 0.8192 | 0.8193 |
| 8                | 0.8075                           | 0.8074 | 0.8074 | 0.8075 | 0.8075 | 0.8075 | 0.8075 | 0.8075 | 0.8075 |
| 9                | 0.7488                           | 0.7513 | 0.7512 | 0.7510 | 0.7506 | 0.7501 | 0.7493 | 0.7482 | 0.7468 |
| 10               | 0.6360                           | 0.6559 | 0.6538 | 0.6512 | 0.6478 | 0.6437 | 0.6387 | 0.6330 | 0.6266 |
| 11               | 0.4994                           | 0.5442 | 0.5376 | 0.5301 | 0.5220 | 0.5134 | 0.5041 | 0.4946 | 0.4849 |
| 12               | 0.3794                           | 0.4324 | 0.4228 | 0.4131 | 0.4034 | 0.3937 | 0.3841 | 0.3748 | 0.3657 |
| 13               | 0.2909                           | 0.3375 | 0.3283 | 0.3194 | 0.3108 | 0.3026 | 0.2947 | 0.2871 | 0.2800 |
| 14               | 0.2283                           | 0.2655 | 0.2579 | 0.2507 | 0.2439 | 0.2374 | 0.2313 | 0.2255 | 0.2199 |
| 15               | 0.1834                           | 0.2127 | 0.2067 | 0.2010 | 0.1956 | 0.1906 | 0.1857 | 0.1812 | 0.1769 |
| 16               | 0.1502                           | 0.1736 | 0.1688 | 0.1643 | 0.1600 | 0.1559 | 0.1521 | 0.1484 | 0.1450 |
| 17               | 0.1250                           | 0.1441 | 0.1401 | 0.1364 | 0.1329 | 0.1296 | 0.1265 | 0.1235 | 0.1207 |
| 18               | 0.1054                           | 0.1212 | 0.1179 | 0.1148 | 0.1120 | 0.1092 | 0.1066 | 0.1042 | 0.1018 |
| 19               | 0.0898                           | 0.1030 | 0.1003 | 0.0977 | 0.0953 | 0.0930 | 0.0908 | 0.0887 | 0.0868 |
| 20               | 0.0769                           | 0.0881 | 0.0858 | 0.0836 | 0.0816 | 0.0796 | 0.0778 | 0.0761 | 0.0744 |
| 21               | 0.0659                           | 0.0753 | 0.0734 | 0.0716 | 0.0699 | 0.0682 | 0.0667 | 0.0652 | 0.0638 |
| 22               | 0.0564                           | 0.0643 | 0.0626 | 0.0611 | 0.0597 | 0.0583 | 0.0570 | 0.0558 | 0.0546 |
| 23               | 0.0482                           | 0.0548 | 0.0535 | 0.0522 | 0.0510 | 0.0498 | 0.0487 | 0.0477 | 0.0467 |
| 24               | 0.0415                           | 0.0471 | 0.0460 | 0.0449 | 0.0439 | 0.0429 | 0.0420 | 0.0411 | 0.0402 |
| 25               | 0.0362                           | 0.0410 | 0.0400 | 0.0391 | 0.0382 | 0.0374 | 0.0366 | 0.0358 | 0.0351 |
| 26               | 0.0319                           | 0.0362 | 0.0353 | 0.0345 | 0.0337 | 0.0330 | 0.0323 | 0.0316 | 0.0310 |
| 27               | 0.0286                           | 0.0324 | 0.0316 | 0.0309 | 0.0302 | 0.0295 | 0.0289 | 0.0283 | 0.0278 |

## Standard Acoustic Emission

**Noise Level (LW):** Values reported correspond to the average estimated Sound Power Level emitted by the WTG at hub height, called LW in TS IEC-61400-14. LW values are expressed in dB(A). To obtain LWd value, as defined in IEC-61400-14, it must be applied a 2 dB increase to LW.

**dB(A):** LW is expressed in decibels applying the “A” filter as required by IEC.

Noise generated at standard power operation mode LW is **106.3 dB(A)**.

| SG 5.0-145          |               |
|---------------------|---------------|
| Wind Speed<br>[m/s] | LW<br>[dB(A)] |
| 3.0                 | 95.1          |
| 3.5                 | 95.1          |
| 4.0                 | 95.1          |
| 4.5                 | 95.1          |
| 5.0                 | 95.1          |
| 5.5                 | 97.2          |
| 6.0                 | 99.2          |
| 6.5                 | 101.1         |
| 7.0                 | 102.7         |
| 7.5                 | 104.3         |
| 8.0                 | 105.7         |
| 8.5                 | 106.3         |
| 9.0                 | 106.3         |
| 9.5                 | 106.3         |
| 10.0                | 106.3         |
| 10.5                | 106.3         |
| 11.0                | 106.3         |
| 11.5                | 106.3         |
| 12.0                | 106.3         |
| 12.5                | 106.3         |
| 13.0                | 106.3         |
| 13.5                | 106.3         |
| 14.0                | 106.3         |
| 14.5                | 106.3         |
| Up to cut out       | ≤106.3        |

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

## Noise Reduction System (NRS) operational modes

The Noise Reduction System NRS is an optional module available with the basic SCADA configuration and it therefore requires the presence of a SGRE SCADA system to work.

The purpose of this system is to limit the noise emitted by any of the functioning turbines and thereby comply with local regulations regarding noise emissions. This allows wind farms to be located close to urban areas, limiting the environmental impact that they imply.

Noise control is achieved through reducing the active power and rotational speed of the wind turbine. This reduction is dependent on the wind speed.

The task of the Noise Reduction System is to control the noise settings of each turbine to the most appropriate level at all times, in order to keep the noise emissions within the limits allowed.

In order to do this, the SCADA control has to consider the wind speed of each turbine, its direction, and a configured schedule/calendar.

There can be up to 8 low noise modes, besides the full operation one. Noise levels corresponding to each mode are the following:

| Mode:               | FP    | N1    | N2    | N3    | N4    | N5    | N6   | N7 | N8 |
|---------------------|-------|-------|-------|-------|-------|-------|------|----|----|
| Noise Level [dB(A)] | 106.3 | 105.7 | 105.2 | 103.7 | 102.7 | 101.7 | 99.9 | 99 | 98 |

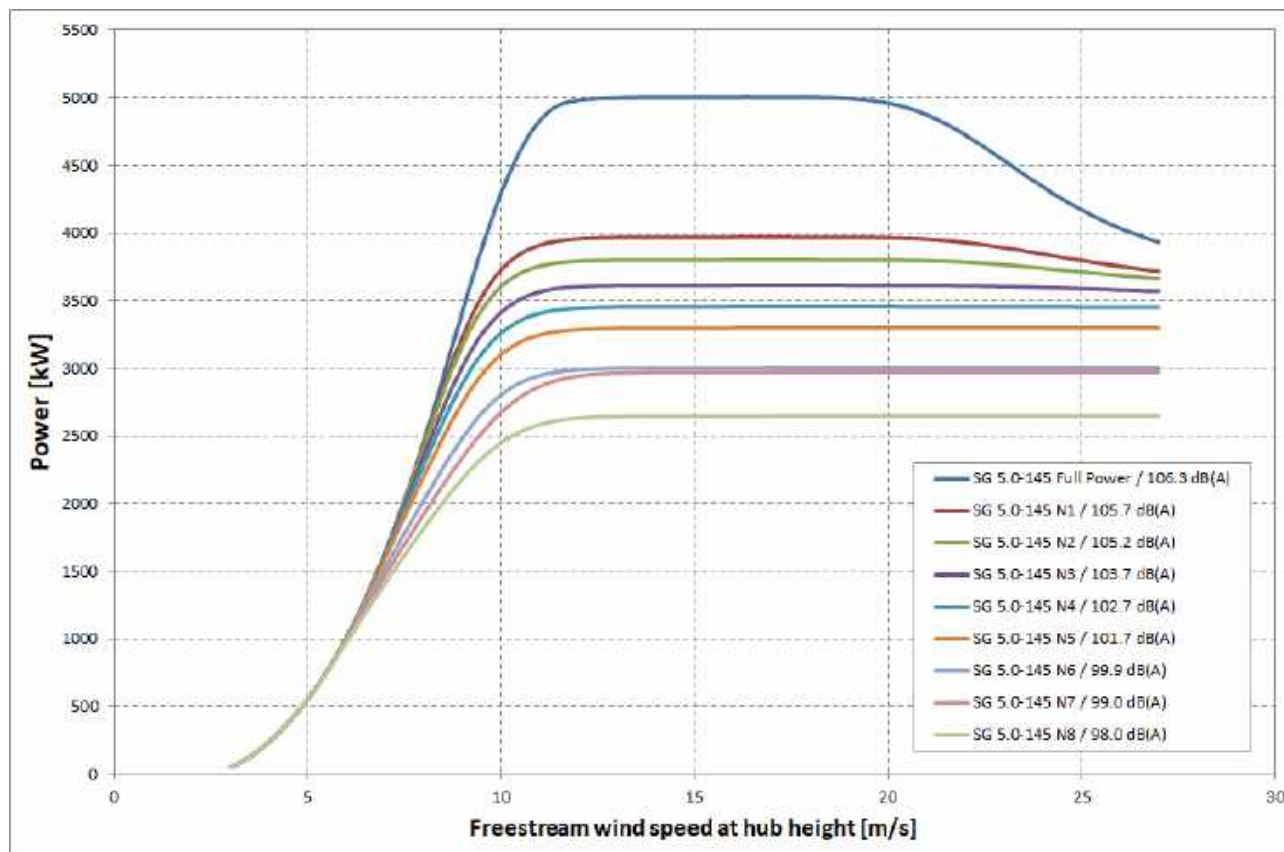
Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

Depending on the type of tower selected, some of the low noise modes defined above may not be compatible. In the following table, feasibility of low noise modes vs tower is presented. Low noise modes feasibility vs other tower designs will be analyzed upon request.

| SG 5.0-145                             | N1  | N2  | N3  | N4  | N5  | N6  | N7  | N8  |
|--|-----|-----|-----|-----|-----|-----|-----|-----|
| H= 91.0 m<br>(Steel, baseline design)  | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| H= 95.5 m<br>(Steel, baseline design)  | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| H= 97.5 m<br>(Steel, baseline design)  | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| H= 102.5 m<br>(Steel, baseline design) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| H= 127.5 m<br>(Steel, baseline design) | No  | No  | No  | No  | Yes | Yes | Yes | Yes |

Next table presents the power production as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings.

| <b><i>P [kW]</i></b>               | <b><i>Low Noise Operation Mode</i></b> |                               |                               |                               |                               |                              |                              |                              |
|------------------------------------|--|-------------------------------|-------------------------------|-------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|
| <b><i>Wind Speed<br/>[m/s]</i></b> | <b>N1<br/>105.7<br/>dB(A)</b>          | <b>N2<br/>105.2<br/>dB(A)</b> | <b>N3<br/>103.7<br/>dB(A)</b> | <b>N4<br/>102.7<br/>dB(A)</b> | <b>N5<br/>101.7<br/>dB(A)</b> | <b>N6<br/>99.9<br/>dB(A)</b> | <b>N7<br/>99.0<br/>dB(A)</b> | <b>N8<br/>98.0<br/>dB(A)</b> |
| <b>3</b>                           | 56                                     | 56                            | 56                            | 56                            | 56                            | 56                           | 56                           | 56                           |
| <b>4</b>                           | 241                                    | 241                           | 241                           | 241                           | 241                           | 241                          | 241                          | 241                          |
| <b>5</b>                           | 555                                    | 555                           | 555                           | 555                           | 555                           | 555                          | 555                          | 554                          |
| <b>6</b>                           | 1009                                   | 1009                          | 1009                          | 1008                          | 1007                          | 1000                         | 990                          | 974                          |
| <b>7</b>                           | 1637                                   | 1636                          | 1629                          | 1615                          | 1592                          | 1521                         | 1470                         | 1410                         |
| <b>8</b>                           | 2437                                   | 2422                          | 2355                          | 2286                          | 2203                          | 2027                         | 1925                         | 1819                         |
| <b>9</b>                           | 3232                                   | 3170                          | 3016                          | 2884                          | 2747                          | 2484                         | 2344                         | 2183                         |
| <b>10</b>                          | 3725                                   | 3604                          | 3416                          | 3257                          | 3101                          | 2803                         | 2677                         | 2449                         |
| <b>11</b>                          | 3907                                   | 3755                          | 3567                          | 3402                          | 3246                          | 2946                         | 2869                         | 2583                         |
| <b>12</b>                          | 3952                                   | 3791                          | 3605                          | 3440                          | 3286                          | 2988                         | 2945                         | 2630                         |
| <b>13</b>                          | 3962                                   | 3798                          | 3613                          | 3448                          | 3294                          | 2998                         | 2967                         | 2642                         |
| <b>14</b>                          | 3963                                   | 3800                          | 3615                          | 3450                          | 3296                          | 3000                         | 2973                         | 2644                         |
| <b>15</b>                          | 3964                                   | 3800                          | 3615                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>16</b>                          | 3964                                   | 3800                          | 3615                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>17</b>                          | 3964                                   | 3800                          | 3615                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>18</b>                          | 3964                                   | 3800                          | 3615                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>19</b>                          | 3963                                   | 3800                          | 3615                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>20</b>                          | 3960                                   | 3799                          | 3615                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>21</b>                          | 3949                                   | 3795                          | 3614                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>22</b>                          | 3925                                   | 3784                          | 3612                          | 3450                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>23</b>                          | 3887                                   | 3765                          | 3607                          | 3449                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>24</b>                          | 3841                                   | 3740                          | 3599                          | 3449                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>25</b>                          | 3794                                   | 3713                          | 3590                          | 3448                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>26</b>                          | 3750                                   | 3685                          | 3580                          | 3446                          | 3296                          | 3000                         | 2974                         | 2645                         |
| <b>27</b>                          | 3715                                   | 3663                          | 3571                          | 3445                          | 3296                          | 3000                         | 2974                         | 2645                         |





Next table presents the  $C_t$  as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings. The calculated  $C_t$  curve data are valid for clean rotor blades, substantially horizontal, undisturbed air flow, normal turbulence intensity and normal wind shear.

| $C_t$ [-]           | Low Noise Operation Mode |                      |                      |                      |                      |                     |                     |                     |
|---------------------|--------------------------|----------------------|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|
| Wind Speed<br>[m/s] | N1<br>105.7<br>dB(A)     | N2<br>105.2<br>dB(A) | N3<br>103.7<br>dB(A) | N4<br>102.7<br>dB(A) | N5<br>101.7<br>dB(A) | N6<br>99.9<br>dB(A) | N7<br>99.0<br>dB(A) | N8<br>98.0<br>dB(A) |
| 3                   | 0.8948                   | 0.8948               | 0.8948               | 0.8948               | 0.8948               | 0.8948              | 0.8948              | 0.8948              |
| 4                   | 0.8438                   | 0.8438               | 0.8438               | 0.8438               | 0.8438               | 0.8438              | 0.8438              | 0.8438              |
| 5                   | 0.8207                   | 0.8207               | 0.8207               | 0.8207               | 0.8207               | 0.8204              | 0.8197              | 0.8176              |
| 6                   | 0.8185                   | 0.8184               | 0.8182               | 0.8171               | 0.8138               | 0.7952              | 0.7753              | 0.7472              |
| 7                   | 0.8174                   | 0.8158               | 0.8027               | 0.7844               | 0.7575               | 0.6907              | 0.6501              | 0.6081              |
| 8                   | 0.7860                   | 0.7747               | 0.7256               | 0.6846               | 0.6412               | 0.5631              | 0.5240              | 0.4862              |
| 9                   | 0.6836                   | 0.6616               | 0.6032               | 0.5618               | 0.5229               | 0.4570              | 0.4249              | 0.3909              |
| 10                  | 0.5319                   | 0.5084               | 0.4675               | 0.4376               | 0.4103               | 0.3623              | 0.3420              | 0.3102              |
| 11                  | 0.3933                   | 0.3747               | 0.3496               | 0.3297               | 0.3117               | 0.2785              | 0.2694              | 0.2412              |
| 12                  | 0.2938                   | 0.2802               | 0.2636               | 0.2498               | 0.2372               | 0.2136              | 0.2098              | 0.1867              |
| 13                  | 0.2261                   | 0.2160               | 0.2039               | 0.1937               | 0.1843               | 0.1666              | 0.1646              | 0.1464              |
| 14                  | 0.1788                   | 0.1710               | 0.1617               | 0.1538               | 0.1465               | 0.1328              | 0.1314              | 0.1170              |
| 15                  | 0.1445                   | 0.1384               | 0.1310               | 0.1247               | 0.1189               | 0.1079              | 0.1068              | 0.0953              |
| 16                  | 0.1190                   | 0.1140               | 0.1079               | 0.1028               | 0.0981               | 0.0891              | 0.0882              | 0.0788              |
| 17                  | 0.0994                   | 0.0953               | 0.0903               | 0.0860               | 0.0821               | 0.0747              | 0.0739              | 0.0661              |
| 18                  | 0.0841                   | 0.0807               | 0.0764               | 0.0728               | 0.0696               | 0.0633              | 0.0626              | 0.0561              |
| 19                  | 0.0719                   | 0.0690               | 0.0654               | 0.0624               | 0.0596               | 0.0543              | 0.0537              | 0.0481              |
| 20                  | 0.0621                   | 0.0597               | 0.0565               | 0.0539               | 0.0515               | 0.0470              | 0.0464              | 0.0417              |
| 21                  | 0.0540                   | 0.0520               | 0.0493               | 0.0471               | 0.0450               | 0.0410              | 0.0405              | 0.0364              |
| 22                  | 0.0473                   | 0.0456               | 0.0434               | 0.0414               | 0.0396               | 0.0361              | 0.0357              | 0.0321              |
| 23                  | 0.0416                   | 0.0404               | 0.0385               | 0.0368               | 0.0352               | 0.0321              | 0.0317              | 0.0286              |
| 24                  | 0.0369                   | 0.0360               | 0.0345               | 0.0330               | 0.0316               | 0.0289              | 0.0285              | 0.0257              |
| 25                  | 0.0330                   | 0.0323               | 0.0312               | 0.0299               | 0.0286               | 0.0261              | 0.0258              | 0.0233              |
| 26                  | 0.0298                   | 0.0293               | 0.0284               | 0.0273               | 0.0261               | 0.0239              | 0.0235              | 0.0212              |
| 27                  | 0.0271                   | 0.0267               | 0.0260               | 0.0251               | 0.0240               | 0.0219              | 0.0216              | 0.0195              |

The table below contains the noise levels as a function of the horizontal wind speed measured at hub height for different noise reduction mode settings.

| <b>Noise<br/>[dB(A)]</b>    | <b>Low Noise Operation Mode</b> |                               |                               |                               |                               |                              |                              |                              |
|-----------------------------|---------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|
| <b>Wind Speed<br/>[m/s]</b> | <b>N1<br/>105.7<br/>dB(A)</b>   | <b>N2<br/>105.2<br/>dB(A)</b> | <b>N3<br/>103.7<br/>dB(A)</b> | <b>N4<br/>102.7<br/>dB(A)</b> | <b>N5<br/>101.7<br/>dB(A)</b> | <b>N6<br/>99.9<br/>dB(A)</b> | <b>N7<br/>99.0<br/>dB(A)</b> | <b>N8<br/>98.0<br/>dB(A)</b> |
| 3.0                         | 95.1                            | 95.1                          | 95.1                          | 95.1                          | 95.1                          | 95.1                         | 95.1                         | 95.1                         |
| 3.5                         | 95.1                            | 95.1                          | 95.1                          | 95.1                          | 95.1                          | 95.1                         | 95.1                         | 95.1                         |
| 4.0                         | 95.1                            | 95.1                          | 95.1                          | 95.1                          | 95.1                          | 95.1                         | 95.1                         | 95.1                         |
| 4.5                         | 95.1                            | 95.1                          | 95.1                          | 95.1                          | 95.1                          | 95.1                         | 95.1                         | 95.1                         |
| 5.0                         | 95.1                            | 95.1                          | 95.1                          | 95.1                          | 95.1                          | 95.1                         | 95.1                         | 95.1                         |
| 5.5                         | 97.2                            | 97.2                          | 97.2                          | 97.2                          | 97.2                          | 97.2                         | 97.2                         | 97.2                         |
| 6.0                         | 99.2                            | 99.2                          | 99.2                          | 99.2                          | 99.2                          | 99.2                         | 99.0                         | 98.0                         |
| 6.5                         | 101.1                           | 101.1                         | 101.1                         | 101.1                         | 101.1                         | 99.9                         | 99.0                         | 98.0                         |
| 7.0                         | 102.7                           | 102.7                         | 102.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 7.5                         | 104.3                           | 104.3                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 8.0                         | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 8.5                         | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 9.0                         | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 9.5                         | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 10.0                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 10.5                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 11.0                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 11.5                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 12.0                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 12.5                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 13.0                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 13.5                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 14.0                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| 14.5                        | 105.7                           | 105.2                         | 103.7                         | 102.7                         | 101.7                         | 99.9                         | 99.0                         | 98.0                         |
| <b>Up to cut out</b>        | ≤105.7                          | ≤105.2                        | ≤103.7                        | ≤102.7                        | ≤101.7                        | ≤99.9                        | ≤99.0                        | ≤98.0                        |

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

The 1/3 octave band noise spectra expressed as A-weighted sound power level for a given frequency band is shown below for 12m/s at hub height, for the standard power operation setting as well as the low noise modes.

| 1/3 octave<br>band,<br>center<br>frequency<br>[Hz] | Noise [dB(A)]              |                |                |                |                |                |               |               |               |
|--|----------------------------|----------------|----------------|----------------|----------------|----------------|---------------|---------------|---------------|
|  | Standard<br>Power<br>5.0MW | N1             | N2             | N3             | N4             | N5             | N6            | N7            | N8            |
|  | 106.3<br>dB(A)             | 105.7<br>dB(A) | 105.2<br>dB(A) | 103.7<br>dB(A) | 102.7<br>dB(A) | 101.7<br>dB(A) | 99.9<br>dB(A) | 99.0<br>dB(A) | 98.0<br>dB(A) |
| 10   | 46.1                       | 46.1           | 46.1           | 46.1           | 46.1           | 46.1           | 46.1          | 46.1          | 46.1          |
| 12.5   | 51.8                       | 51.8           | 51.8           | 51.8           | 51.8           | 51.8           | 51.8          | 51.7          | 51.7          |
| 16   | 57.5                       | 57.4           | 57.4           | 57.4           | 57.4           | 57.4           | 57.3          | 57.3          | 57.3          |
| 20   | 62.8                       | 62.8           | 62.8           | 62.7           | 62.6           | 62.6           | 62.5          | 62.4          | 62.3          |
| 25   | 67.4                       | 67.3           | 67.3           | 67.1           | 67.0           | 66.9           | 66.7          | 66.6          | 66.5          |
| 31.5   | 72.0                       | 71.9           | 71.8           | 71.6           | 71.4           | 71.3           | 71.0          | 70.8          | 70.7          |
| 40   | 76.1                       | 75.9           | 75.8           | 75.5           | 75.3           | 75.1           | 74.6          | 74.4          | 74.2          |
| 50   | 80.6                       | 80.4           | 80.2           | 79.8           | 79.5           | 79.2           | 78.6          | 78.3          | 78.0          |
| 63   | 84.7                       | 84.5           | 84.3           | 83.7           | 83.3           | 82.9           | 82.2          | 81.8          | 81.4          |
| 80   | 87.1                       | 86.8           | 86.5           | 85.8           | 85.3           | 84.8           | 83.8          | 83.4          | 82.8          |
| 100  | 88.8                       | 88.4           | 88.1           | 87.2           | 86.6           | 86.0           | 84.8          | 84.2          | 83.6          |
| 125  | 90.1                       | 89.7           | 89.3           | 88.2           | 87.5           | 86.7           | 85.3          | 84.6          | 83.8          |
| 160  | 90.9                       | 90.4           | 90.0           | 88.6           | 87.7           | 86.8           | 85.2          | 84.3          | 83.4          |
| 200  | 91.9                       | 91.2           | 90.7           | 89.2           | 88.1           | 87.1           | 85.2          | 84.2          | 83.2          |
| 250  | 93.4                       | 92.7           | 92.2           | 90.7           | 89.6           | 88.6           | 86.7          | 85.7          | 84.7          |
| 315  | 93.7                       | 93.1           | 92.6           | 91.0           | 90.0           | 89.0           | 87.1          | 86.1          | 85.0          |
| 400  | 93.5                       | 92.8           | 92.3           | 90.8           | 89.7           | 88.7           | 86.8          | 85.8          | 84.7          |
| 500  | 93.6                       | 92.9           | 92.4           | 90.9           | 89.8           | 88.8           | 86.9          | 85.9          | 84.8          |
| 630  | 95.2                       | 94.5           | 94.0           | 92.5           | 91.4           | 90.4           | 88.5          | 87.5          | 86.4          |
| 800  | 95.0                       | 94.3           | 93.8           | 92.3           | 91.2           | 90.2           | 88.3          | 87.3          | 86.3          |
| 1000   | 96.0                       | 95.3           | 94.8           | 93.3           | 92.2           | 91.2           | 89.3          | 88.3          | 87.3          |
| 1250   | 96.7                       | 96.0           | 95.5           | 94.0           | 92.9           | 91.9           | 90.0          | 89.0          | 88.0          |
| 1600   | 96.6                       | 95.9           | 95.4           | 93.9           | 92.8           | 91.8           | 89.9          | 88.9          | 87.9          |
| 2000   | 95.5                       | 94.8           | 94.3           | 92.8           | 91.7           | 90.7           | 88.8          | 87.8          | 86.8          |
| 2500   | 94.1                       | 93.4           | 92.9           | 91.4           | 90.3           | 89.3           | 87.4          | 86.4          | 85.4          |
| 3150   | 91.9                       | 91.2           | 90.7           | 89.2           | 88.1           | 87.1           | 85.2          | 84.2          | 83.2          |
| 4000   | 88.8                       | 88.1           | 87.6           | 86.1           | 85.0           | 84.0           | 82.1          | 81.1          | 80.1          |
| 5000   | 84.5                       | 83.8           | 83.3           | 81.8           | 80.7           | 79.7           | 77.8          | 76.8          | 75.8          |
| 6300   | 79.3                       | 78.6           | 78.1           | 76.6           | 75.5           | 74.5           | 72.6          | 71.6          | 70.6          |
| 8000   | 73.5                       | 72.8           | 72.3           | 70.8           | 69.7           | 68.7           | 66.8          | 65.8          | 64.8          |
| 10000  | 68.9                       | 68.2           | 67.7           | 66.2           | 65.1           | 64.1           | 62.2          | 61.2          | 60.2          |

Further information about noise spectra, including other wind speeds, is available upon request.

Noise values included in the present document correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade.

## Electrical Specifications

### Nominal output and grid conditions

|                              |   |
|------------------------------|---|
| Nominal power .....          | 5000 kW   |
| Nominal voltage .....        | 690 V   |
| Power factor correction..... | Frequency converter control                                 |
| Power factor range .....     | 0.9 capacitive to 0.9 inductive at nominal balanced voltage |

### Generator

|                     |                   |
|---------------------|-------------------|
| Type.....           | DFIG Asynchronous |
| Maximum power ..... | 5150 kW           |

|                    |  |
|--------------------|--|
| Nominal speed..... | 1120 rpm-6p (50Hz)<br>1344 rpm-6p (60Hz) |
|--------------------|--|

### Generator Protection

|                            |                         |
|----------------------------|-------------------------|
| Insulation class .....     | Stator F/H<br>Rotor F/H |
| Winding temperatures.....  | 6 Pt 100 sensors        |
| Bearing temperatures ..... | 2 Pt 100                |
| Slip Rings                 | 1 Pt 100                |
| Grounding brush.....       | On side no coupling     |

### Generator Cooling

|                            |                                       |
|----------------------------|---------------------------------------|
| Cooling system .....       | Liquid cooling                        |
| Internal ventilation ..... | Air                                   |
| Control parameter.....     | Winding, Liquid, Bearings temperature |

### Frequency Converter

|                               |                     |
|-------------------------------|---------------------|
| Operation.....                | 4Q B2B Partial Load |
| Switching .....               | PWM                 |
| Switching freq., grid side... | 2.5 kHz             |
| Cooling .....                 | Liquid/Air          |

### Main Circuit Protection

|                                |                 |
|--------------------------------|-----------------|
| Short circuit protection ..... | Circuit breaker |
| Surge arrester.....            | varistors       |

### Peak Power Levels

|                     |                    |
|---------------------|--------------------|
| 10 min average..... | Limited to nominal |
|---------------------|--------------------|

### Grid Requirements

|   |                  |
|---|------------------|
| Nominal grid frequency .....  | 50 or 60 Hz      |
| Minimum voltage.....  | 90 % of nominal  |
| Maximum voltage.....  | 112 % of nominal |
| Minimum frequency.....  | 94 % of nominal  |
| Maximum frequency.....  | 106 % of nominal |
| Maximum voltage imbalance (negative sequence of component voltage). ..... | ≤5 %             |
| Max short circuit level at controller's grid                              |                  |
| Terminals (690 V) .....   | 67 kA            |

### Power Consumption from Grid (approximately)

|                              |       |
|------------------------------|-------|
| At stand-by, No yawing ..... | 10 kW |
| At stand-by, yawing.....     | 41 kW |

### Controller back-up

|                            |                        |
|----------------------------|------------------------|
| UPS Controller system..... | Online UPS, Li battery |
| Back-up time .....         | 1 min                  |
| Back-up time Scada.....    | 24 h                   |

### Transformer Requirements

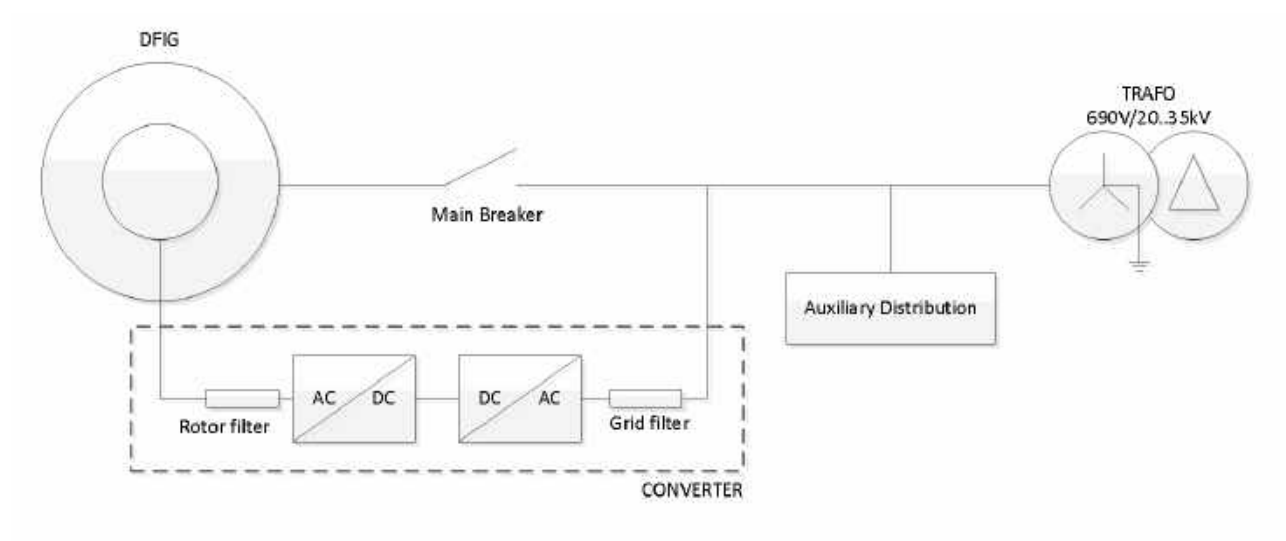
|  |                                      |
|--|--------------------------------------|
| Transformer impedance requirement..... | 8.0 % -9.5%                          |
| Secondary voltage .....                | 690 V                                |
| Vector group .....                     | Dyn 11 or Dyn 1 (star point earthed) |

### Earthing Requirements

|                             |   |
|-----------------------------|---|
| Earthing system .....       | Acc. to IEC62305-3 ED 1.0:2006                        |
| Foundation reinforcement .. | Must be connected to earth electrodes                 |
| Foundation terminals .....  | Acc. to SGRE Standard                                 |
| HV connection.....          | HV cable shield shall be connected to earthing system |

All data are subject to tolerances in accordance with IEC.

## Simplified Single Line Diagram



## Transformer Specifications ECO 20 kV\*

**Transformer**

|  |   |
|--|---|
| Type .....                             | Dry type                                |
| Nominal power .....                    | 5500 kVA @nominal<br>voltage +12%/-10 % |
| Nominal voltage .....                  | 20/0.69 kV                              |
| Frequency .....                        | 50 Hz                                   |
| Transformer impedance ....             | 8.59%                                   |
| Loss ( $P_0 / P_{n120^\circ C}$ )..... | 8/45 kW                                 |
| Vector group .....                     | Dyn11                                   |
| Offload tap changer .....              | Optional ( $\pm 2.5\%$ / $\pm 5\%$ )    |
| Standard.....                          | IEC 60076<br>ECO Design Directive       |

**Transformer Cooling**

|                        |   |
|------------------------|---|
| Cooling system.....    | AF  |
| Ventilation .....      | Forced ventilation of the<br>transformer room |
| Control parameter..... | Winding & Magnetic core<br>temperature        |

**Transformer Monitoring**

|                          |              |
|--------------------------|--------------|
| Winding Temperature..... | PT100 sensor |
| Mag. Core temperature... | PT100 sensor |

**Transformer Earthing**

|                  |  |
|------------------|--|
| Star point ..... | The star point of the<br>transformer must be<br>connected to earth |
|------------------|--|

## Transformer Specifications 34.5 kV\*

**Transformer**

|  |  |
|--|--|
| Type .....                             | Dry type                               |
| Nominal power .....                    | 5500 kVA @nominal<br>voltage +12/-10 % |
| Nominal voltage .....                  | 34.5/0.69 kV                           |
| Frequency .....                        | 60 Hz                                  |
| Transformer impedance ....             | 8.77%                                  |
| Loss ( $P_0 / P_{n120^\circ C}$ )..... | 8/45 kW                                |
| Vector group .....                     | Dyn1                                   |
| Offload tap changer .....              | Optional ( $\pm 2.5\%$ / $\pm 5\%$ )   |
| Standard.....                          | IEEE std C57.12                        |

**Transformer Cooling**

|                        |   |
|------------------------|---|
| Cooling system.....    | AF  |
| Ventilation .....      | Forced ventilation of the<br>transformer room |
| Control parameter..... | Winding & Magnetic core<br>temperature        |

**Transformer Monitoring**

|                          |              |
|--------------------------|--------------|
| Winding Temperature..... | PT100 sensor |
| Mag. Core temperature... | PT100 sensor |

**Transformer Earthing**

|                  |  |
|------------------|--|
| Star point ..... | The star point of the<br>transformer must be<br>connected to earth |
|------------------|--|

## Switchgear Specification

The installation of a switchgear is an option available upon request. The minimum requirements that must be complied with, from the point of view of electrical protection, are:

Switchgear Specification (38 kV)

### Technical Data for Switchgear

#### Switchgear

|                                   |   |
|-----------------------------------|---|
| Type                              | Gas-insulated switchgear                |
| Operating voltage                 | 30 - 36 kV                              |
| Rated current                     | 630 A                                   |
| Short time withstand current      | 20 kA/1s                                |
| Peak withstand current            | 50 kA                                   |
| Power frequency withstand voltage | 70 kV                                   |
| Lightning withstand voltage       | 170 kV                                  |
| Insulating medium                 | SF <sub>6</sub>                         |
| Switching medium                  | vacuum                                  |
| Consist of                        | 1, 2 or 3 panels                        |
| Grid cable feeder                 | Load break switch or direct cable riser |
| Circuit breaker feeder            | Circuit breaker                         |
| Degree of protection, vessel      | IPX8                                    |
| Degree of protection, front cover | IP2XD                                   |
| Degree of protection, LV Comp.    | IP2XD                                   |
| Internal arc classification IAC:  | A FL 20 kA 1s                           |
| Pressure relief                   | Down                                    |
| Standard                          | IEC 62271                               |
| Temperature range                 | -30°C to +40°C                          |

#### Grid Cable feeder

|                              |                       |
|------------------------------|-----------------------|
| Rated current , cubicle      | 630 A                 |
| Rated current , load breaker | 630 A                 |
| Short time withstand current | 20 kA/1s              |
| Short circuit making current | 50 kA/1s              |
| Three position switch        | Closed, open, earthed |
| Switch mechanism             | Spring operated       |
| Control                      | Local                 |
| Voltage detection system     | Capacitive            |

#### Circuit breaker feeder

|                                 |                       |
|---------------------------------|-----------------------|
| Rated current , Cubicle         | 630 A                 |
| Rated current , circuit breaker | 630 A                 |
| Short time withstand current    | 20 kA/1s              |
| Short circuit making current    | 50 kA/1s              |
| Short circuit breaking current  | 20 kA/1s              |
| Three position CB switch        | Closed, open, earthed |
| Switch mechanism                | Spring operated       |
| Tripping mechanism              | Stored energy         |
| Motor voltage                   | Under request         |
| Control                         | Local                 |
| Coil for external trip          | 230 V AC              |
| Voltage detection system        | Capacitive            |

#### Protection

|                     |                            |
|---------------------|----------------------------|
| Over-current relay  | Ekor.wtp                   |
| Functions           | 50/51 50N/51N              |
| Power supply        | Dual (Self & Aux. powered) |
| Current transformer | 300/1A; 0.18VA, Cl. 5P20   |

#### Interface- MV Cables

|   |   |
|---|---|
| Grid cable feeder                       | 630A bushings type C M16<br>Max 2 feeder cables |
| Cable entry                             | From bottom                                     |
| Cable clamp size (cable outer diameter) | up to 48mm                                      |
| Circuit breaker feeder                  | 630 A bushings type C M16                       |
| Cable entry                             | From bottom                                     |

#### Interface to turbine control

|                        |                      |
|------------------------|----------------------|
| Breaker status         | 1 NO + 1 NC contacts |
| Insulation supervision | Under request        |
| External trip          | 230 V AC             |

All data are subject to tolerances in accordance with IEC.

Example for a 38 kV Switchgear. For other Medium Voltage variants or different grounding systems, contact SGRE.

## Preliminary Foundation Loads

Detailed information about foundation loads will be available upon request.



## Tower Dimensions

SG 5.0-145 presents a tower portfolio with hub heights ranging from 79.5m to 165m. Information for the baseline towers is included below:

- Tower hub height 91m. Baseline design (T91.41).

| TOWER HH 91 SG 5.0-145             |                    |           |                 |
|------------------------------------|--------------------|-----------|-----------------|
|                                    | Section 1 (bottom) | Section 2 | Section 3 (top) |
| External diameter upper flange (m) | 4.224              | 3.481     | 3.503           |
| External diameter lower flange (m) | 4.470              | 4.224     | 3.481           |
| Section's height (m)               | 25.073             | 29.260    | 34.500          |
| Section structural weight (kgs)    | 76134.7            | 61649.8   | 55581.0         |
| Section total weight (kgs)         | 78556.7            | 62966.5   | 57133.5         |
| Total tower height (m)             | <b>88.833</b>      |           |                 |
| Total tower weight (kg)            | <b>198656.7</b>    |           |                 |

- Tower hub height 95.5m. Baseline design (4 sections, T95.5.41).

| TOWER HH 95.5 SG 5.0-145           |                    |           |           |                 |
|------------------------------------|--------------------|-----------|-----------|-----------------|
|                                    | Section 1 (bottom) | Section 2 | Section 3 | Section 4 (top) |
| External diameter upper flange (m) | 4.4987             | 4.4933    | 3.9677    | 3.5030          |
| External diameter lower flange (m) | 4.5000             | 4.4987    | 4.4933    | 3.9677          |
| Section's height (m)               | 17.940             | 24.535    | 25.897    | 25.120          |
| Section structural weight (kgs)    | 61029.0            | 59730.0   | 47174.0   | 40929.8         |
| Section total weight (kgs)         | 63177.7            | 60834.1   | 48339.4   | 42060.2         |
| Total tower height (m)             | <b>93.492</b>      |           |           |                 |
| Total tower weight (kg)            | <b>214411.4</b>    |           |           |                 |

- Tower hub height 97.5m. Baseline design (4 sections, T97.5.41).

| TOWER HH 97.5 SG 5.0-145           |                       |              |              |                    |
|------------------------------------|-----------------------|--------------|--------------|--------------------|
|                                    | Section<br>1 (bottom) | Section<br>2 | Section<br>3 | Section<br>4 (top) |
| External diameter upper flange (m) | 4.4243                | 4.4195       | 4.0159       | 3.5030             |
| External diameter lower flange (m) | 4.6800                | 4.4243       | 4.4195       | 4.0159             |
| Section's height (m)               | 19.220                | 21.090       | 26.290       | 28.900             |
| Section structural weight (kgs)    | 64257.2               | 52845.8      | 50163.7      | 46061.4            |
| Section total weight (kgs)         | 66305.4               | 53794.9      | 51346.8      | 47361.9            |
| Total tower height (m)             | <b>95.500</b>         |              |              |                    |
| Total tower weight (kg)            | <b>218808.9</b>       |              |              |                    |

- Tower hub height 102.5m (4 sections, T102.5.42).

| TOWER HH 102.5 SG 5.0-145          |                       |              |              |                    |
|------------------------------------|-----------------------|--------------|--------------|--------------------|
|                                    | Section<br>1 (bottom) | Section<br>2 | Section<br>3 | Section<br>4 (top) |
| External diameter upper flange (m) | 4.43                  | 4.422        | 4.017        | 3.503              |
| External diameter lower flange (m) | 4.40                  | 4.43         | 4.422        | 4.017              |
| Section's height (m)               | 19.700                | 25.300       | 28.100       | 27.336             |
| Section structural weight (kgs)    | 77660.4               | 70833.2      | 58363.2      | 46332.5            |
| Section total weight (kgs)         | 79730.4               | 71971.7      | 59627.7      | 47562.6            |
| Total tower height (m)             | <b>100.446</b>        |              |              |                    |
| Total tower weight (kg)            | <b>258893</b>         |              |              |                    |

- Tower hub height 102.5m (5 sections, T102.5.43).

| TOWER HH 102.5 SG 5.0-145          |                    |           |           |           |                 |
|------------------------------------|--------------------|-----------|-----------|-----------|-----------------|
|                                    | Section 1 (bottom) | Section 2 | Section 3 | Section 4 | Section 5 (top) |
| External diameter upper flange (m) | 4.431              | 4.424     | 4.419     | 4.416     | 3.503           |
| External diameter lower flange (m) | 4.481              | 4.431     | 4.424     | 4.419     | 4.416           |
| Section's height (m)               | 14.100             | 16.900    | 19.700    | 25.300    | 24.434          |
| Section structural weight (kgs)    | 61263.3            | 54665.5   | 49105.0   | 49175.9   | 42364.9         |
| Section total weight (kgs)         | 63239.2            | 55426.0   | 49991.5   | 50314.4   | 43464.5         |
| Total tower height (m)             | <b>100.434</b>     |           |           |           |                 |
| Total tower weight (kg)            | <b>262435.6</b>    |           |           |           |                 |

- Tower hub height 127.5m. Baseline design (6 sections, T127.5.45).

| TOWER HH 127.5 SG 5.0-145          |                    |           |           |           |           |                 |
|------------------------------------|--------------------|-----------|-----------|-----------|-----------|-----------------|
|                                    | Section 1 (bottom) | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 (top) |
| External diameter upper flange (m) | 4.6550             | 4.4900    | 4.4838    | 4.2698    | 3.9167    | 3.5030          |
| External diameter lower flange (m) | 4.6800             | 4.6550    | 4.4900    | 4.4838    | 4.2698    | 3.9167          |
| Section's height (m)               | 13.510             | 17.620    | 19.955    | 22.980    | 24.435    | 27.000          |
| Section structural weight (kgs)    | 66214.8            | 64777.9   | 62217.4   | 56958.4   | 46152.6   | 43549.4         |
| Section total weight (kgs)         | 68164.2            | 65570.8   | 63115.4   | 57992.5   | 47252.2   | 44764.4         |
| Total tower height (m)             | <b>125.500</b>     |           |           |           |           |                 |
| Total tower weight (kg)            | <b>346859.4</b>    |           |           |           |           |                 |

- Tower hub height 127.5m. Baseline design (7 sections, T127.5.46).

| TOWER HH 127.5 SG 5.0-145          |                       |              |              |              |              |              |                    |
|------------------------------------|-----------------------|--------------|--------------|--------------|--------------|--------------|--------------------|
|                                    | Section<br>1 (bottom) | Section<br>2 | Section<br>3 | Section<br>4 | Section<br>5 | Section<br>6 | Section<br>7 (top) |
| External diameter upper flange (m) | 4.4850                | 4.486        | 4.4770       | 4.4728       | 4.0900       | 3.8167       | 3.503              |
| External diameter lower flange (m) | 4.5000                | 4.4850       | 4.486        | 4.4770       | 4.4728       | 4.0900       | 3.8167             |
| Section's height (m)               | 10.005                | 11.785       | 15.095       | 18.568       | 22.205       | 24.845       | 23.000             |
| Section structural weight (kgs)    | 54606.8               | 51948.4      | 54614.4      | 54672.8      | 52405.4      | 44963.9      | 36768.1            |
| Section total weight (kgs)         | 56267.0               | 52478.7      | 55293.6      | 55508.4      | 53404.6      | 46081.9      | 37803.1            |
| Total tower height (m)             | 125.503               |              |              |              |              |              |                    |
| Total tower weight (kg)            | 356837.4              |              |              |              |              |              |                    |

Information about other tower heights will be available upon request.

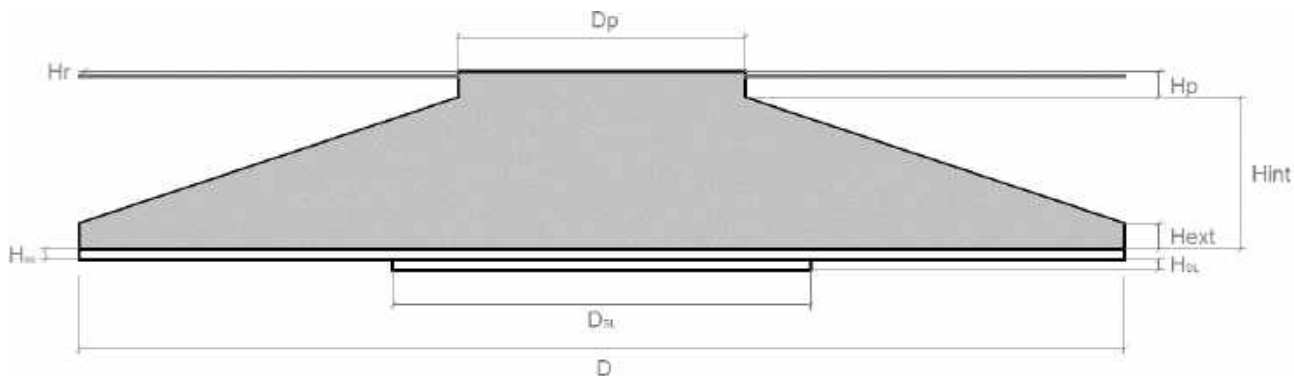
## Estimated Foundation Design

Hub height: 91 m

### Volumes

Concrete volume ~431.22 m<sup>3</sup>, C30/47 – C40/50 MPa

Reinforcement steel ~39991 kg, B 500 S



| FOUNDATION GEOMETRY                            |      |
|--|------|
| D= Slab diameter [m]                           | 18.8 |
| Hext= Outer egde height [m]                    | 0.50 |
| Hint= Inner edge height [m]                    | 2.7  |
| Dp= Pedestal diameter [m]                      | 5.50 |
| Hp= Pedestal height [m]                        | 0.50 |
| D <sub>SL</sub> =Soil improvement diameter [m] | 9.5  |

The estimated foundation design is based on the following assumptions:

- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m<sup>3</sup>
- Friction angle 30.0°

Additional factors that may impact the foundation design:

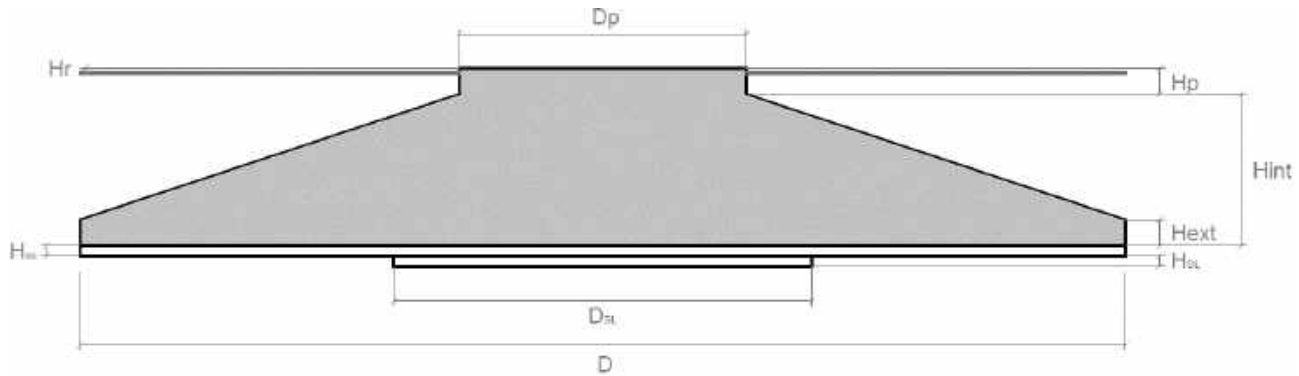
Soil conditions, country, designer practice, national codes and standards.

**Hub height: 95.5 m**

## Volumes

Concrete volume ~453.44 m<sup>3</sup>, C35/40 – C40/50 MPa

Reinforcement steel ~42921 kg, B 500 S



| FOUNDATION GEOMETRY                            |      |
|--|------|
| D= Slab diameter [m]                           | 19.3 |
| Hext= Outer egde height [m]                    | 0.50 |
| Hint= Inner edge height [m]                    | 2.7  |
| Dp= Pedestal diameter [m]                      | 5.6  |
| Hp= Pedestal height [m]                        | 0.50 |
| D <sub>SL</sub> =Soil improvement diameter [m] | 9.1  |

**The estimated foundation design is based on the following assumptions:**

- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m<sup>3</sup>
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**

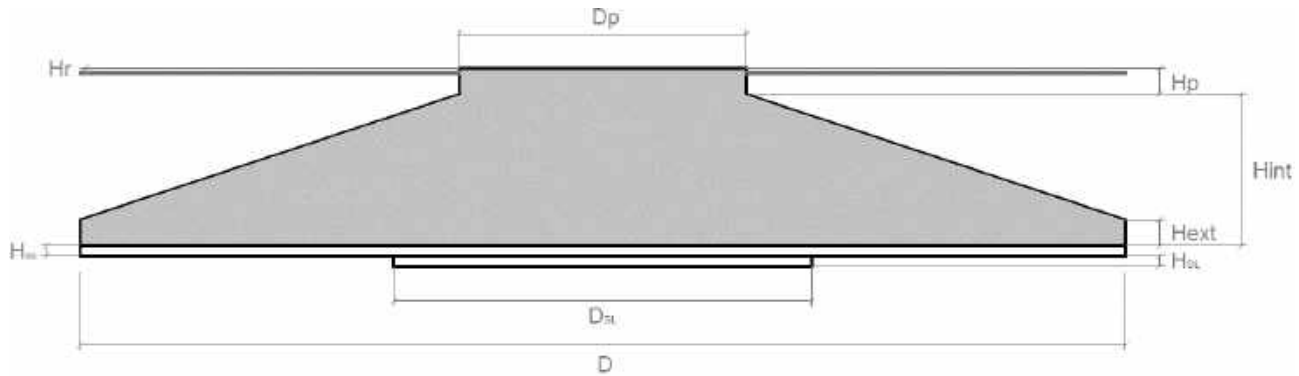
Soil conditions, country, designer practice, national codes and standards.

**Hub height: 97.5 m**

## Volumes

Concrete volume ~455.65 m<sup>3</sup>, C35/40 – C40/50 MPa

Reinforcement steel ~43295 kg, B 500 S



| FOUNDATION GEOMETRY                            |      |
|--|------|
| D= Slab diameter [m]                           | 19.3 |
| Hext= Outer egde height [m]                    | 0.50 |
| Hint= Inner edge height [m]                    | 2.7  |
| Dp= Pedestal diameter [m]                      | 5.70 |
| Hp= Pedestal height [m]                        | 0.50 |
| D <sub>SL</sub> =Soil improvement diameter [m] | 9.4  |

**The estimated foundation design is based on the following assumptions:**

- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m<sup>3</sup>
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**

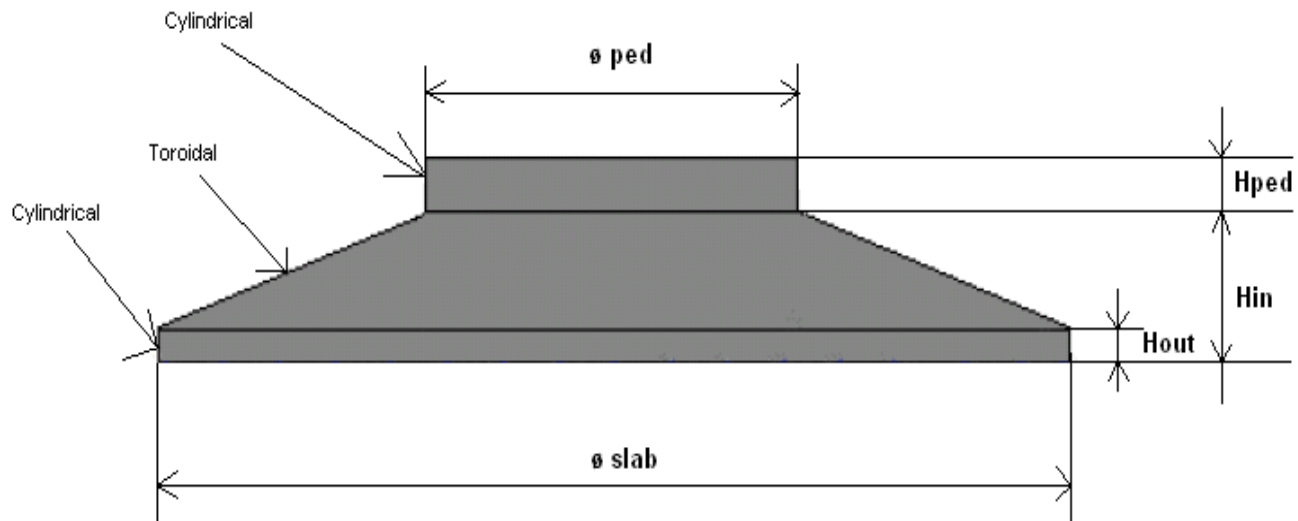
Soil conditions, country, designer practice, national codes and standards.

**Hub height: 102.5 m (valid for 4 sections & 5 sections tower options)**

## Volumes

Concrete volume ~544.50 m<sup>3</sup>, C35/45 – C40/50 MPa

Reinforcement steel ~50910 kg, B 500 S



| FOUNDATION GEOMETRY                               |      |
|---|------|
| $\varnothing \text{ slab}$ = Slab diameter [m]    | 20.8 |
| Hout= Outer egde height [m]                       | 0.50 |
| Hin= Inner edge height [m]                        | 2.9  |
| $\varnothing \text{ ped}$ = Pedestal diameter [m] | 5.50 |
| Hped= Pedestal height [m]                         | 0.50 |

**The estimated foundation design is based on the following assumptions:**

- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m<sup>3</sup>
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**

Soil conditions, country, designer practice, national codes and standards.

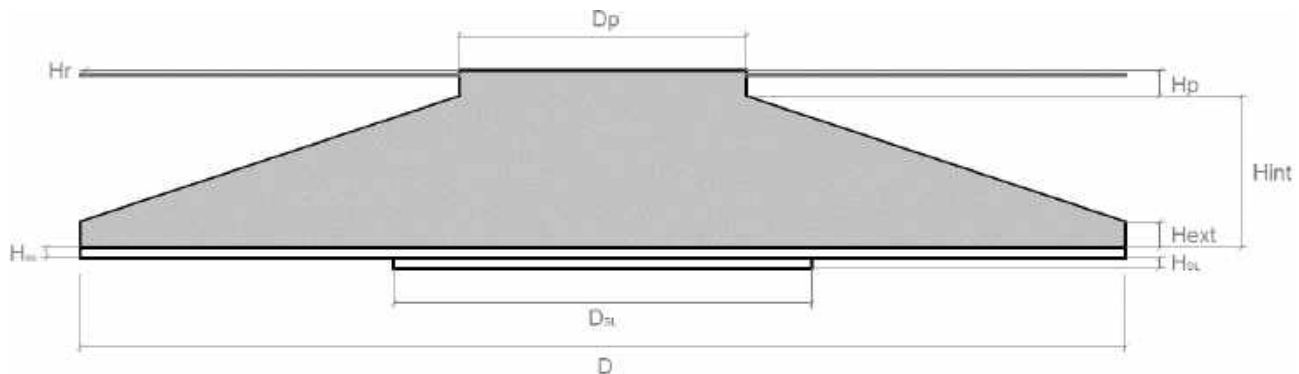


**Hub height: 127.5 m (T127.5.45)**

## Volumes

Concrete volume ~547.89 m<sup>3</sup>, C35/40 – C50/60 MPa

Reinforcement steel ~57783 kg, B 500 S



| FOUNDATION GEOMETRY                            |      |
|--|------|
| D= Slab diameter [m]                           | 21.4 |
| Hext= Outer egde height [m]                    | 0.50 |
| Hint= Inner edge height [m]                    | 2.7  |
| Dp= Pedestal diameter [m]                      | 5.70 |
| Hp= Pedestal height [m]                        | 0.50 |
| D <sub>SL</sub> =Soil improvement diameter [m] | 9.3  |

**The estimated foundation design is based on the following assumptions:**

- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m<sup>3</sup>
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**

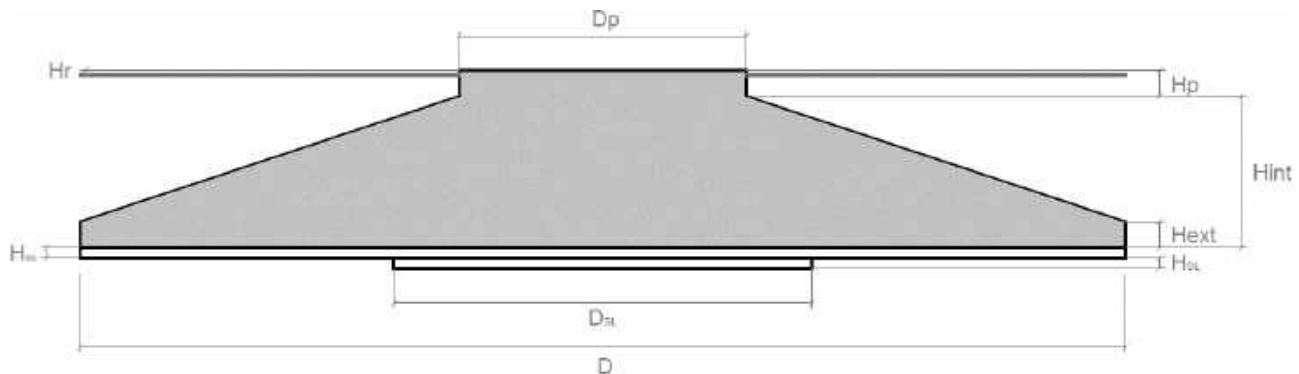
Soil conditions, country, designer practice, national codes and standards.

**Hub height: 127.5 m (T127.5.46)**

## Volumes

Concrete volume ~545.47 m<sup>3</sup>, C35/40 – C50/60 MPa

Reinforcement steel ~57783 kg, B 500 S



| FOUNDATION GEOMETRY                            |      |
|--|------|
| D= Slab diameter [m]                           | 21.4 |
| Hext= Outer egde height [m]                    | 0.50 |
| Hint= Inner edge height [m]                    | 2.7  |
| Dp= Pedestal diameter [m]                      | 5.60 |
| Hp= Pedestal height [m]                        | 0.50 |
| D <sub>SL</sub> =Soil improvement diameter [m] | 9.3  |

**The estimated foundation design is based on the following assumptions:**

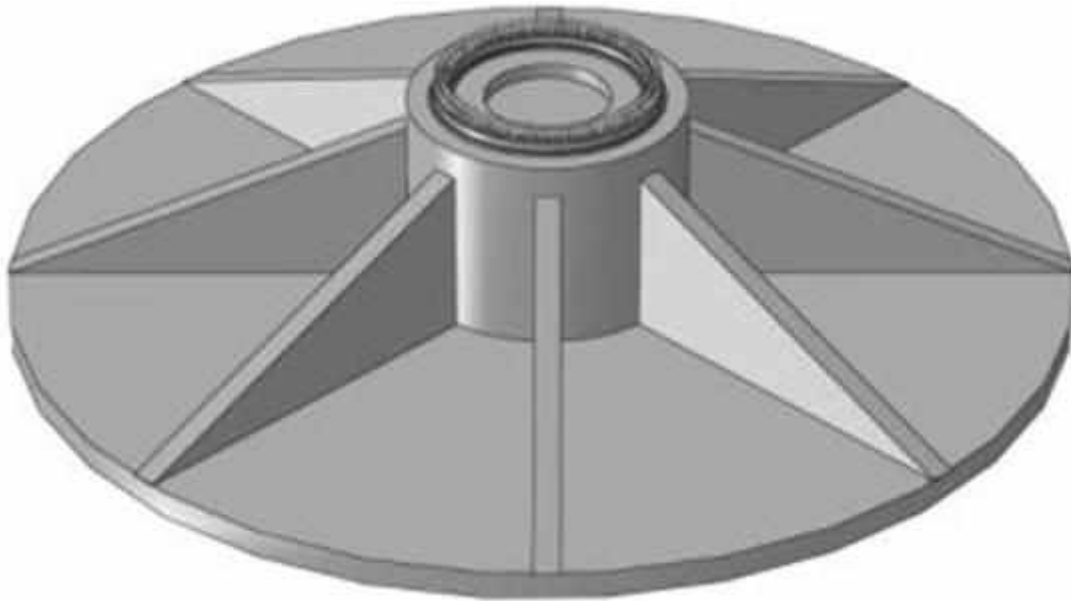
- Gravity based flat foundation without buoyancy
- Specific weight of backfill 18.0 kN/m<sup>3</sup>
- Friction angle 30.0°

**Additional factors that may impact the foundation design:**

Soil conditions, country, designer practice, national codes and standards.

Although the standard and most common foundation concept is the previously shown circular tapered slab, it is also possible to design, based on site specific conditions, the optimized “8 Walls foundation”.

See figure below:



## Preliminary Grid Performance Specification, 50 Hz

### General

This document describes the grid performance of the SG 5.0-145, 50 Hz wind turbine. Siemens Gamesa Renewable Energy (SGRE) will provide wind turbine technical data for the developer to use in the design of the wind power plant and the evaluation of requirements compliance. The developer will be responsible for the evaluation and ensuring that the requirements are met for the wind power plant.

The capabilities described in this document are based on the assumption that the electrical network is designed to be compatible with operation of the wind turbine. SGRE will provide a document with guidance to perform an assessment of the network's compatibility.

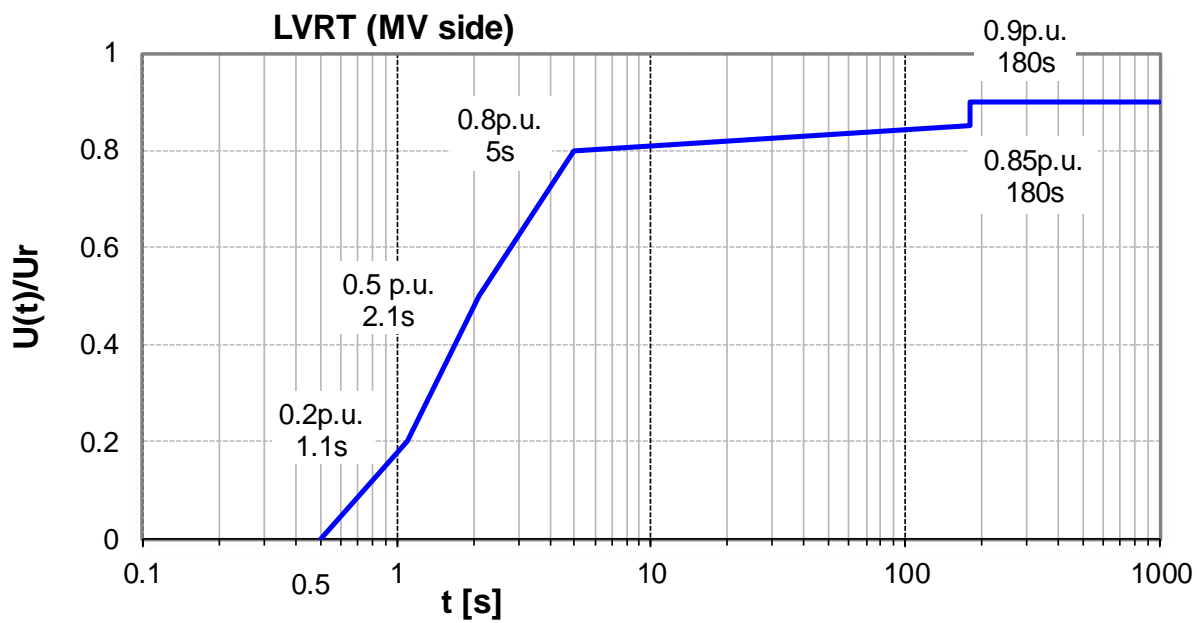
### Fault Ride Through (FRT) Capability

The wind turbine is capable of operating when voltage transient events occur on the interconnecting transmission system above and below the standard voltage lower limits and time slot according to Figure 1 and Figure 2.

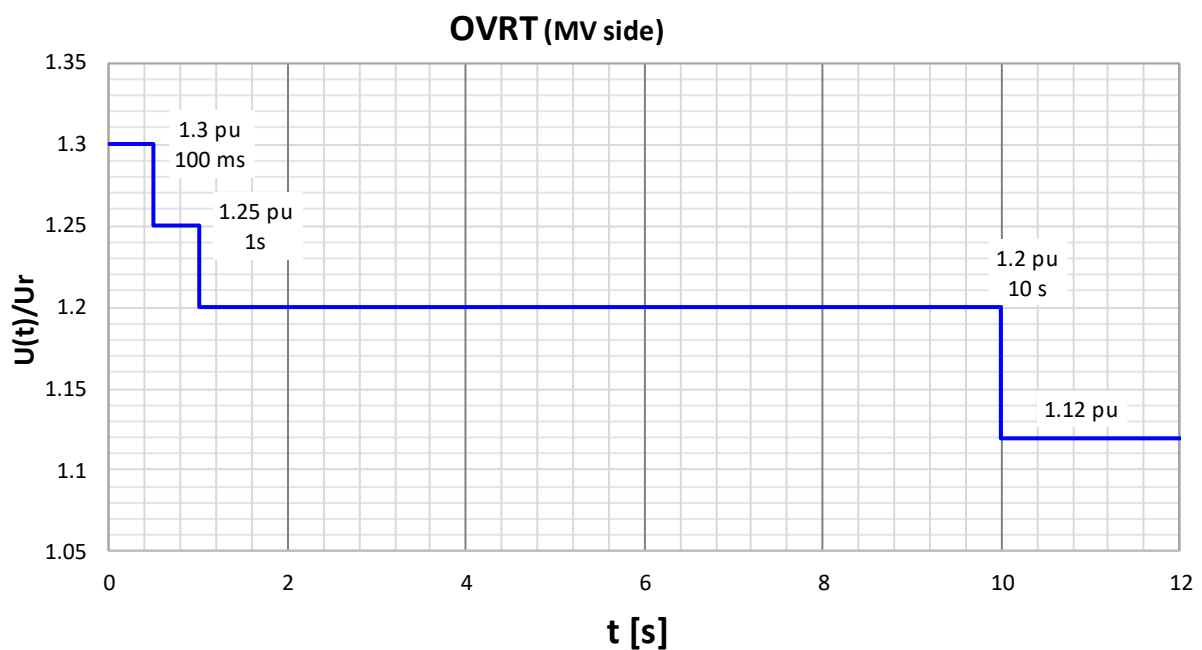
This performance assumes that the installed amount of wind turbines is in the right proportion to the strength of the grid, which means that the short circuit ratio ( $S_k/S_n$ ) and the X/R ratio of the grid at the wind turbine transformer terminals must be adequate.

Evaluation of the wind turbine's fault ride through capability in a specific system must be based on simulation studies using the specific network model and a dynamic wind turbine model provided by SGRE in PSS/E. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.

The standard voltage limits for the SG 5.0-145, 50 Hz wind turbine are presented in Figure 1 between 100 -1000 seconds and in Figure 2 between 0 – 12 seconds.



**Figure 1.** Lower voltage limits for SG 5.0-145, 50 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).



**Figure 2.** Upper voltage limits for SG 5.0-145, 50 Hz wind turbine in the range of 0-12 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).

## **Power Factor (Reactive Power) Capability**

The wind turbine is able to operate in a power factor range of 0.9 leading to 0.9 lagging at the low voltage side of the wind turbine transformer, at nominal balanced voltage and nominal frequency. The control mode for the wind turbine is with reactive power set-points.

## **Supervisory Control and Data Acquisition (SCADA) Capability**

The SGRE SCADA system has the capability to transmit and receive instructions from the transmission system provider for system reliability purposes depending on the configuration of the SCADA system. The project specific SCADA requirements must be specified in detail for design purposes.

## **Frequency Capability**

The wind turbine is able to operate in the frequency range between 47 Hz and 53 Hz.

## **Voltage Capability**

The voltage operation range for the wind turbine is between 90% and 112% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 100ms, see Figure 2. The wind turbine's target voltage shall stay between 95% and 105% in order to support the best possible performance by staying within the operation limits.

## **Flicker and Harmonics**

Flicker and Harmonics values will be provided in the power quality measurement report extract in accordance with IEC 61400-21 Edition 2.

## **Reactive Power -Voltage Control**

The power plant controller can operate in four different modes:

- Q Control – In this mode reactive power is controlled at the point of interconnection, according to a reactive power reference
- V Control – Voltage is directly controlled at the point of interconnection, according to a voltage reference
- V-Q static – Voltage is controlled at the point of interconnection, by means of a pre-defined voltage – reactive power characteristic
- Power factor (cosphi) control – Power factor is controlled at the point of interconnection, according to a power factor reference

The SCADA system receives feedback/measured values from the Point Of Interconnection depending on the control mode it is operating. The wind power plant controller then compares the measured values against the target levels and calculates the reactive power reference. Finally, reactive power references are distributed to each individual wind turbine. The wind turbine's controller responds to the latest reference from the SCADA system and will generate the required reactive power accordingly from the wind turbine.

## **Frequency Control**

The frequency control is managed by the SCADA system together with the wind turbine controller. The wind power plant frequency control is carried out by the SCADA system which distributes active power set-points to each individual wind turbine, to the controllers. The wind turbine controller responds to the latest reference from the SCADA system and will maintain this active power locally.

All data are subject to tolerances in accordance with IEC.

## Preliminary Grid Performance Specification, 60 Hz

### General

This document describes the grid performance of the SG 5.0-145, 60 Hz wind turbine. Siemens Gamesa Renewable Energy (SGRE) will provide wind turbine technical data for the developer to use in the design of the wind power plant and the evaluation of requirements compliance. The developer will be responsible for the evaluation and ensuring that the requirements are met for the wind power plant.

The capabilities described in this document are based on the assumption that the electrical network is designed to be compatible with operation of the wind turbine. SGRE will provide a document with guidance to perform an assessment of the network's compatibility.

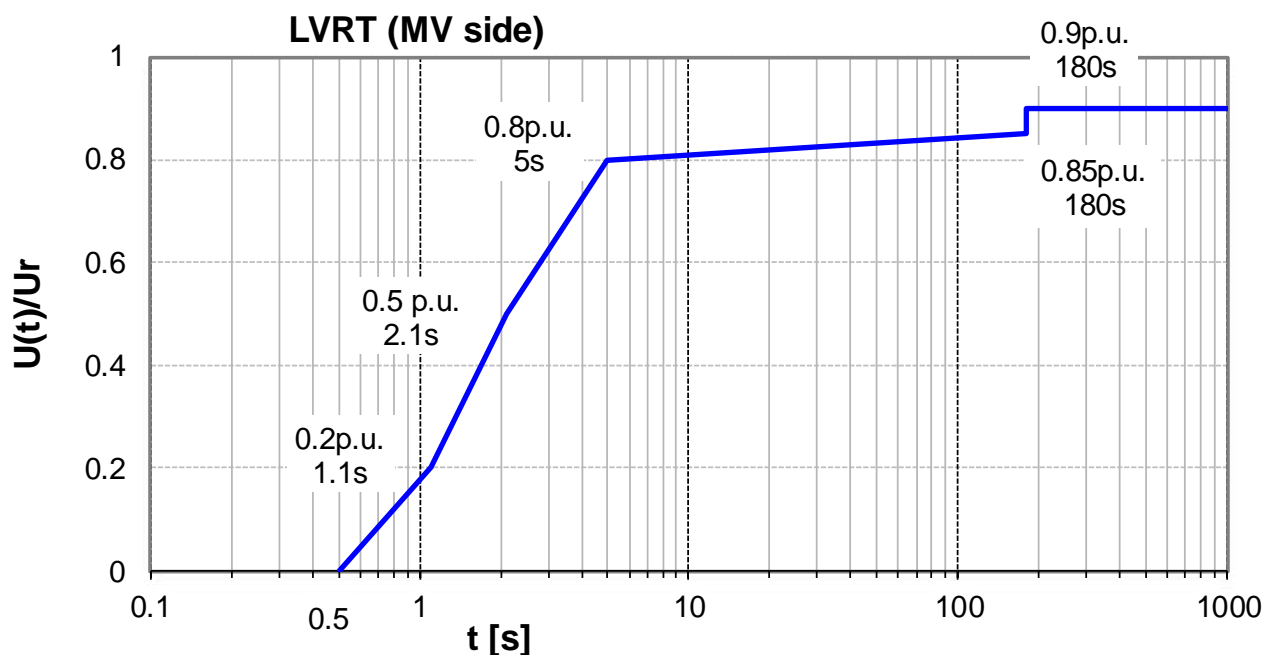
### Fault Ride Through (FRT) Capability

The wind turbine is capable of operating when voltage transient events occur on the interconnecting transmission system above and below the standard voltage lower limits and time slot according to Figure 3 and Figure 4.

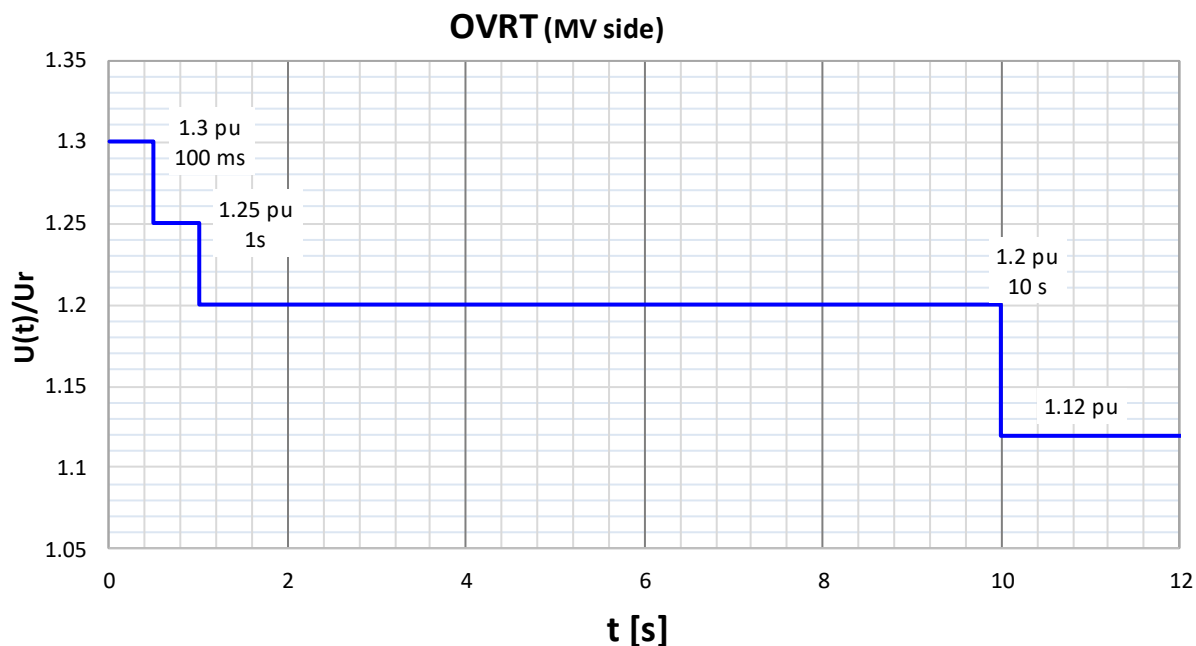
This performance assumes that the installed amount of wind turbines is in the right proportion to the strength of the grid, which means that the short circuit ratio ( $S_k/S_n$ ) and the X/R ratio of the grid at the wind turbine transformer terminals must be adequate.

Evaluation of the wind turbine's fault ride through capability in a specific system must be based on simulation studies using the specific network model and a dynamic wind turbine model provided by SGRE in PSS/E. This model is a reduced order model, suitable for balanced simulations with time steps between 4-10 ms.

The standard voltage limits for the SG 5.0-145, 60 Hz wind turbine are presented in Figure 3 between 100 -1000 seconds and in Figure 4 between 0 – 12 seconds.



**Figure 3.** Lower voltage limits for SG 5.0-145, 60 Hz wind turbine in the range of 0-1000 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).



**Figure 4.** Upper voltage limits for SG 5.0-145, 60 Hz wind turbine in the range of 0-12 seconds. The nominal voltage is 690 V (i.e. 1 p.u.).



## Power Factor (Reactive Power) Capability

The wind turbine is able to operate in a power factor range of 0.9 leading to 0.9 lagging at the low voltage side of the wind turbine transformer, at nominal balanced voltage and nominal frequency. The control mode for the wind turbine is with reactive power set-points.

## Supervisory Control and Data Acquisition (SCADA) Capability

The SGRE SCADA system has the capability to transmit and receive instructions from the transmission system provider for system reliability purposes depending on the configuration of the SCADA system. The project specific SCADA requirements must be specified in detail for design purposes.

## Frequency Capability

The wind turbine is able to operate in the frequency range between 56.4 Hz and 63.6 Hz.

## Voltage Capability

The voltage operation range for the wind turbine is between 90% and 112% of nominal voltage at the low voltage side of the wind turbine transformer. The voltage can be up to 130% for 100ms, see Figure 4. The wind turbine's target voltage shall stay between 95% and 105% in order to support the best possible performance by staying within the operation limits

## Flicker and Harmonics

Flicker and Harmonics values will be provided in the power quality measurement report extract in accordance with IEC 61400-21 Edition 2.

## Reactive Power -Voltage Control

The power plant controller can operate in four different modes:

- Q Control – In this mode reactive power is controlled at the point of interconnection, according to a reactive power reference
- V Control – Voltage is directly controlled at the point of interconnection, according to a voltage reference
- V-Q static – Voltage is controlled at the point of interconnection, by means of a pre-defined voltage – reactive power characteristic
- Power factor (cosphi) control – Power factor is controlled at the point of interconnection, according to a power factor reference

The SCADA system receives feedback/measured values from the Point Of Interconnection depending on the control mode it is operating. The wind power plant controller then compares the measured values against the target levels and calculates the reactive power reference. Finally, reactive power references are distributed to each individual wind turbine. The wind turbine's controller responds to the latest reference from the SCADA system and will generate the required reactive power accordingly from the wind turbine.

## Frequency Control

The frequency control is managed by the SCADA system together with the wind turbine controller. The wind power plant frequency control is carried out by the SCADA system which distributes active power set-points to each individual wind turbine, to the controllers. The wind turbine controller responds to the latest reference from the SCADA system and will maintain this active power locally.

All data are subject to tolerances in accordance with IEC.

## Reactive Power Capability, 50 Hz

### General

This document describes the reactive power capability of SG 5.0-145, 50 Hz wind turbines during active power production. SG 5.0-145 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

### Reactive Power Capability Curves

The reactive power capability for the wind turbine at the LV side of the wind turbine transformer will be presented in the following Figures.

Figure 5 shows the reactive power capability on the LV side of the wind turbine depending on the generated power at LV terminals.

Figure 6 shows the reactive power capability on the LV side of the wind turbine transformer at various voltages between 0.90 p.u. and 1.13 p.u. at the LV terminals.

Figure 7 includes reactive power capability at no wind ( $Q_{wP0}$ ).

The SCADA can send voltage references to the wind turbine in the range of 0.92 p.u. to 1.08 p.u. The wind power plant should be designed to maintain the wind turbine voltage references between 0.95 p.u. and 1.05 p.u. during steady state operation.

The tables and figures assume that the phase voltages are balanced, and that the grid operational frequency and component values are nominal. Unbalanced voltages will decrease the reactive power capability. Component tolerances were not considered in determining curve parameters. Instead, the curves and data are subject to an overall tolerance of  $\pm 5\%$  of the rated power.

The reactive power capability presented in this document is the net capability and accounts for the contribution from the wind turbine auxiliary system, the reactor and the filter.

The reactive power capability described is valid while operating the wind turbine within the limits specified in the Design Climatic Conditions.

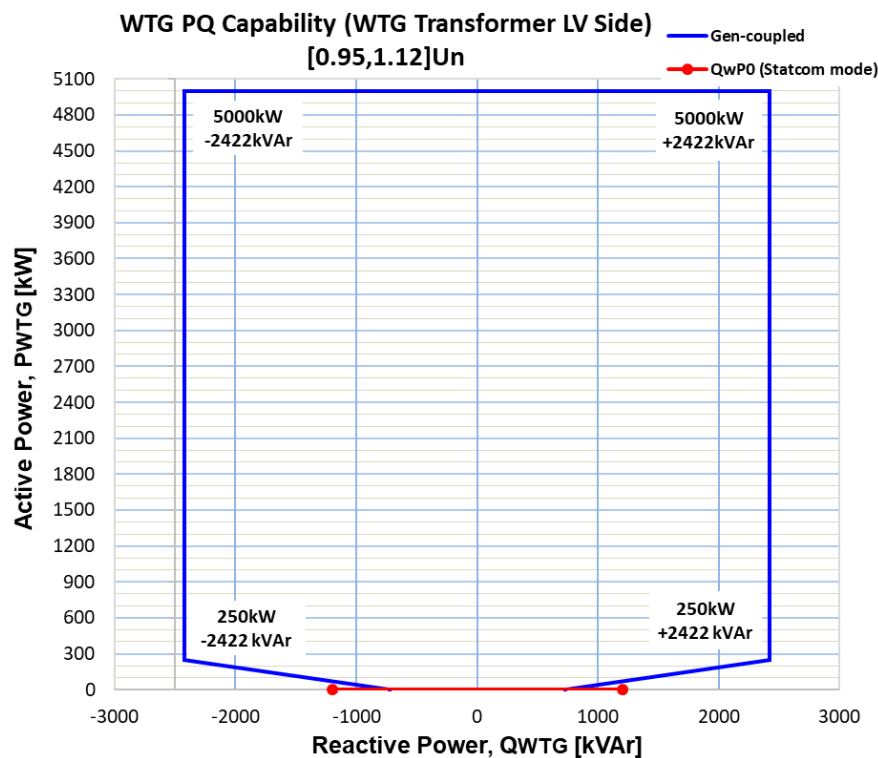


Figure 5: Reactive power capability curves, 50 Hz wind turbine, at LV side of wind turbine transformer.

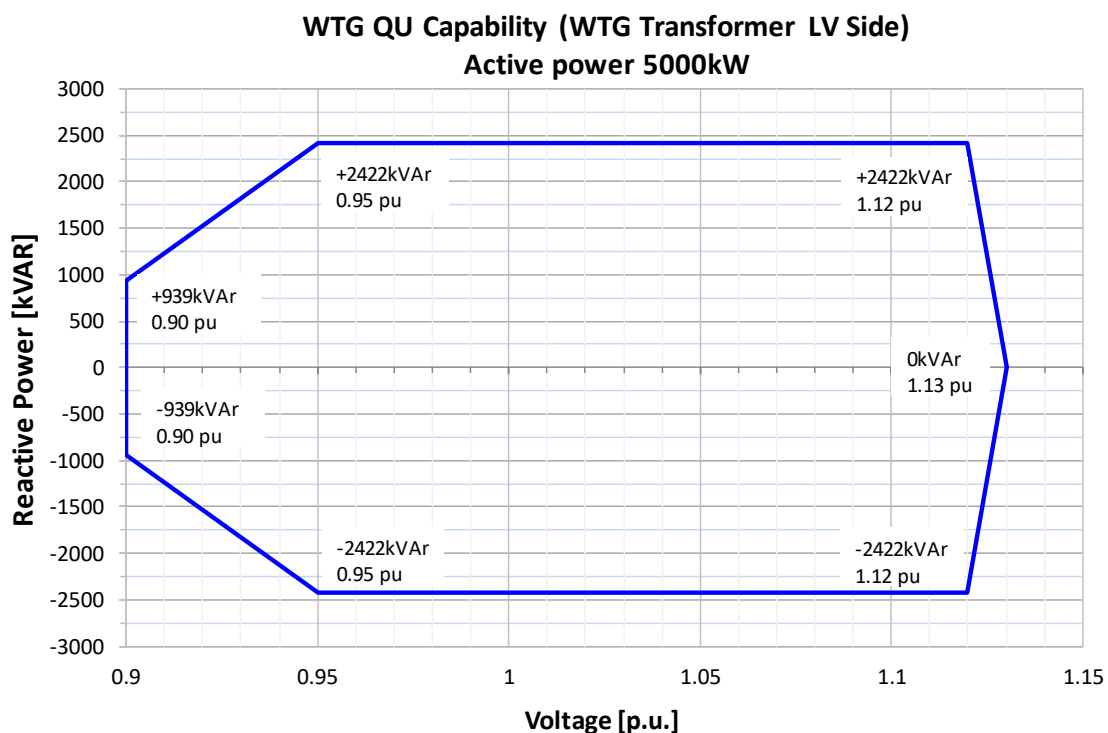
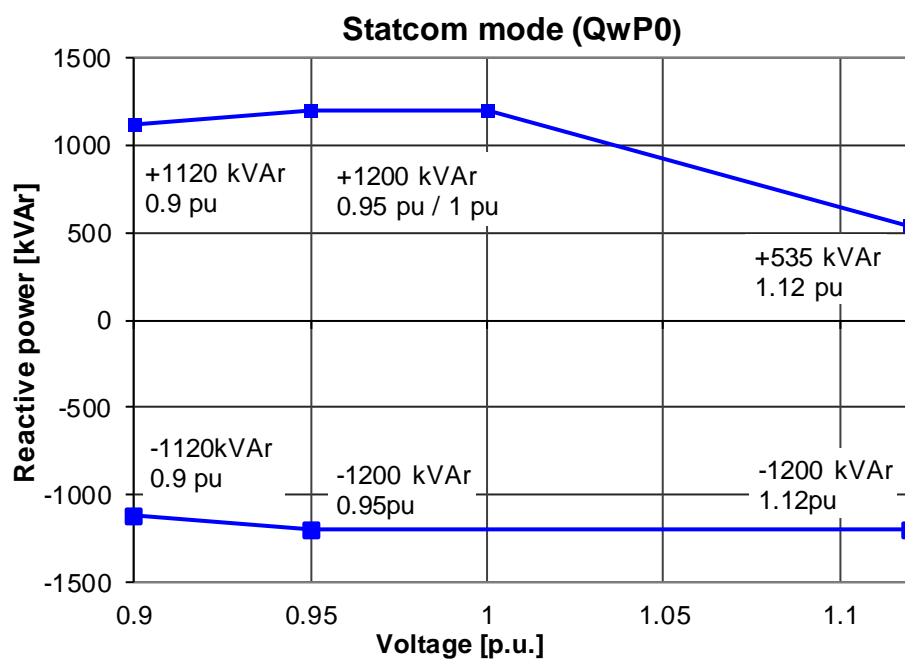


Figure 6. Reactive power capability versus voltage.



**Figure 7.** Reactive power capability at no wind (QwP0)

All data are subject to tolerances in accordance with IEC.

## Reactive Power Capability, 60 Hz

### General

This document describes the reactive power capability of SG 5.0-145, 60 Hz wind turbines during active power production. SG 5.0-145 wind turbines are equipped with a B2B Partial load frequency converter which allows the wind turbine to operate in a wide power factor range.

### Reactive Power Capability Curves

The reactive power capability for the wind turbine at the LV side of the wind turbine transformer will be presented in the following Figures.

Figure 8 shows the reactive power capability on the LV side of the wind turbine depending on the generated power at LV terminals.

Figure 9 shows the reactive power capability on the LV side of the wind turbine transformer at various voltages between 0.90 p.u. and 1.13 p.u. at the LV terminals.

Figure 10 includes reactive power capability at no wind ( $Q_{wP0}$ ).

The SCADA can send voltage references to the wind turbine in the range of 0.92 p.u. to 1.08 p.u. The wind power plant should be designed to maintain the wind turbine voltage references between 0.95 p.u. and 1.05 p.u. during steady state operation.

The tables and figures assume that the phase voltages are balanced, and that the grid operational frequency and component values are nominal. Unbalanced voltages will decrease the reactive power capability. Component tolerances were not considered in determining curve parameters. Instead, the curves and data are subject to an overall tolerance of  $\pm 5\%$  of the rated power.

The reactive power capability presented in this document is the net capability and accounts for the contribution from the wind turbine auxiliary system, the reactor and the filter.

The reactive power capability described is valid while operating the wind turbine within the limits specified in the Design Climatic Conditions.

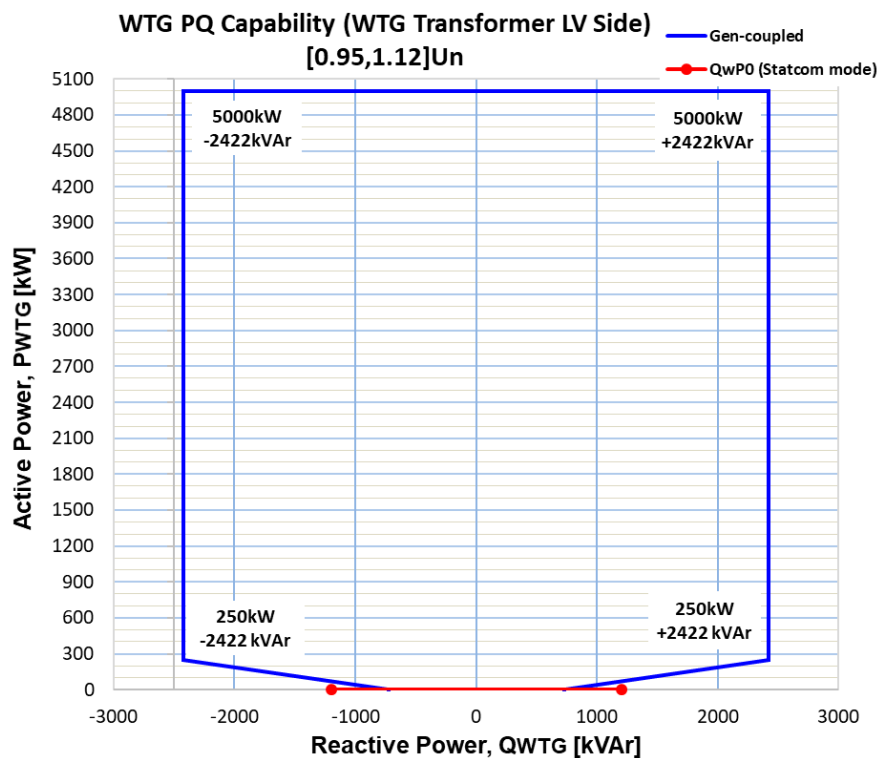


Figure 8. Reactive power capability curves, 60 Hz wind turbine, at LV side of wind turbine transformer

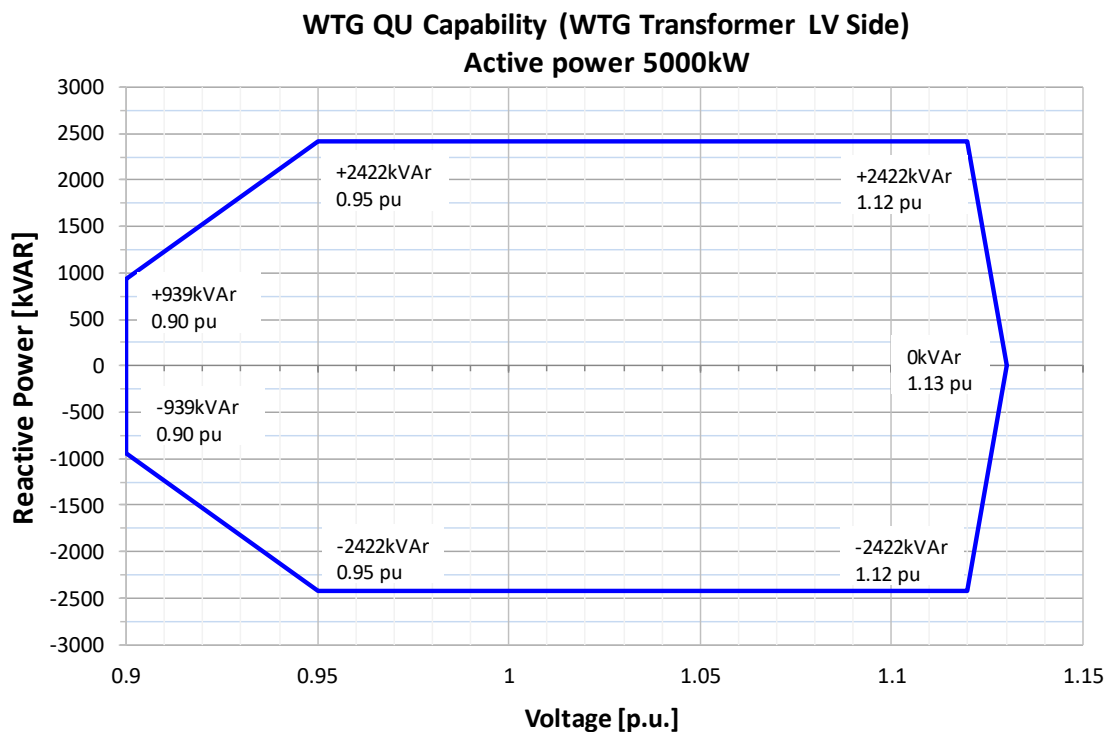


Figure 9. Reactive power capability versus voltage

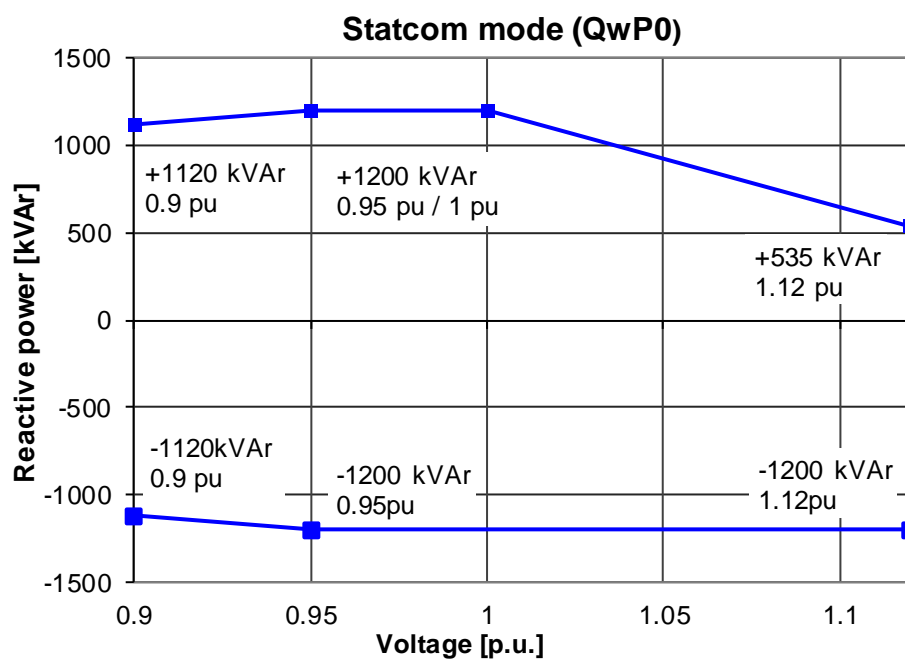


Figure 10. Reactive power capability at no wind (QwP0).

## SCADA, System Description

### General

This is a general description of the Siemens Gamesa Renewable Energy (SGRE) SCADA System.

SGRE SCADA system is a wind farm management tool. Overall, the SCADA enables:

- Supervising, monitoring and/or controlling SGRE wind turbines in a given wind farm,
- Monitoring of wind farm components such as meteorological masts, substations, measuring devices, etc.
- Storing and managing information, which provides an advanced capacity to generate reports.
- Connecting to control centers or higher level management systems.
- Wind farm power regulation for both active as well as reactive power.
- Wind farm electricity generation based on environmental conditions.

In short, the SGRE SCADA system is an indispensable communications gateway for incoming and outgoing wind farm data.

### Main Features

The SGRE SCADA system has the following main features:

- Wind turbine supervision and control.
- Meteorological mast supervision.
- Monitoring of the wind farm's feed-in substation.
- Alarms and notifications SGRE management.
- Reporting for technical and economic wind farm exploitation.
- Access security via user and profile management.
- Multiple-wind farm management capacity enabling various wind farms to be managed from a single SCADA installation. Optimized SQL database for data management.
- Integration with a preventive maintenance system (PMS)
- Additionally, the SGRE SCADA system has the following optional features:
  - Data server for access and/or integration in upper systems: OPC-UA server and IEC104 server.
  - Integration of the SGRE Power Manager tool, which includes the active power/frequency regulating tools and reactive power/voltage regulation for the wind farm
  - NRS® (Noise Reduction System) to safeguard the acoustic integrity of the area based on wind direction and time
  - Shadow Control System to prevent the undesired effects of shadows in residential areas near the wind farm
  - Wake Cancellation System for protecting wind turbines from intense turbulence based on wind direction
  - Ice Detection System for protecting the surrounding area against ice thrown from wind turbine blades
  - Bat Shield System for protecting bats
  - Bird Detection System for protecting birds
  - Alarm Notification application for distributing SMS and/or email messages to operators and maintenance technicians (SIM card not included)
  - ODBC access to the database.



## Wind Farm Management System

SGRE's wind farm management system comprises the central system, Service Operations Center (SOC), the SCADAs installed in wind farms and the wide area network (WAN) that links them all together.

During maintenance and/or the warranty period, wind farms with SGRE wind turbines must be integrated in SGRE's central system under the control of the SOC (Service Operations Center). This system compiles data from all connected wind farms, checking and storing the retrieved data in keeping with the specified storage policy. The centralization of wind farm supervision offers excellent resources for monitoring the product, maintenance planning and reports on operating status and maintenance intended for clients.

External access to the wind farm from SGRE's central system requires communication line supplied by the Employer. Nonetheless, other communications solutions can be assessed whenever they meet the technical requirements for communications specified by SGRE.

## Communication Network in Wind Farm

A wind farm's internal communications infrastructure is a network that links the SGRE SCADA system to the various wind farm devices (e.g., wind turbines, meteorological masts and substations).

Internal wind farm communications are based on a local area network (LAN) with Ethernet communications on ring-configured fiber optics. This is a "logical" round-trip ring through the same fiber optic cable so that the send path runs through two fibers and the return path runs through another two in the same cable. The wind turbines alternate where fibers connect to one another in the routing to prevent long links whenever possible.

The selection of the fiber optics for the wind farm and the overall layout of the ring network must meet SGRE specifications and will always be defined or validated by SGRE.

Likewise, the final configuration of a specific LAN network for a given wind farm will be jointly agreed between SGRE and the wind farm client.

External communication outside the wind farm through external protocols and/or SCADA clients can be based on any type of telecommunications system such as satellite links, ADSL/DSL lines, GPRS links, PSTN modems, GSM modems, etc. The primary criteria for selecting the appropriate means are the bandwidth requirements, need for continuous or on-demand connection, and the amount of data exchanged.

## Client Interface

Wind farm operators can view all the data in a simple and intuitive user interface based on web browser technology.

All operational aspects and access to SCADA system options are available through a standard web browser.

## Data Analysis

SGRE SCADA system includes 3 different wind farm data analysis tools:

- Reports: designed for exploitation reports
- Trending: designed for in-depth analysis of wind turbine variables.

Comparatives: designed for instantaneously comparing two variables of all the wind turbines in the farm.

## Codes and Standards

The wind turbine is designed and certified with an external certification body according to:

- IEC 61400-1:2005 +AMD1:2010 Edition 3 - Wind turbines - Part 1: Design requirements
- IEC 61400-22:2010 Edition 1 - Wind turbines – Part 22: Conformity testing and certification
- ISO 9001:2015 - Quality management systems – Requirements.
- Directive 2006/42/CE - Machinery (MD)

## Other Performance Features

Siemens Gamesa Renewable Energy (SGRE) offers the following optional performance features for SG 5.0-145 that can optimize your wind farm by boosting performance, enhancing environmental agility, supporting compliance with legal regulation, and supporting grid stability.

### Flexible Rating

In order to have the best product and solution for our clients, the SG 5.0-145 wind turbine is designed to integrate the OptimaFlex philosophy: a design strategy that provides a high degree of adaptability, including several power rating options and possibilities for tower optimization.

Inside the OptimaFlex philosophy, Flexible Rating strategy has been designed to allow modifying the turbine rated power depending on project specific conditions related to temperature, electrical requirements and mechanical loads. This feature is optional and applicability depends on the fulfilment of the defined temperature, electrical and mechanical loads requirements.

The SG 5.0-145 wind turbine can be configured to operate with a flexible power rating, enabling site specific optimization. It is designed to work at 5.0 MW rated power as baseline, but additional ratings are also available under certain project and environmental conditions.

In the SG 5.0-145 Flexible Rating strategy, different Application Modes (AM) with different power ratings are available. Each Application Mode is associated with a specific set of performance conditions.

Flexible Rating application procedure and concept:

- Upfront analysis: If Flexible Rating optional strategy wants to be enabled, an upfront analysis is needed for each project in order to define which is the maximum Application Mode admissible considering the specific site mechanical loads and general grid requirements.
- Wind turbine operation: Flexible Rating controller algorithm dynamically defines which is the active power than can be delivered depending on the ambient temperature and grid demands, always limited by the maximum Application Mode defined in the upfront analysis for each site. Temperature and reactive power demand is prioritized. If grid demands higher reactive power (Q) than the one allowed for an AM, active power (P) will be decreased.

In the following table, a summary of the SG 5.0-145 Flexible Rating strategy is presented.

| AM         | Rated power   | Wind Conditions [1]            | Maximum Temperature (full power operation) [2] | Maximum Temperature (with power derating) [3] | Electrical performance limits             | Maximum Noise Emission level [dB(A)] [4] |
|------------|---------------|--------------------------------|--|---|---|--|
| AM+1       | 5.2 MW        | Less demanding wind conditions | +20.0°C  | +45°C   | cos PHI 0.95 @[0.95,1.12]Un @±2%frequency | 106.3                                    |
| <b>AM0</b> | <b>5.0 MW</b> | <b>IIB</b>                     | <b>+25.0°C</b>                                 | <b>+45°C</b>                                  | cos PHI 0.9 @[0.95,1.12]Un @±3%frequency  | <b>106.3</b>                             |
| AM-1       | 4.9 MW        | More demanding wind conditions | +30.0°C  | +45°C   |   | 106.3                                    |
| AM-2       | 4.8 MW        |                                | +35.0°C  | +45°C   |   | 106.3                                    |
| AM-3       | 4.7 MW        |                                | +36.6°C  | +45°C   |   | 106.3                                    |
| AM-4       | 4.6 MW        |                                | +38.3°C  | +45°C   |   | 106.3                                    |
| AM-5       | 4.5 MW        |                                | +40.0°C  | +45°C   |   | 106.3                                    |
| AM-6       | 4.2 MW        |                                | +41.0°C  | +45°C   |   | 106.3                                    |
| AM-7       | 4.0 MW        |                                | +41.6°C  | +45°C   |   | 106.3                                    |
| AM-8       | 3.0 MW        |                                | +44.0°C  | +45°C   |   | 106.3                                    |

[1] Each “Application Mode” is associated with a specific set of wind conditions.

[2] Maximum external ambient temperature outside nacelle, for altitudes below 1000m, full power operation.

[3] Maximum external ambient temperature outside nacelle, for altitudes below 1000m, with power derating. Operation maximum temperature is extended up to +45°C including “Power Derating due to external ambient temperature and altitude” feature. See section “Other Performance Features” for further information.

[4] Noise values presented correspond to the wind turbine configuration equipped with noise reduction add-ons attached to the blade. The turbine can be supplied without noise reduction add-ons, if required, without impacting in the other performance parameters.

**DFIG Premium Converter**

The DFIG Premium Converter improves turbine performance in weak grids and assures compliance with the most stringent grid codes. It has an enhanced control in weak grids, regulating the behavior of the wind turbine and reacting to static and transient events while ensuring grid stability.

Optional functionalities available upon request to ensure optimal suitability to site conditions:

- Extended High Voltage Ride Through.
- Enhanced Low Voltage Ride Through
- Series Compensation Compatibility.
- Anti-islanding.
- Turbine operation in grids with Short Circuit Ratio (SCR) as low as 1.5.

| Concept                           | Description  | Premium Converter |
|-----------------------------------|--|-------------------|
| HVRT Extended                     | Extended HVRT profile (from 1.1pu to 1.5pu)                | ✓                 |
| LVRT Enhanced                     | Reactive current control in asymmetrical faults            | ✓                 |
| Series Compensation Compatibility | Control of Sub-Synchronous resonance events                | ✓                 |
| Anti-islanding                    | Detection of islanding events and controlled disconnection | ✓                 |
| Low SCR* (<3)                     | Operation in weak grids                                    | ✓                 |

\*SCR at turbine connection point is subject to grid conditions at project site.

**High Wind Derated operational mode**

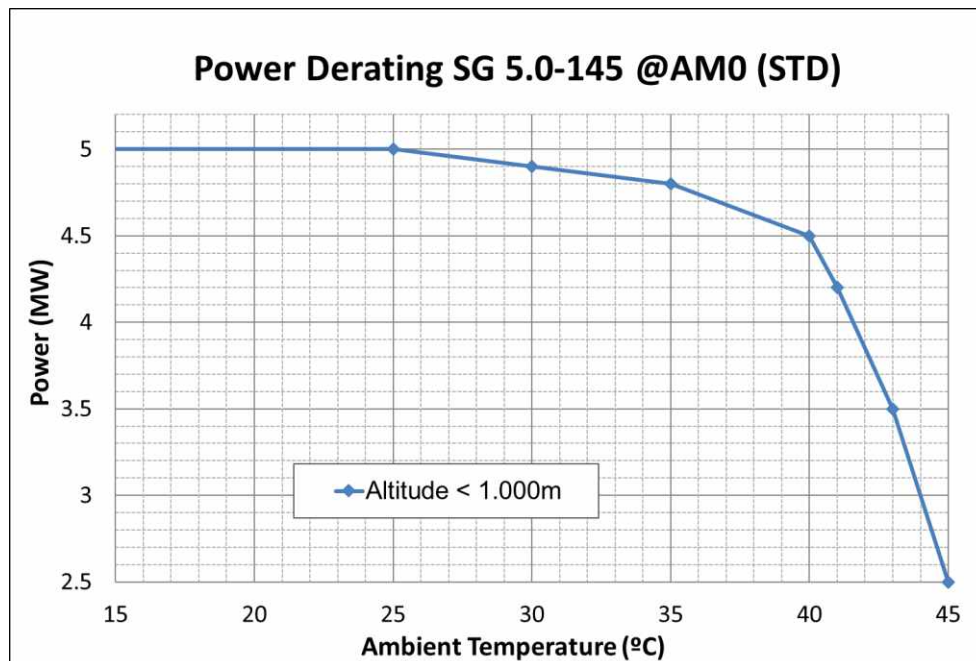
In the case of SG 5.0-145 high wind derated mode, it is enabled by default as it can be observed on the different power curves included in this document. The power production is limited once the wind speed exceeds a threshold value defined by design, until cut-out wind speed is reached and the wind turbine stops producing power. This functionality extends the range of operation in high wind conditions, limiting turbine loads dependent of maximum operational wind speed, providing more predictable energy output, minimizing production losses, and improving grid stability by reducing the risk of simultaneous power cut outs.

## High Temperature Derated operational mode (also known as Power Derating due to external temperature and altitude)

Ventilation and cooling systems are designed to allow the turbine operation at rated power up to a certain external nominal temperature and a certain altitude. For sites located beyond 1000m above the sea level, the air density reduction affects the turbine components ventilation capacity, reducing the maximum operational temperature at rated power. However, this maximum ambient temperature can be extended by reducing the delivered power with the temperature derated mode.

Considering the individual component requirements in temperatures at different altitude levels, and their dissipated heat at different power limits, several power-temperature curves are generated. These curves define the envelopes inside which the SG 5.0-145 can operate assuring the integrity of all components.

Next chart shows the power output as a function of the external temperature for an altitude at hub height of up to 1.000m (AM0). Additional information about other altitudes or Application Modes (AM) is available upon request.



The control system, considering the turbine thermal variant and altitude above sea level, will dynamically adjust the maximum allowed power as a function of the ambient temperature.

## Ice Detection System

A default Ice Detection System (IDS) is included in SG 5.0-145. This system is required in order to prevent the turbine operating under non desirable ice conditions that could represent an out-of-design situation with risk for the turbine integrity or H&S.

The default Ice Detection System can be improved by application of additional features, described as follows:

- Ice on nacelle sensor (optional kit). Additional sensor is installed to detect ice on nacelle.

## **Adaptative Operation under ice conditions (comercially presented as “OWI 2.0”)**

An optional controller algorithm is available in the SG 5.0-145 to improve performance under ice conditions without requiring additional hardware modifications.

In the case of ice build up on blades, the wind turbine performance is reduced and blades can be under stall conditions. The basis of this algorithm is to have an adaptative operation that finds the optimal operational setting through pitch angle and rotational speed modifications, for maximum power production on icing conditions without exceeding the load capabilities of the wind turbine.

## **Noise Reduction System**

The Noise Reduction System (NRS) is an optional module available with the basic SCADA configuration and it therefore requires the existence of a SGRE SCADA system to work.

The purpose of this system is to limit the noise emitted by any of the functioning turbines and thereby comply with local regulations regarding noise emissions. This allows wind farms to be located closer to urban areas, limiting the environmental impact that they imply.

## **Bat Protection System**

To support the installation of wind turbines in areas that constitute a natural habitat for bats, SGRE has developed a Bat Protection System. Bats are usually more active at certain times of the night and at certain times of the year, depending on the local habitat and/or migration routes. The purpose of the SGRE Bat Protection System is to monitor the local environmental conditions in order to reduce the risk of impact on bats.

Specific environmental conditions can be monitored by means of dedicated additional sensors: temperature, light, humidity and rainfall. If conditions for the existence of bats are met, the Bat Protection System tool will request the wind turbines to be paused. As soon as one of the conditions is no longer met, the affected wind turbine will return to its initial status prior to receiving the pause order from the tool, depending on the configured hysteresis values.

The tool does not require all the sensors associated with the conditions to be installed and, depending on each site, the sensors needed will be configured. If there is no sensor for a specific environmental variable, condition is configured as fulfilled.

Additionally, Bat Protection System can be configured to be triggered depending on calendar (day/time), wind speed range or wind direction.

## **Bird Detection System**

The Bird Detection System is a stand-alone system that monitors the wind farm's surrounding air space and detects flying birds in real time. At the same time, it is capable of handling real-time actions related to bird detection, such as warning and deterring birds at risk of colliding with the wind turbines or automatic shutdown of the selected wind turbines.

## Modular configurations

To support the transportation of main nacelle components in markets with special logistic requirements, the Siemens Gamesa 4.X platform is designed with a wide range of modular transportation alternatives to fit optimally with the project's height and/or total weight limitations for components, providing the best possible approach for transportation by sea, road or railway.

## Fire protection system (Standard)

The SG 5.0-145 is equipped by default with different sensors directly or indirectly involved in fire detection and prevention. These sensors connected to the turbine controller will trip the medium voltage switchgear, disconnecting the wind turbine from the grid. These switches will detect arcs in the transformer compartment, faults to earth which trip the neutral protection relay, smoke in the nacelle room and in the tower base, transformer fuses melt or high temperature in the transformer windings.

In addition, arc detectors are placed in the transformer room and passive fire protection blankets (wool rock isolation covered by aluminum fiber) are installed.

## Optional Active Fire Extinguishing System

This system combined with the passive protection system minimizes the threat of fire and prevents its propagation. The Active Fire Extinguishing System also works when the wind turbine is stopped or even when the wind farm has no energy supply.

The detection is carried out by means of high-efficiency aspirating detectors (ASD) which constantly absorb air samples from inside the nacelle and the electrical cabinets and transport them through a piping network until the analysing chambers, in order to take the reading of existing smoke concentration in the air. Depending on the different readings and according to the pre-established comparison levels, the corresponding alarm signals will be activated.

Fire detection is done at a very early stage so that preventive measures can be taken on time to abort it.

The alarm communications are sent through electrical signals to the control system of the wind turbine (PLC) and through optical-acoustic devices.

The extinguishing system discharges a fire protection agent applied as a gas through a nozzle to the electrical cabinets. This extinguishing agent offers a unique combination of safety, low environmental impact and high extinguishing performance.

## Automatic lubrication systems

An optional Automatic Lubrication System may be provided for several turbine components such as the blade bearings, the low speed shaft bearings, the generator bearings and the yaw system.

The lubrication systems consist of an electrically driven pump, which supplies grease to the turbine components to increase the time between greasing maintenance operations.



---

## **2.2. CARACTERÍSTICAS DE VIALES Y PLATAFORMAS APARA AEROGENERADORES SG 6.6 170**

(Utilizadas como base para la obra civil del proyecto.)

# Site Roads and Hardstands

## SG 6.6-170

| Document ID and revision | Status | Date (yyyy-mm-dd) | Language |
|--------------------------|--------|-------------------|----------|
| D3120697/004             | Draft  | 2022-03-01        | en-US    |

Original or translation of

Original

File name

D3120697\_004-SGRE ON SG 6.6-170 Site Roads and Hardstands.docx/.pdf

Updates made since the previous revision

Update of hardstand gradients in section 3.2.4.  
Change of T145&T150 main crane boom assembly area length.  
Actualization of minimum supported load values with mounted crane movement in Section 3.1.3.  
Added comment from BoP in reference to the possibility of adapting to local standard sections 3.1.2., 3.1.8.& 5.2.  
Added comment from BoP in reference the obligatoriness of maintaining text in corresponding sections.  
Construction comment added in section 1. regarding the obligatoriness of respecting minimum values.  
Logistic comment in section 3.1.4., 3.1.5., 3.1.6. & 3.1.7 in reference to the need to validate inputs by local team.  
Update of hardstands layouts legends in section 3.2.5.  
Inclusion of comments about the minimum features required for the blade storage area in section 3.2.5.  
Definition as SGRE Standard Strategy 4 in section 1.  
Addition of section 5.4. Additional documentation

Applicable Siemens Gamesa 5.X Product Variants

SG 5.X-170

Siemens Gamesa Renewable Energy S.A. Parque Tecnológico de Bizkaia, Edificio 222, 48170, Zamudio, Vizcaya, Spain  
+34 944 03 73 52 – info@siemensgamesa.com – www.siemensgamesa.com

### Disclaimer of liability and conditions of use

To the extent permitted by law, neither Siemens Gamesa Renewable Energy A/S nor any of its affiliates in the Siemens Gamesa group including Siemens Gamesa Renewable Energy S.A. and its subsidiaries (hereinafter "SGRE") gives any warranty of any type, either express or implied, with respect to the use of this document or parts thereof other than the use of the document for its intended purpose. In no event will SGRE be liable for damages, including any general, special, incidental or consequential damages, arising out of the use of the document, the inability to use the document, the use of data embodied in, or obtained from, the document or the use of any documentation or other material accompanying the document except where the documents or other material accompanying the documents becomes part of an agreement between you and SGRE in which case the liability of SGRE will be regulated by the said agreement. SGRE reviews this document at regular intervals and includes appropriate amendments in subsequent issues. The intellectual property rights of this document are and remain the property of SGRE. SGRE reserves the right to update this documentation from time to time, or to change it without prior notice.

Table of contents

1. Aim and scope .....3

2. Definitions and acronyms .....5

3. Description .....6

4. Additional documentation .....30

5. Annexes .....31

## 1. Aim and scope

The aim of this specification is to describe the requirements of the roads and hardstands required for a safe component transportation and assembly of the wind turbines. These requirements must be revised and adapted by the SGRE local teams, always respecting the limitations set for each parameter. Additionally, it includes the minimum deliverables that will be needed from SGRE to start with the transportation and erection works. The scope includes all W.F. with the following WTG models and erection strategies:

| Tower  | No. of tubular steel section | Power | Blade |
|--------|------------------------------|-------|-------|
| T100   | 4                            | 6.6   | SG170 |
| T110.5 | 6                            | 6.6   |       |
| T115   | 5                            | 6.6   |       |
| T135   | 6                            | 6.6   |       |
| T145   | 6                            | 6.6   |       |
| T150   | 7                            | 6.6   |       |
| T155   | 7                            | 6.6   |       |
| T165   | 8                            | 6.6   |       |
| T165MB | 2                            | 6.6   |       |

Table 1. WTG models

| Tower  | STG3 | STG4<br>(SGRE Standard) |
|--------|------|-------------------------|
| T100   | ✓    | ✓                       |
| T110.5 | ✓    | ✓                       |
| T115   | ✓    | ✓                       |
| T135   | ✓    | ✓                       |
| T145   | ✓    | ✓                       |
| T150   | ✓    | ✓                       |
| T155   | ✓    | ✓                       |
| T165   | ✓    | ✓                       |
| T165MB | ✓    | ✓                       |

Table 2. SGRE strategies








| Strategy                        | Nacelle   | DT  | Hub  | Blade  |
|---------------------------------|---|---|--|--|
| <b>Strategy 3</b>               | <b>Modular</b><br> | <b>DT/Hub</b><br> |  | <b>Blade To Blade (SBI)</b><br> |
| <b>SGRE Standard Strategy 4</b> | <b>Modular</b><br> | <b>DT</b><br>      | <b>Hub</b><br> | <b>BladeTo Blade (SBI)</b><br>  |

Table 3. Components of each strategy

This document should be used either adding the project specific requirement in external notes or as a base for a complete project specific requirement. In both cases the parameters/ texts set as minimum must be respected.

Note:

This specification sets a guide to be followed for the design and construction of a wind farm civil engineering project. The project undertaken in accordance with this specification must be reviewed and approved by SGRE prior to execution. However, the civil designer is solely responsible for making sure that the design complies with this specification, the contract requirements and local norms and standards.

## 2. Definitions and acronyms

| Acronyms                 | Definition  |
|--------------------------|---|
| SGRE                     | Siemens Gamesa Renewable Energy   |
| Main crane               | Capable of lifting each component to its position in the wind turbine.  |
| Pre-installation crane   | Used for installing elements at the lower part of the tower.  |
| Tailing crane            | Supports the main and pre-installation crane for mounting and unloading components.   |
| Mobile crane             | Telescopic mobile crane   |
|                          | Lattice boom mobile crane   |
| NTC                      | Narrow-Track Crawler Crane  |
| WTC                      | Wide-Track Crawler Crane  |
| Intermediate hardstand   | The work area for wind turbine assembly is parallel and close to the internal roads of the wind farm.                                 |
| End-of-road hardstand    | Work area for wind turbine assembly at the end of an internal wind farm road.   |
| Wind farm access roads   | These roads do not pass by asphalt roads and they are used to transport components and disassembled cranes.                           |
| Wind farm internal roads | Roads that pass between wind turbines for the transportation of components/crane and if required with the capacity for moving cranes. |
| SP                       | Standard Proctor  |
| MP                       | Modified Proctor  |
| WTG                      | Wind Turbine Generator  |

Table 4. Acronyms and definitions

## 3. Description

### 3.1. Roads

#### 3.1.1. Reference legislation

The legislation of the corresponding country on the design of civil engineering must be applied. If there is no such legislation, the legislation given as a reference in section 5. Annexes should be followed as a guide.

#### 3.1.2. Design of the windfarm internal roads

In case there is no legislation for the road design the dimensioning of the road pavement should be based on the AASHTO method for roads with a low volume of traffic (Part 2, Chapter 4). This methodology is based on an empirical formula that relates the characteristics of the pavement layers with their performance, in order to determine whether the road pavement section will be capable of bearing the traffic loads to which it will be applied.

The design of the road and the geotechnical report will be provided to Siemens Gamesa together with the quality control of the roads during the handover of the civil works and before starting with the transportation and the erection process.

This text (3.1.2.) must be kept intact in the project specific requirements and can only be adapted to the local standard, if any, for these specific low volume roads.

#### Road composition and structure

Wind farm access roads must support a **minimum load** of 12t per axle corresponding to the transportation of wind turbine elements and crane elements.

Internal wind farm roads must support a **minimum load** of:

- Without mounted crane movement:
  - 1.4 kg per cm<sup>2</sup> in the case of crawler cranes (NTC and WTC).
  - 22.5t per axle in the case of mobile cranes.
- With mounted crane movement:
  - 2.45 kg per cm<sup>2</sup> in the case of crawler cranes (NTC and WTC).
  - 22.5t per axle in the case of lattice boom mobile cranes.
  - 24.5t per axle in the case of telescopic mobile cranes.
  - 14.7t per axle in the case of pre-installation telescopic mobile cranes.

The dimensions of the roadbed must be in accordance with the number of WTGs at the wind farm, allowing for the number of transport vehicles per WTG.

Tests must be carried out on the material used for the subgrade and for the roadbed, in order to control the compaction of the different layers and ensure that the civil works are correctly executed. The quality control and the requirements for the civil works design is defined according to the **5.2 Quality tests and requirements for civil works plan projects**.

Suitable compaction means must be used to find a subgrade of enough elasticity modulus value. The elasticity module will be measured from the compressibility module of the second cycle of the loading plate test as per DIN 18134 (or in its absence, NLT-357), the acceptance criteria will be indicated in the road section design.

The dry density required after compaction for the different types of materials forming the roadbed is 98% of that obtained in the Modified Proctor (MP) test or above.

Fill material will be compacted in layers to a maximum thickness of 30 cm to ensure the effectiveness of the machinery along the entire section.

Where expansive material (expansive clay, etc.) or loose soil conditions are indicated in the geotechnical report, the use of geosynthetics is strongly recommended (at least with the soil reinforcement and separation functions).

The elasticity module of the finished roadbed must be measured based on the compressibility module of the second cycle of the load plate test as per DIN 18134 (or in its absence, NLT-357), and the result must never be less than  $E_{v2}=80$  MPa (\*). Likewise, the relation between the first and second load cycle must be less than 3.

(\*) In countries where the load plate is not usually used, use the following relationship to obtain the acceptance criteria for the roadbed built:

$$E = \frac{\pi \cdot (1 - \nu^2)}{3} \cdot E_{v2}$$

- E: elasticity module
- $\nu$ : Poisson's ratio
- $E_{v2}$ : second plate loading test cycle compressibility module

Additionally, the dry density compaction level for the different types of materials forming the roadbed will be 98% of the MP test result or above.

This text must be kept intact in the project specific requirements. If the text cannot be kept, please contact the BOP Technical Office.



### 3.1.3. Road width

The road width will vary for curves according to the following section 3.1.5. Curve widening – General.

| Minimum road width  |  |
|---|--|
| <b>A. Wind farm access road transportation of components</b>  | <p><b>As a minimum and usable 4.5m<sup>(**)</sup> + 2 x 0.50m of obstacles in straight sections.</b></p> <p><b>As a minimum and usable 5.0m<sup>(**)</sup> + 2 x 0.50m free of obstacles in curves.</b></p> <p><b>As a minimum and usable 5.5m<sup>*</sup> + 2 x 0.50m free of obstacles in case of reverse driving.</b></p> |
| <b>B. Internal wind farm road with crane movement</b>   | <p><b>Pneumatic Crane</b></p> <p><b>As a minimum and usable 4.5m + 2 x 0.75m free of obstacles</b></p>   |
|   | <p><b>WTC</b></p> <ul style="list-style-type: none"> <li>Usable 12 to 14m<sup>*</sup></li> <li>4m + 3m parallel tread (making 12 to 14 m)</li> </ul>   |
|   | <p><b>NTC</b></p> <p><b>As a minimum and usable 7m</b></p>   |
| <b>C. Access road to the wind farm Transportation of components and Internal roads of the wind farm without crane movement. (Wind Farms in the United States)</b> | <p><b>As a minimum and usable 5m + 2 x 0.8m free of obstacles</b></p>  |

Note:

**Usable m (meters) - Space capable of bearing the loads to which the road will be submitted without the risk of caving-in, sliding or sinking. Furthermore, the last 50cm prior to the curbs on these roads (not included in the usable meters) are not valid for withstanding weights, due to the danger of horizontal creep of the ground. Thus, the carrier transporting the nacelle and heavy haulers in general must never go beyond these limits under any circumstances whatsoever.**

**This table marks the minimum requirement for the road width as general.**

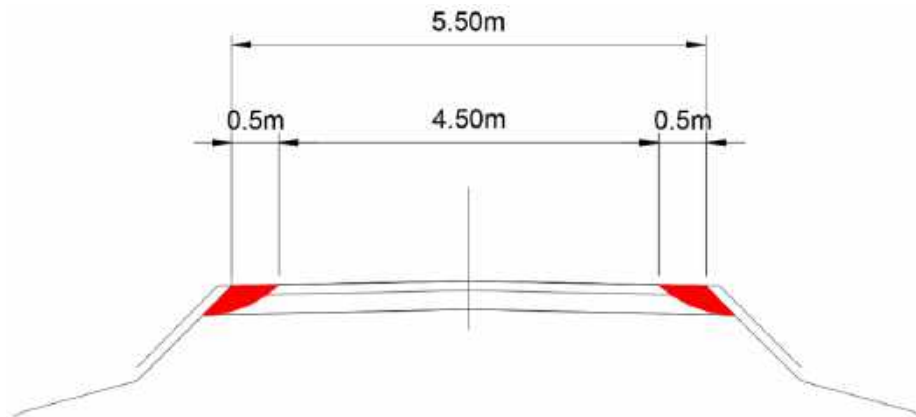
**There may be more limitations on the use of road width project specific. On the one hand, the safety distances or calculation limitations on the edge of high embankments and on the other hand, the possibility of splitting the road into two parts for crawling with WTC cranes. These should be mentioned by the wind farm designer.**

\*Width based on crane model

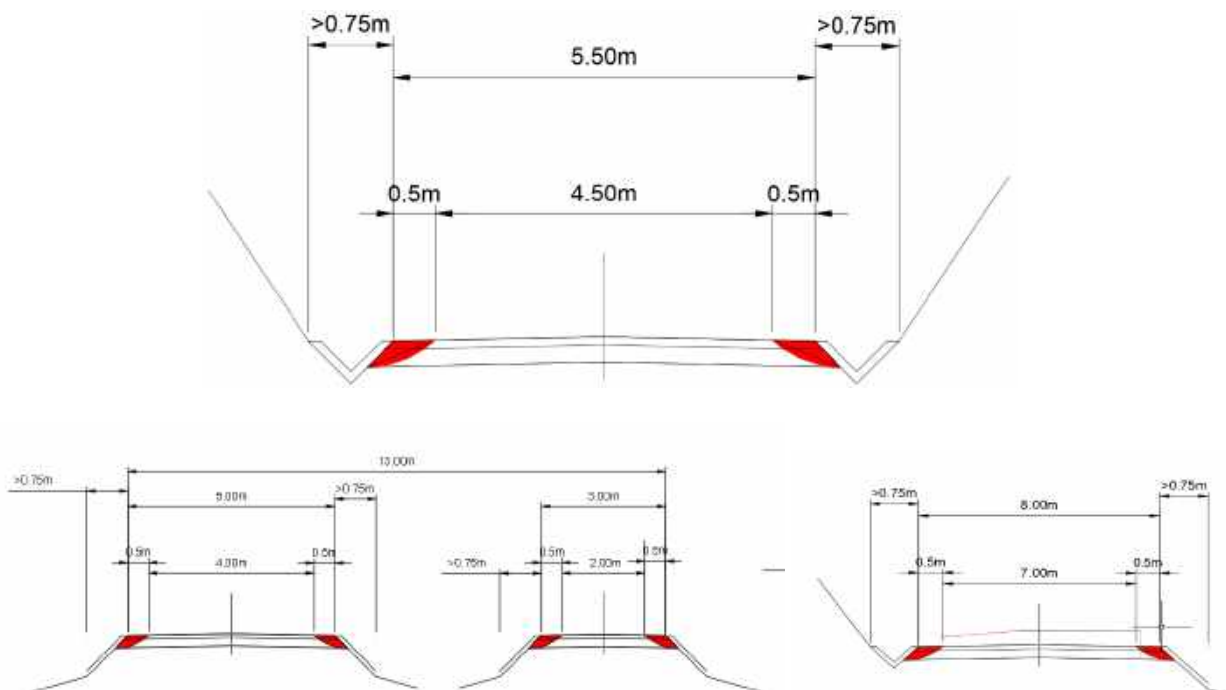
(\*\*) The minimum useful width to assure a safe transportation of the wind turbine components must be 4.5m on straight and 5.0m in curves. In the case of not being able to meet the minimum width depending on the characteristics of the site and the availability of transport equipment for cost optimization, environmental issues, or others, this should be agreed between the SGRE's customer, the own SGRE Local and the transport company awarded the project. Regarding the usable width in curves, a new turning radius study should be carried out by SGRE Local.

Table 5. Minimum road width in access and internal roads

### A. Wind farm access road Transportation of components



### B. Internal wind farm road with crane movement



### C. Access road to the wind farm. Transportation of components and Internal wind farm road without circulation of cranes (e.g wind farms in the United States)

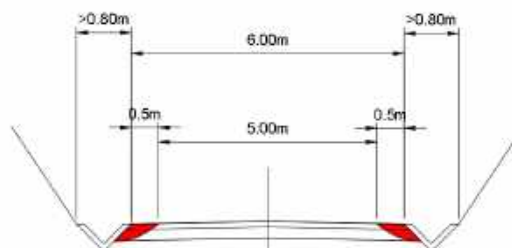


Figure 1. Minimum road width in access and internal roads

For curves with an interior cleared profile, the inside curb of the curve must be pipelined or have a maximum depth of 10 cm.

The slope of cutting on internal roads must be limited in accordance with the wind farm's geotechnical survey and determined by the crane being used for assembly. The most restrictive case is movement of NTC without dismounting.

This section (3.1.3) cannot be removed in the project specific requirements, in case it does not apply it will be indicated as such.

### 3.1.4. Curve widening – General

The smaller the curve radius of the alignment curve, the greater the road width must be (difference between outside and inside radius) at the curve.

Blade transportation is considered a limiting element in the calculation of curve widening.

The following example table is completed for each model with these widths:

- A: Road width
- SAE: Exterior widening
- SAI: Interior widening
- De: Entrance widening development
- Ds: Exit widening development

| RADIUS - ANGLES |     |     |     |     |     |
|-----------------|-----|-----|-----|-----|-----|
|                 | 90° |     |     |     |     |
|                 | A   | SAe | SAi | De  | Ds  |
| R35             | 7   | 24  | 11  | 1   | 20  |
| R40             | ... | ... | ... | ... | ... |
| R45             | ... | ... | ... | ... | ... |



Figure 2. Curve widening

The conclusions of the study will be reflected in a table where:

- A: Road width
- SAI: Is the maximum interior sweep of the vehicle or its cargo
- SAe: Is the maximum exterior sweep of the vehicle or its cargo
- R35: Represents the radius curve at the centre of the road
- 60°: Represents the angle formed by two straight sections of road joined by a curve of a given radius
- De: Distance from the first point of tangency to the beginning of the widening
- Ds: Distance from the end of the widening to the second point of tangency

The transport vehicles used to transport various components of the turbine up to the site should be equipped with self-steering rear axles in those countries and projects where this type of equipment is feasible.

A study for guidance was made taking in to account an estimate vehicle (General vehicle). Each region will provide a study of curve radius with its most restrictive vehicles. As an example in the **5.1 Transport requirements**, the general results analysis for turbine model is included. This example should not be used as the values are not updated.

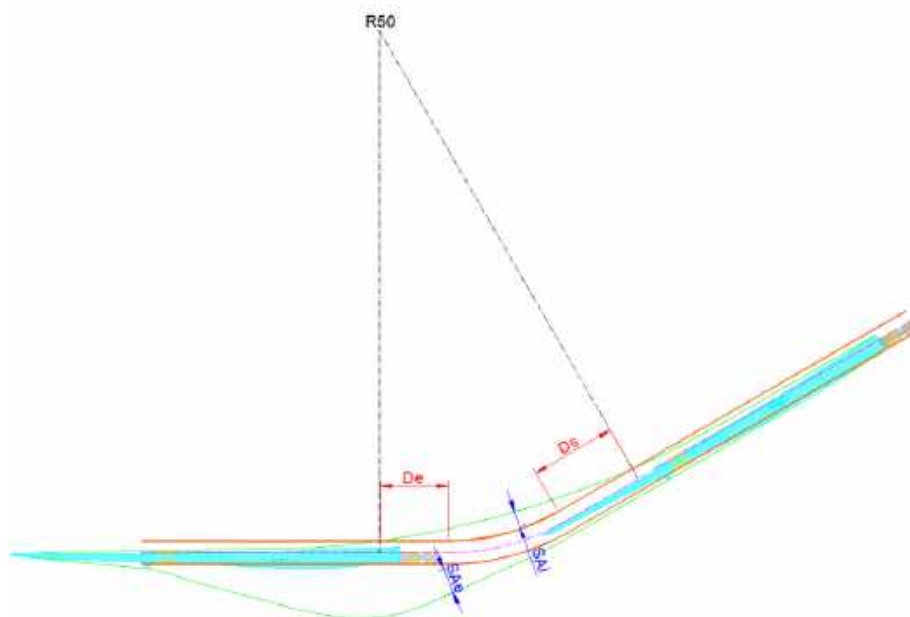
SGRE local team shall confirm/validate or update the data included in the generic specification where estimated theoretical vehicles have been considered against planned vehicles to be contacted for each specific project.

Besides, per each specific project, inner and outer widening for each curve along the route should be studied per transport simulation.

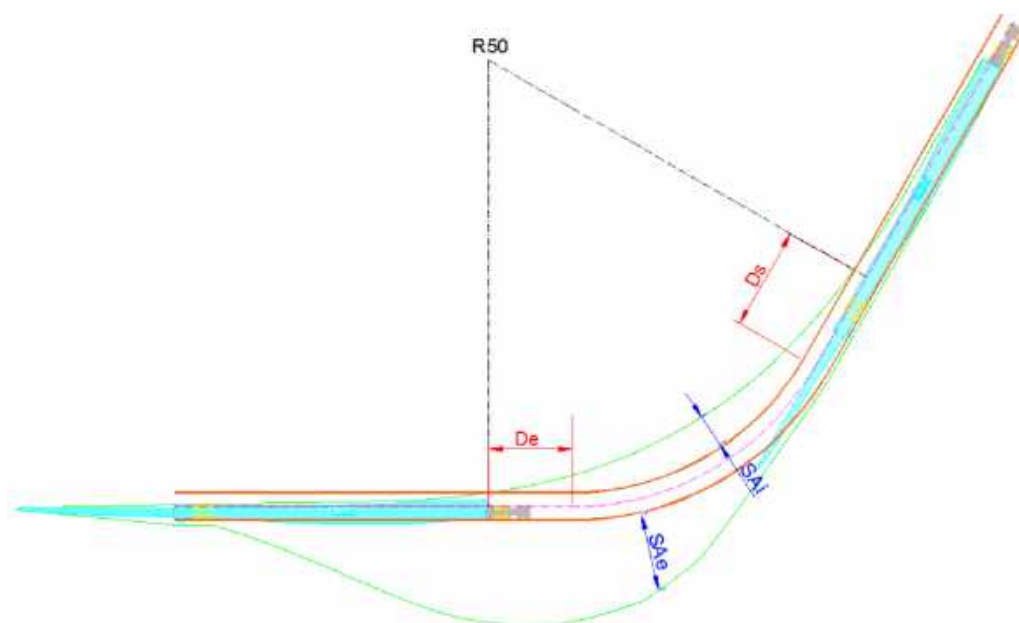
SGRE has available curve widening table for each region with a generic transport, which should be validated project by project.

Below are three examples to follow for the definition of curve widening. Final drawings are to be submitted by the region.

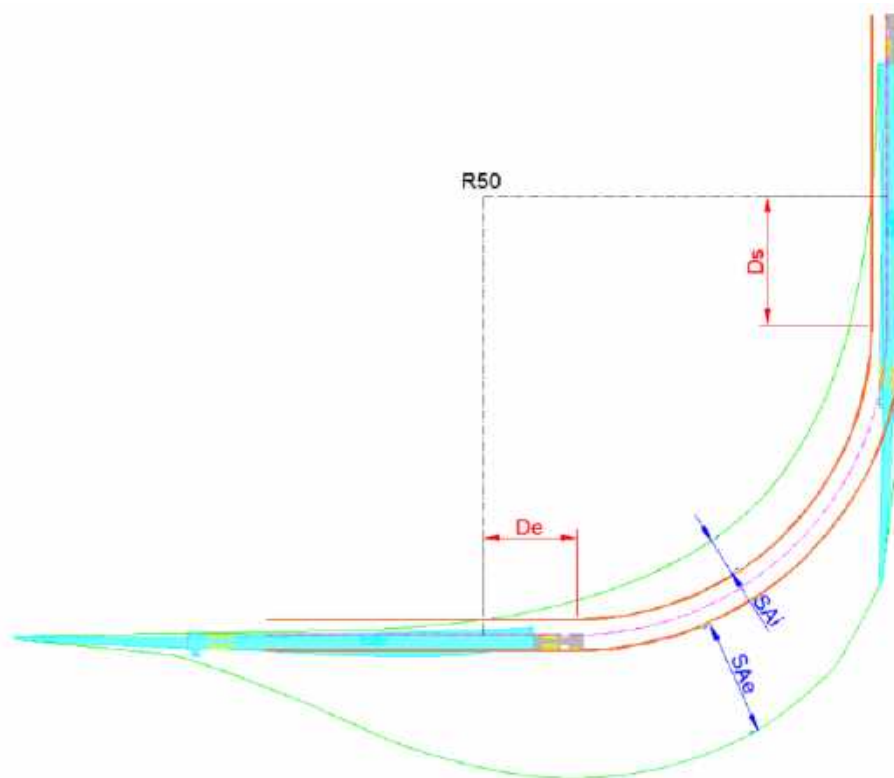
- **SG 170 Alineación a 30° y Radio 50m:**



- **SG 170 Alineación a 60° y Radio 50m:**



- **SG 170 Alineación a 90° y Radio 50m:**



This section (3.1.4) cannot be removed in the project specific requirements, in case it does not apply it will be indicated as such.

### 3.1.5. Gradients and grade changes

SGRE local team shall confirm/validate or update the data included in this document where estimated theoretical vehicles have been considered against planned vehicles to be contacted for each specific project.

The below values are to be confirmed by the region project by project.

|   | Longitudinal Gradients (%)  |   |                  |                | Transversal Gradients (%) |         |
|---|---|---|------------------|----------------|---------------------------|---------|
|   | Maximum   |   | Minimums         |                | Maximum                   | Minimum |
|   | Straight section  | Curved section  | Straight section | Curved section | Straight/ curved section  |         |
| <b>Wind farm access road and internal wind farm road</b>  | >10 and ≤13 without concreting if gradient < 200 m. <sup>(1)</sup>            | Up to 7 without concreting <sup>(1)</sup>               |                  |                |                           |         |
|   | >10 and ≤13 improved concreting or paving if gradient > 200 m. <sup>(1)</sup> | >7 and ≤10 improved concreting or paving <sup>(1)</sup> | 0.50             | 0.50           | 2                         | 0.20    |
|   | >13 and ≤15 improved concreting or paving + 6x6 tractor unit                  |   |                  |                |                           |         |
|   | >15 need for towing study   | >10 need for towing study                               |                  |                |                           |         |
| <b>Access and internal roads reverse driving</b>  | ≤ 3 up to a max. of 1000 m without concreting.                                | <2 up to max. 500 m without concreting.                 | 0.50             | 0.50           | 2                         | 0.20    |
|   | >3 and ≤5 max. 1000m improved concreting or paving                            | ≥2 and ≤3 max. 500 m improved concreting or paving      |                  |                |                           |         |
| (1) SGRE standard values are ≤13 % for longitudinal gradients and <10 % for curved sections.<br>(2) Improved paving: Roadbed with friction coefficient of at least 0.35 |   |   |                  |                |                           |         |

Table 6. Gradients and grade changes

For gradients near 10% without concreting, 6 x 4 tractor units or four-wheel drive truck will be required.

In the specified cases in which road paving must be improved, the solution to be used and the envisaged friction coefficient must be submitted so that transport can be executed.

In the specified cases in which road paving must be improved, the technical characteristics of the solution to be used must be submitted, as well as the friction coefficient for the roadway layer envisaged for said solution, thereby ensuring that all components are transported correctly.

If the longitudinal gradient is  $>13\%$  and  $\leq 15\%$ , improved concreting or paving will be required, and a 6 x 6 tractor unit used. This means that the slope will also have to be reviewed since it is not within SGRE standards.

In the extreme case that a longitudinal gradient in a straight section is  $>15\%$  and/or is  $>10\%$  in a curved section, a towing study must be conducted in addition to improving the road paving along the affected section. This study must be conducted by the logistics company in charge of supplying the wind farm with the wind turbine components.

Regarding to guarantee the proper transitions between gradient changes, the minimum straight-line total length of the convoy must be kept in mind. According to the complexity of the wind farm project, these points must be analyzed and discussed to find the proper solution.



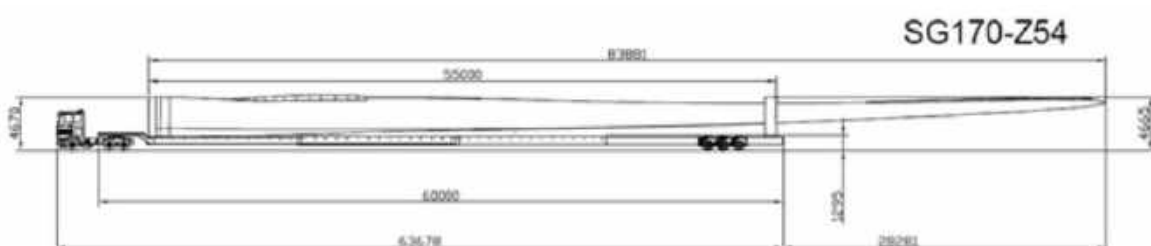
Figure 3. Transitions between gradient changes

For the calculation of the more restrictive KV that appears in this document, estimated generic vehicles have been considered. This does not mean that there are not others that improve or even worsen the KV figure. It is advisable to carry out a specific study in each region of the SGRE, with the vehicles planned to be used in local projects.

The KV value considered in the wind farm design for this WTG model shall be, **as a minimum**:

| Transport | Z54 | Dolly |
|-----------|-----|-------|
| Kv Value  | 690 | 610   |

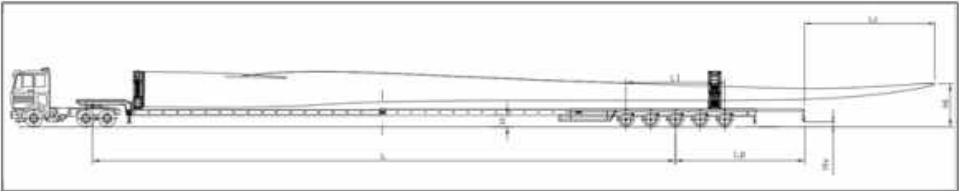
With the information we have now, **the most restrictive transport would be the SG170 blade on Z54 transport.** Bearing in mind that all the axles of the platform would be in contact with the ground. Considering that all the axles of the platform would be in contact with the ground and a rear overhang of 15,64m. Which of course will be different considering the restrictions of each country. The overhang may differ according to the restrictions of each country, which should be considered.



SIEMENS Gamesa

Reference: Blade SG170 254 in Lowbed  
Component: Blade  
Vehicle: Lowbed

Is any rear axle going to hang? No



| Drawing dimensions (m)                  |         |
|---|---------|
| L                                       | 53,16 m |
| H (When suspension is completely down)  | 0,51 m  |
| Lc                                      | 28,28 m |
| Lp                                      | 2,06 m  |
| L1                                      | 2,72 m  |
| H1 (When suspension is completely down) | 4,15 m  |
| Hv (When suspension is completely down) | 0,50 m  |

| Other inputs (cm)                  |       |
|------------------------------------|-------|
| Security distance (ground-vehicle) | 7 cm  |
| Rear Suspension (total)            | 20 cm |

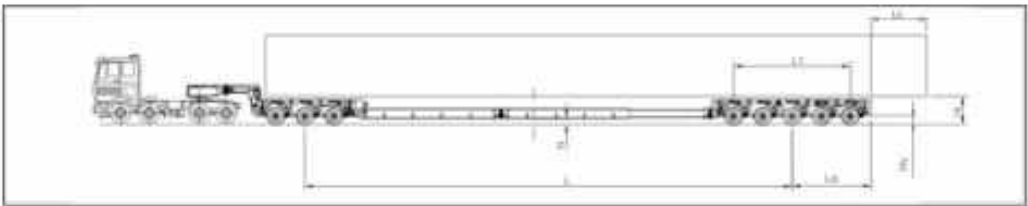
|              |       |
|--------------|-------|
| CALCULATE KV | 689 m |
|--------------|-------|

|  |  |       |
|--|--|-------|
|  | This KV is theoretical and only valid when the suspension of the vehicle, from its lower limit, is set on: |       |
|  | Rear   | Front |
|  | 15 cm  | -     |

Figure 4. The most restrictive transport and its respective KV

SIEMENS Gamesa

Reference: S4 T115-534  
Component: Tower section  
Vehicle: Modular



| Drawing dimensions (m)                  |         |
|---|---------|
| L                                       | 39,91 m |
| H (When suspension is completely down)  | 0,00 m  |
| Lc                                      | 0,00 m  |
| Lp                                      | 4,04 m  |
| L1                                      | 6,08 m  |
| H1 (When suspension is completely down) | 0,00 m  |
| Hv (When suspension is completely down) | 0,21 m  |

| Other inputs (cm)                  |         |
|------------------------------------|---------|
| Security distance (ground-vehicle) | 7 cm    |
| Front Suspension (total)           | 50,6 cm |
| Rear Suspension (total)            | 50,6 cm |

|              |       |
|--------------|-------|
| CALCULATE KV | 606 m |
|--------------|-------|

|  |  |       |
|--|--|-------|
|  | This KV is theoretical and only valid when the suspension of the vehicle, from its lower limit, is set on: |       |
|  | Rear   | Front |
|  | 40 cm  | 40 cm |

Figure 5. The most restrictive transport in dolly and its respective KV



The value above is for reference only, project value to be confirmed by the region. Depending on the complexity of the terrain, the KV value that minimizes LCoE (levelized cost of energy) might be higher (flat wind farm) or lower (mountainous wind farm). Prior to signing the contract, a specific study shall be done in order to define the proper KV for the wind farm, considering development constraints in force and locally available transports in order to adapt logistics means accordingly.

The specific study could include nonstandard solutions and extra resources for each solution.

The roads must be smooth, removing, as far as possible, any protrusions such as stones, rocks, etc., which could damage the nacelle hardstand or the tower sections and hinder transportation.

This section (3.1.5) cannot be removed in the project specific requirements, in case it does not apply it will be indicated as such.

### 3.1.6. Passing areas and turning points

Passing areas will be created at intervals of approximately 5 km, attempting to take advantage of the areas where there are less actions to be performed if possible and they must have an extra width of 5 m with a minimum length equal to the total length of the convoy ( $L_{tot}$ ) with a greater length. It is important to consider the entry and exit areas to facility access to the area. The waiting areas must be clear of any obstacle, levelled, compacted and drained. QHSE will determine the number of rest areas that must be created.

The turning points must be defined according with the maximum allowed reverse manoeuvre as described at the item **3.1.5 Gradients and grade changes**.

Where dead end roads are constructed or where loaded transports must turn around prior to delivery to the Installation Area, turning Areas are required to avoid long reverse driving. For each wind farm project, these points must be analysed to find the proper solution.

(Note) Truck length\* - The turning area will be different considering two situations: Loaded truck and empty truck. The additional area must be considered around the turning point - cleared of obstacles and levelled to allow oversail/overhang during transportation. The turning point could be adapted regarding the orography and/or complexity of the windfarm terrain, the new geometry must be approved by SGRE in order to comply with the transport requirements.

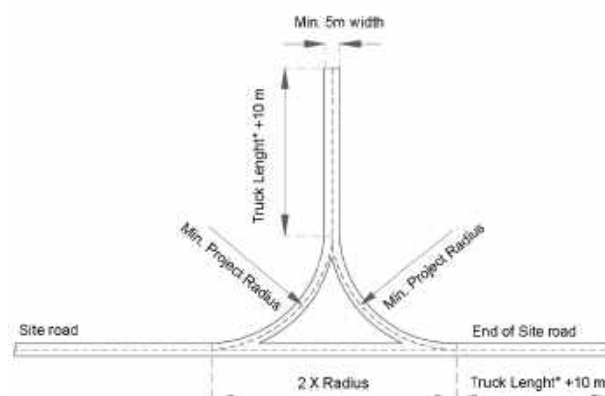


Figure 5. Turning point geometry suggestion

SGRE local team shall confirm/validate or update the data included in this document where estimated theoretical vehicles have been considered against planned vehicles to be contacted for each specific project.

These can be adjusted on project specific.

This section (3.1.6) cannot be removed in the project specific requirements, in case it does not apply it will be indicated as such.

### 3.1.7. Drainage

The surface drainage system must be of a size to collect any rainwater from the roadway layer as well as any water collected from small flows of runoff water intercepted by the road or even, where applicable, to provide continuity for any larger natural watercourses also intercepted. The calculation will be considered for a minimum return period of 25 years for transverse drainage and 10 years for longitudinal drainage works.

This text (3.1.7.) must be kept intact in the project specific requirements and can only be adapted to the local standard, if any, for these specific low volume roads.

## 3.2. Hardstands

The hardstands will include a crane work area and areas defined as storage areas. The main components will be stored on the storage area, and they will be hoisted by the cranes from the hardstand – crane work area, as a standard concept. Regarding the high-power and communications networks avoid placing them across the hardstand. If this cannot be avoided, then the network must be pipelined, and the pipes covered with concrete.

This text must be kept intact in the project specific requirements. If the text cannot be kept, please contact the BOP Technical Office.

### 3.2.1. Hardstand design

The design of the hardstand section must be done based on the geotechnical report and the load transferred by the crane support legs, also it must be considered the use of crane mats if any, under the crane support.

The structural verifications that must be performed and the criteria to be used is as follows:

- For the bearing capacity analysis, Meyerhof and Hanna (1978) methodology will be used.
- The safety factor for the verification of the bearing capacity will be 2, for both long term and short term.
- For the analytical calculation of the settlements, the Steinbrenner methodology will be used.
- The maximum differential settlement under the crane support leg will be 40 mm.

When it comes to unfavourable geotechnical conditions, in addition to the verifications carried out with analytical methodologies, described above, it will be necessary to develop a finite element model (FEM) to compare and contrast the results obtained with analytical methodologies.

The design of the hardstand and the geotechnical report will be provided to Siemens Gamesa together with the quality control of the hardstand, during the handover of the civil works and before starting with the erection process.

This text must be kept intact in the project specific requirements. If the text cannot be kept, please contact the BOP Technical Office.

### 3.2.2. Bearing capacity

|                           | Crane work area  | Component storage area | Boom assembly area |
|---------------------------|--|------------------------|--------------------|
| <b>SGRE standard</b>      | 2.5  | 2                      | 2                  |
| <b>Without crane mats</b> | 3 (T100)<br>3 (T110.5)<br>3 (T115m)<br>4 (T135m)<br>5 (T145m)<br>5 (T150m)<br>5 (T155m)<br>5 (T165m) | 2                      | 2                  |

Table 7. Load -bearing capacity (kg/cm2)

The composition of the crane work area must have a good subgrade,  $E_{v2}=60\text{MPa}$  or above. Transmitted loads must be  $2.5\text{kg/cm}^2$  (approx.  $0.2\text{MPa}$ ). A surface of  $30\text{ m}^2$  must be laid, 6 crane mats ( $5\text{ m} \times 1\text{ m}$ ) per crane leg or crane chain.

This text must be kept intact in the project specific requirements. If the text cannot be kept, please contact the BOP Technical Office.

If opting not to use crane mats, the necessary bearing capacity will be  $3\text{ kg/cm}^2$  for T100m, T110.5m and T115m,  $4\text{ kg/cm}^2$  for T135m and  $5\text{ kg/cm}^2$  for T145m, T150m, T155m and T165m tower models. The possible supply of crane mats is not included in the scope of SGRE, whereby if opting to use crane mats, the cost thereof shall be incurred by the Contracting Party.

### 3.2.3. Hardstand composition and structure

In the hardstand, the upper level of the subgrade must be above the highest foreseeable level of the water table. Where expansive material (expansive clay, etc.) or loose soil conditions are indicated in the geotechnical report, the use of geosynthetics is strongly recommended (at least with the soil reinforcement and separation functions).

The fill material will be compacted on the hardstands and in the storage areas in layers to a maximum thickness of 30 cm to ensure the effectiveness of the machinery along the entire section. The compaction level will be such that the dry density after compaction is 95% MP or higher. The elasticity module of the subgrade must be measured based on the compressibility module of the second cycle of the load plate test as per DIN 18134 (or in its absence, NLT-357), the acceptance criteria will be indicated in the hardstands section design.

Regarding the finished hardstand, the compaction level will be such that the dry density after compaction is 98% MP or higher. The elasticity module of the finished hardstand surface must be measured based on the compressibility module of the second cycle of the load plate test as per DIN 18134 (or in its absence, NLT-357), and the result must never be less than  $E_{v2}>80\text{ MPa}$ .

In case there is a doubt about the hardstand capacity, it will be necessary to execute at least one borehole, in the centre of the crane area, with core recovery and a depth of 8m. During the execution of the borehole, the following works should be conducted:

- SPT: from the surface where a test must be performed every meter.
- Extracting non-disturbed samples, plus laboratory test (triaxial tests or direct shear tests).
- Determining the ground water level depth, if encountered.
- Collect sampling for laboratory characterization of all the encountered materials.

The storage areas that are at the same level and position of the crane work area (for towers and nacelle), the requirements for the subgrade and finished layer are the same as above-mentioned. For the blade storage areas, the compaction level of the subgrade will be such that the dry density after compaction is 95% MP or higher. In case of need of granular layer, the compaction level will be such that the dry density after compaction is 98% MP or higher.

In case the subgrade of the storage areas is good enough to withstand the loads, no layer of granular material will be needed, but this must be justified accordingly in the design.

Tests must be carried out on the material used for the subgrade and for the roadbed, in order to control the compaction of the different layers and ensure that the civil works are correctly executed. The quality control and the requirements for the civil works design is defined according to the **5.2 Quality tests and requirements for civil works plan projects**.

Before the arrival of the transport vehicles and crane, the hardstand must be accepted by SGRE for the works to commence.

This text must be kept intact in the project specific requirements. If the text cannot be kept, please contact the BOP Technical Office.

### 3.2.4. Hardstand gradients

| Crane Type           | Hardstand gradients (%) |         |                        |         |
|----------------------|-------------------------|---------|------------------------|---------|
|                      | Crane work area         |         | Component storage area |         |
|                      | Maximum                 | Minimum | Maximum                | Minimum |
| NTC or Mobile cranes | 3                       | 0.2     | 2                      | 0.2     |
| WTC                  | 0.5                     |         |                        |         |

Table 8. Hardstand gradients

The minimum slope in the crane work area as well as the storage area is 0.2%, for the drainage of surface water; concave areas that may result in the formation of pools and the consequential drift of material under heavy loads cannot be accepted. Furthermore, take care that the hardstand or storage area surface must not drain off onto its access road.

### 3.2.5. Hardstand dimensions

Hardstand layout considers standard SGRE assembly strategy 4.

Foundation diameter subject to change. In case of using special foundation solution (uplifted, braced foundation, etc.), the hardstand dimension must be evaluated and approved by specific study.












(Note) – Following hardstand layouts covering tailing crane offloading and self-offloading transports

Use of clamp system doesn't require cranes for off-loading but additional space for manoeuvring of trailers to release the tower sections is needed. The system is not available for all regions and must confirmed by SGRE before building the windfarm. Bear in mind, once chose the hardstands without to consult or to require a confirmation from SGRE, the decision is responsibility of the civil designer. The different concept reflects an impact in hardstand layout, assembly phase and costs. Unusual situations must be evaluated and approved project specific.

Position of blade fingers is depending on location of transport equipment (TEQ) on blade -> Use of TEQ concept and/or positioning on blade might be different per region. Final location of blade fingers must be evaluated and approved project specific.

| Area | Description   |
|------|---|
| q1   | Hardstand for main crane  |
| q2   | Hardstand for assistant crane   |
| q3   | Storage area for containers and miscellaneous items                                   |
| q4   | Blade storage area (including the blade fingers position)                             |
| q5   | Storage area for components   |
| q6   | Hardstand for boom assembly   |
| q7   | Free obstacles area for rotation superlift ballast or suspended ballast of main crane |

Table 9. Installation area codes and description

| HARDSTAND LEGEND  |                               |   |                                    |  |  |
|---|-------------------------------|---|------------------------------------|--|--|
|  | Site Road                     |  | q4 Trestle area for blades         |  | Area prepared as Hardstands q1 and q2                        |
|  | q1 Hardstand for Main Crane   |  | q5 Storage area for components     |  | Cleared area of any obstacles and prepared as a working area |
|  | q2 Hardstand for Assist Crane |  | q6 Hardstand for Boom Assembly     |  | Foundation area, leveled with q1 and Site Road               |
|  | q3 Storage/Assembly Area      |  | q7 Hardstand for Superlift ballast |  |  |

The hardstand drawings can be found in annexes, section 5.5 *hardstand dimensions*.

In all hardstands, 2 additional areas of 19 m x 12 m and 16 m x 12 m will be required for storing the containers and miscellaneous items. These areas must be close to the hardstand. They can be positioned alongside the foundation providing they remain accessible for removing material by boom truck or telescopic forklift.

The blade storage area will be formed by two different zones in q4. The first zone are two reinforced and levelled “fingers” where blades are supported. The second zone is the surrounding area of blade fingers in q4. As standard, the entire q4 area should be levelled with road and/or hard support next to it and cleared of obstacles in addition to maintain the said area as a working area (working area: area that must remain accessible to the cherry picker and workers during construction).

It may be necessary to include a third finger in case the transport tool and the blade preparation tool are not at the same point, in addition to the different options for locating the tip finger depending on the transport tool. This will be defined project by project by SGRE.

The top part of the blade fingers must be at the same level as the surrounding hardstand.

If the blade fingers area is higher or lower than the adjoining road, this must be approved by Siemens Gamesa as it will have an impact on the delivery of the blades.

It is considered that the leading edge of the blade is positioned in the side of the road. In case the edge of the blade is at the other side of the road a study would be necessary for the installation of the clamp. It is also essential to ensure that there is minimum 1m of area from the edge of the blade for the workers. This will be defined project by project by SGRE.

The dimensions of the vehicle and crane work areas as well as the storage areas inevitably determine the configurations of the equipment used for assembly. For this reason, this section also defines some of the standard or normal conditions used to define the basic prices as well as relevant exceptional cases.

The recommendable distance from the centre of the ring to the start of the useable surface of the hardstand will be 5 m. (Each specific case may be studied).

The concrete foundation pedestal and hardstand must have the same level where possible.

It can be lower with prior approval from SGRE.

If design requirements call for the foundation pedestal level to differ from the ground surface potentially the level of standard hardstand layout will differ from foundation pedestal, too. In case of a project specific evaluation together with SGRE is required (e.g adaptation of hardstand level to foundation pedestal level or change of crane set up and updated of size of the hardstand).

(Note: If opting for an elevated foundation due to design reasons, its height in relation to the hardstand should be considered as tower height.)

Intermediate hardstand adjacent to the road, but at a different level, must have a separate hardstand entrance and exit. Otherwise, it must be considered end-of-road hardstand.

For end-of-road hardstands, the foundation should be at the end of the hardstand, avoiding having the foundation at the entrance of the hardstand as much as possible.

The hardstand and road must be at the same level to be able to operate support cranes located partially on hardstand and road.

### 3.2.6. Requirements for tower assembly with T-flange configuration between section 1 and 2

A compacted area around the tower (on top of foundation) needs to be prepared in advance of start of 1<sup>st</sup> tower section installation. This is needed to enable tower access from all sides for installation of T-flange bolt joints with e.g., cherry picker (man basket).

The compacted area needs to have a minimum width of 10m for operation of cherry picker.

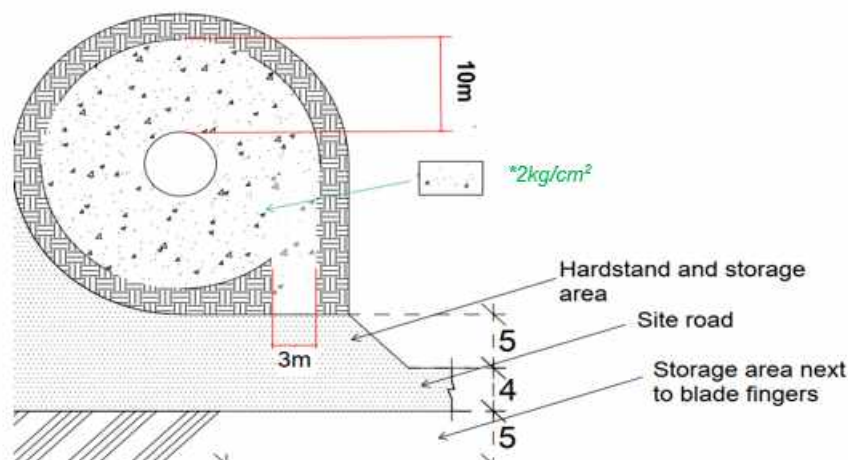


Figure 6. Example of hardstand layout and access road/ramp

Note:

If an elevated foundation is applicable a road/ramp for access to compacted must be created, too. Maximum gradient of 15% must be considered.

\*The bearing capacity for the backfilling is a recommendation for complying with the CNS requirements. This number needs to also fulfil the foundation design requirements.

### 3.2.7. Requirements for assembly the main crane

If there are several branches far away from one another, an area must be prepared for assembling and disassembling the boom of the main crane at the beginning and end of each wind farm branch or on each hardstand depending on the crane model to be used.

The boom assembly configuration and area may vary according to the crane models to be used.

If there are very steep gradients, power lines, etc., more assembly and disassembly areas for the boom of the main crane may be needed on each hardstand.

This area must have a minimum length in a straight line equal to:

- 100m tower: Tower height + 19m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 110.5m tower: Tower height + 19m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 115m tower: Tower height + 19m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 135m tower: Tower height + 15m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 145m tower: Tower height + 15m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 150m tower: Tower height + 12m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 155m tower: Tower height + 12m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)
- 165m tower: Tower height + 12m and a minimum width of 3m, with two 6m x 6m supporting areas (depending on the crane, the location of the crane and the boom configuration)

|                              |                    | T100m   | T110.5m | T115m | T135m | T145m | T150m | T155m | T165m | T165m MB |
|------------------------------|--------------------|---|---------|-------|-------|-------|-------|-------|-------|----------|
| Mobile/<br>Crawler<br>cranes | Wheeler Crane      | Area for assembly and disassembly on each hardstand and along site road |         |       |       |       |       |       |       |          |
|                              | NTC                |   |         |       |       |       |       |       |       |          |
|                              | WTC                | Assembly area at the beginning and end of the Wind Farm or each branch  |         |       |       |       |       |       |       |          |
| Dimensions                   | In a straight line | 119m  | 130m    | 134m  | 150m  | 160m  | 162m  | 167m  | 177m  | 177m     |



|  |             |    |    |    |    |    |    |    |    |    |
|--|-------------|----|----|----|----|----|----|----|----|----|
|  | <b>Wide</b> | 3m | 3m | 3m | 3m | 3m | 3m | 3m | 3m | 3m |
|--|-------------|----|----|----|----|----|----|----|----|----|

There must be areas without vegetation, flat and compacted with a surface area of  $10\text{ m} \times 12\text{ m} + 7\text{ m} \times 12\text{ m} / 2$ , every 30 m along the boom for assembly for the tailing cranes operation:

Table 10. Requirements for assembly the main crane

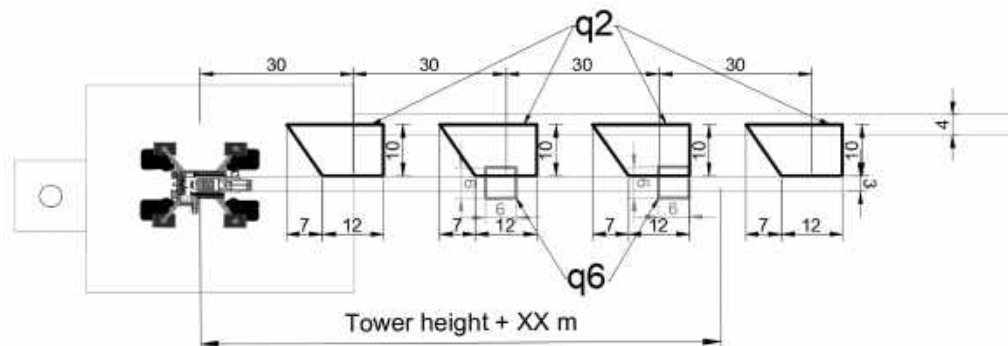
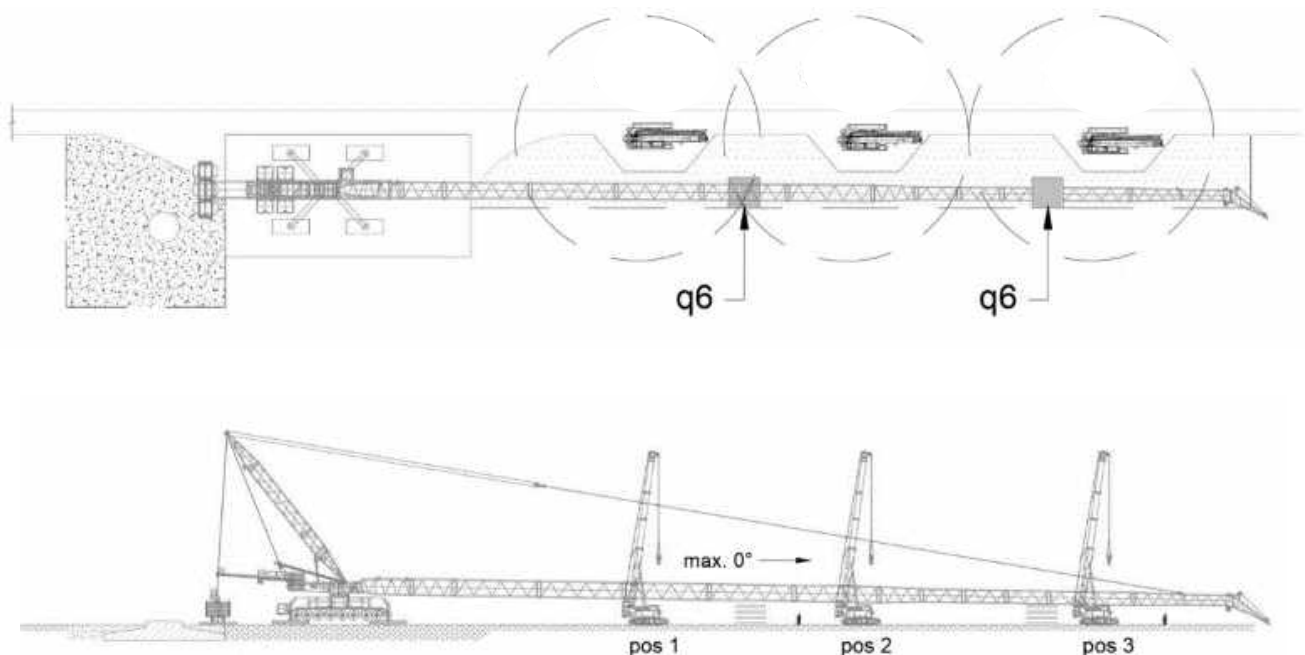


Figure 7. Distribution areas for main crane boom assembly

This area must also be as horizontal as possible, and any gradient should preferably be upward (in the direction in which the boom assembly advances). Were it downward, the boom assembly conditions would be more complex, increasing the crane means required for the assembly process. This would not be a SGRE standard and a specific study would need to be done.



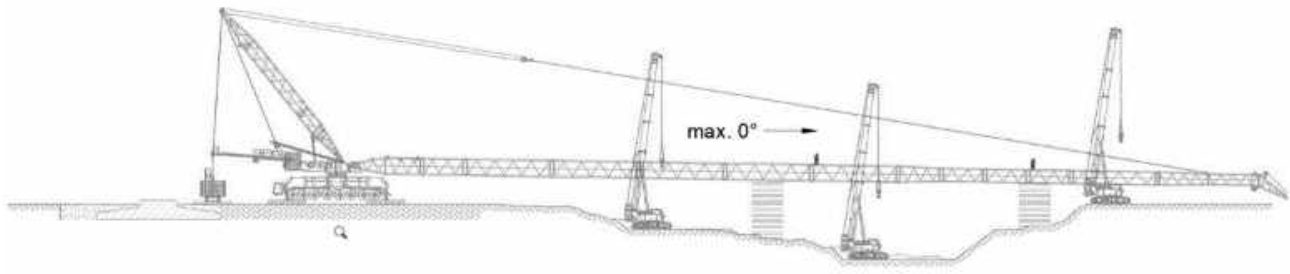


Figure 8. Boom assembly on flat and hilly terrain

Furthermore, the subgrade for assembly and disassembly of the boom, including the pre-installation crane positioning areas, must have a supporting capacity over the entire area at work level of 2 kg/cm<sup>2</sup> (approx. 0.2 MPa).

The areas for mounting and dismounting the main crane should be next to a hardstand but not overlap the hardstand area. Furthermore, they will be laid out as parallel as possible to the road reaching the hardstand, but without overlapping it, **in order to avoid invading the outgoing WF road in case of.**

### 3.2.8. Areas for Tag Lines

Rotor Assembly and Single blade Installation Methods (see Figure 9) require special attention for ensuring a cleared area for the safe use of tag lines.

The Employer shall ensure that the areas around the hardstand, rotor assembly area, and operating area for tag lines are prepared to allow rotor assembly and installation, or single blade installation to be completed safely. An example of the area required is shown in Figure 9. This area shall be prepared as a Working Area (free from trees, obstacles and trip hazards and prepared as to allow persons to move freely and safely). Once the Employer's civil design is finalised, the Contractor shall work with the Employer to further define and optimize these areas in order to minimise the felling and ground preparation works to be carried out by the Employer. Prior to turbine erection, the Employer and Contractor shall together survey the area to be used for tag lines and identify any safety hazards (e.g. holes, level changes, marsh etc.). The Employer and Contractor will mutually agree appropriate mitigations measures, which will be carried out by the Employer, to ensure Safe Working Access.

The drawings below are indicative only and can be further refined during the site visit. This is relevant for rotor assembly only.

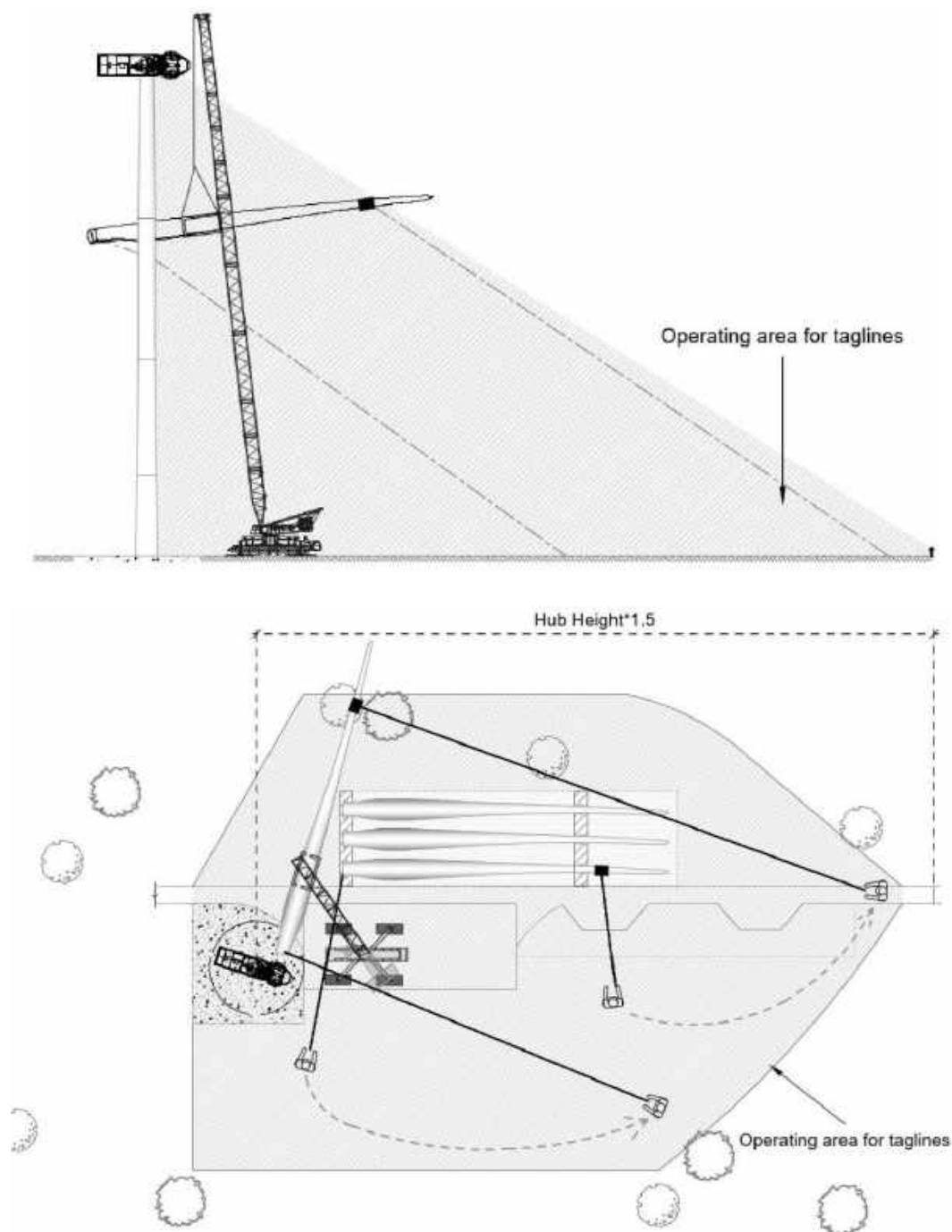


Figure 9. Indicative drawing of area requirements for the use of tag lines with single blade installation method

### 3.3. Minimum Requirements for temporary site compounds of wind farms

The objective of this Internal Note is to specify the minimum requirements for the temporary site hardstands including the area of the site office sheds/containers, the parking area for light vehicles and the storage area for minor materials. Normally all these areas form a single space usually called “**site compound**”, which is divided into the pertinent specific areas.

The site compound is needed for the construction of a wind farm, and each area must be in good conditions for each specific purpose. Therefore, these temporary areas must be built in accordance with specific requirements.

The location of the site compound must be carefully studied, avoiding areas susceptible to suffering flood events and avoiding areas with critical natural slopes or large embankments. Preferred locations are flat areas with easy access by car or truck.

The design of this site compound must consider a slope between 1% and 3%, for a proper drainage of the rainwater in accordance with the site-specific conditions. If necessary, temporary drain ditches or culverts should also be considered to collect and divert the rainwater to the appropriate discharge points.

The construction of these temporary areas will require the following activities:

- 1- The area must be cleared to eliminate the topsoil, trees, stumps, weeds, etc. The topsoil can be stockpiled in small piles in the vicinity of the site compound for later use in landscape restoration if required.
- 2- Embankments: If relevant embankments are necessary to build the hardstand, at least the following requirements are recommended:
  - Before the construction of the embankment, the natural subgrade must be compacted until reaching 95% of the maximum dry density from the Modified Proctor test (M.P.).
  - Embankment construction must be carried out by placing fill material in max. 30cm thick layers and compacting this fill material until reaching 95% of its maximum dry density from the M.P.
  - It is recommended using a fill material with a CBR  $\geq 4\%$  at 95% M.P, free of organic matter, LL<50, non-collapsible, free swelling <3%.
- 3- Excavations: If excavation is necessary to build the hardstand, the exposed natural subgrade must be compacted until reaching 95% of the maximum dry density from M.P.
- 4- Pavement: The pavement details will depend on the use of each area but, as a general approach, it is recommended a granular material with a fine content  $\leq 20\%$ , a CBR  $\geq 40\%$  at 98% M.P. and a maximum grain size of 32mm, when possible. This material must also be correctly compacted in max. 30cm thick layers until reaching at least 98% of the maximum dry density from M.P. (“=well compacted granular material”).

Paved areas and the thickness of the pavement will depend on the site soil conditions and the associated evaluation will adequately consider the detailed geotechnical information. There may even be the case that the use of geotextiles could be necessary.

Recommended thickness of the pavement in each area is indicated below. The thicknesses must be considered as a minimum and obviously it can also be increased if the site soil conditions are not good enough.

- Temporary office area: it is recommended applying 10cm of well compacted granular material.
- Parking area for light vehicles: it is recommended applying 15cm of well compacted granular material.
- Storage area for minor materials and access road: trucks are going to use these areas. Therefore, the thickness of pavement will depend on the quality of the natural soil (subsoil):
  - Poor subsoil conditions ( $\text{CBR} < 2\%$  at 95% P.M.): it is recommended applying at least 30cm of well compacted granular material.
  - Fair subsoil conditions ( $2\% < \text{CBR} < 7\%$  at 95% P.M.): it is recommended applying at least 20cm of well compacted granular material.
  - Good subsoil conditions ( $\text{CBR} > 7\%$  at 95% P.M.): it is recommended applying at least 15cm of well compacted granular material.
  - If rock or rocky soils are encountered, it would be enough to apply 10cm of well compacted granular material in all the areas to build a uniform, plain and sufficiently bearing hardstand.

Above recommendations must be understood as a general guide or a first approach to the structural design of the temporary hardstands.

In any case, it is always necessary to maintain adequately the pavements. If necessary, additional granular material must be placed and correctly compacted during the use of these temporary areas.

If these temporary areas are going to be used for storing of the turbine components and/or very heavy items that require the use of cranes, they will be considered as a usual WTG hardstand and analysed and designed in accordance with the Site-Specific Requirements (SSR) of each project.

This text must be kept intact in the project specific requirements. If the text cannot be kept, please contact the BOP Technical Office.

### 3.4. Safety distance from power lines

**The Orders and Regulations in force in each country must be considered where high and low-voltage lines pass over the internal wind farm roads or wind farm access roads.**

Distance limits for working areas are included as a reference.

| $U_n$    | $D_{PEL-1}$ | $D_{PEL-2}$ | $D_{PROX-1}$ | $D_{PROX-2}$ |
|----------|-------------|-------------|--------------|--------------|
| $\leq 1$ | 50          | 50          | 70           | 300          |
| 3        | 62          | 52          | 112          | 300          |
| 6        | 62          | 53          | 112          | 300          |
| 10       | 65          | 55          | 115          | 300          |
| 15       | 66          | 57          | 116          | 300          |
| 20       | 72          | 60          | 122          | 300          |
| 30       | 82          | 66          | 132          | 300          |
| 45       | 98          | 73          | 148          | 300          |
| 66       | 120         | 85          | 170          | 300          |
| 110      | 160         | 100         | 210          | 500          |
| 132      | 180         | 110         | 330          | 500          |
| 220      | 260         | 160         | 410          | 500          |
| 380      | 390         | 250         | 540          | 700          |

Table 11. Safety distance from power lines to work areas

(Note)

The distances for intermediate voltage values will be calculated using linear interpolation.

Where:

- $U_n$  - Rated voltage of the installation (kW).
- $D_{PEL-1}$  - Distance to the outer limit of the danger area whenever there is a risk of voltage stressing due to lightning (cm).
- $D_{PEL-2}$  - Distance to the outer limit of the danger area when there is no risk of overvoltage due to lightning (cm).
- $D_{PROX-1}$  - Distance to the outer limit of the danger area whenever it is possible to mark out the work area accurately and control that this is not exceeded during the carrying-out of the work (cm).
- $D_{PROX-2}$  - Distance to the outer limit of the danger area whenever it is not possible to mark out the work area accurately and control that this is not exceeded during the carrying-out of the work (cm).

This section (3.4.) cannot be removed in the project specific requirements, in case it does not apply it will be indicated as such.

## 4. Additional documentation

This document is of a general character, and it is necessary to include another document (e.g. External Note) specifying any additional requirements or revision/confirmation of the parameters of this document, in addition to:

- Number of WTGs.
- Turbine type. If there is more than one type, this should be specified position by position.
- Installation strategy and storage conditions. If there is more than one type, this should be specified position by position.
- Main, pre-assembly and assist crane proposed.
- Road width in the access road and between positions.
- Semi – mounted crane movement road requirements and affected road sections.
- Auxiliary means for transports as pull units. This should also include the road sections in which this auxiliary means are needed.
- Additional hardstands, in case needed (temporary storage).
- Confirmation of the widening curves table.
- Revision/confirmation of the parameters, e.g. KV, longitudinal gradients...
- Specification of dimension and other requirements of site facilities.
- Any other project specific requirements.

HSE, project by project, must also define their requirements. I.e. safety distances to the edge of the hardstands, in case there is a high difference in level.

To define the above information, receiving the Layout of the WF and other information is required.

This data will give a visualization of each wind turbine of the windfarm and it will convey any needed extra methods or measures in addition to the SGRE standards.

## 5. Annexes

### 5.1. Transport requirements

(Note): The data represented below is the result of the of the study was obtained from the modelling, showing the following widening according to the cargo and bed. The values are a reference considering the transport from the item **3.1.5 Gradients and grade changes**. For each windfarm and region, please bear in mind some changes could be possible. Concerning this, a new study must be done by Logistics department according with the transport available per region/project to avoid some nonconformities.

This section (5.1) cannot be removed in the project specific requirements, in case it does not apply it will be indicated as such.



VEHICLE: SG170, LEFT TURN

|    | 10° |     |     | 20° |     |     | 30° |     |     | 40° |     |      | 50° |     |      | 60° |     |      |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|------|-----|-----|------|
|    | A   | Sae | Sai | A   | Sae | Sai | A   | Sae | Sai | A   | Sae | Sai  | A   | Sae | Sai  | A   | Sae | Sai  |
|    |     |     |     |     |     |     |     |     |     |     |     |      |     |     |      |     |     |      |
| 5  | 5   | 1,5 | 1,5 | 6   | 1,5 | 4,5 | 6   | 1,5 | 8   | 6   | 4   | 11   | 7   | 5,5 | 15   | 7   | 7   | 19   |
| 10 | 5   | 1,5 | 1,5 | 6   | 1,5 | 4,5 | 6   | 1,5 | 8   | 6   | 3,5 | 11   | 7   | 5,5 | 14,5 | 7   | 7   | 18   |
| 15 | 5   | 1,5 | 1,5 | 6   | 1,5 | 4,5 | 6   | 1,5 | 7,5 | 6   | 3,5 | 10,5 | 7   | 5   | 14   | 7   | 6,5 | 17,5 |
| 20 | 5   | 1,5 | 1,5 | 6   | 1,5 | 4,5 | 6   | 1,5 | 7,5 | 6   | 3,5 | 10,5 | 7   | 5   | 14   | 7   | 6   | 16,5 |
| 25 | 5   | 1,5 | 1   | 6   | 1,5 | 4,5 | 6   | 1,5 | 7,5 | 6   | 3   | 10   | 7   | 4,5 | 13,5 | 7   | 6   | 16   |
| 30 | 5   | 1,5 | 1   | 5   | 1,5 | 4,5 | 6   | 1,5 | 7   | 6   | 3   | 10   | 7   | 4,5 | 12,5 | 7   | 5,5 | 15   |
| 35 | 5   | 1,5 | 1   | 5   | 1,5 | 4   | 6   | 1,5 | 7   | 6   | 3   | 9,5  | 6   | 4   | 12   | 7   | 5,5 | 14,5 |
| 40 | 5   | 1,5 | 1   | 5   | 1,5 | 4   | 6   | 1,5 | 6,5 | 6   | 2,5 | 9    | 6   | 4   | 11,5 | 7   | 5   | 13,5 |
| 45 | 5   | 1,5 | 1   | 5   | 1,5 | 4   | 6   | 1,5 | 6,5 | 6   | 2,5 | 9    | 6   | 3,5 | 11   | 7   | 4,5 | 13   |
| 50 | 5   | 1,5 | 1   | 5   | 1,5 | 4   | 6   | 1,5 | 6,5 | 6   | 2,5 | 8,5  | 6   | 3,5 | 10,5 | 6   | 4,5 | 12   |
| 55 | 5   | 1,5 | 1   | 5   | 1,5 | 4   | 6   | 1,5 | 6,5 | 6   | 2,5 | 8    | 6   | 3,5 | 10   | 6   | 4   | 11,5 |
| 60 | 5   | 1,5 | 1   | 5   | 1,5 | 4   | 6   | 1,5 | 6   | 6   | 2   | 8    | 6   | 3   | 9,5  | 6   | 4   | 10,5 |
| 65 | 5   | 1,5 | 1   | 5   | 1,5 | 3,5 | 6   | 1,5 | 6   | 6   | 2   | 7,5  | 6   | 3   | 9    | 6   | 3,5 | 9,5  |
| 70 | 5   | 1,5 | 1   | 5   | 1,5 | 3,5 | 6   | 1,5 | 5,5 | 6   | 1,5 | 7,5  | 6   | 2,5 | 8,5  | 6   | 3,5 | 9    |
| 75 | 5   | 1,5 | 1   | 5   | 1,5 | 3,5 | 6   | 1,5 | 5,5 | 6   | 1,5 | 7    | 6   | 2,5 | 8    | 6   | 3   | 8    |
| 80 | 5   | 1,5 | 1   | 5   | 1,5 | 3,5 | 6   | 1,5 | 5,5 | 6   | 1,5 | 6,5  | 6   | 2   | 7,5  | 6   | 2,5 | 7,5  |
| 85 | 5   | 1,5 | 1   | 5   | 1,5 | 3,5 | 6   | 1,5 | 5   | 6   | 1,5 | 6,5  | 6   | 2   | 7    | 6   | 2   | 7    |
| 90 | 5   | 1,5 | 1   | 5   | 1,5 | 3,5 | 6   | 1,5 | 5   | 6   | 1,5 | 6    | 6   | 1,5 | 6,5  | 6   | 1,5 | 6,5  |

|    | 70° |     |      | 80° |     |      | 90° |     |      | 100° |     |      | 110° |     |      | 120° |     |      |
|----|-----|-----|------|-----|-----|------|-----|-----|------|------|-----|------|------|-----|------|------|-----|------|
|    | A   | Sae | Sai  | A   | Sae | Sai  | A   | Sae | Sai  | A    | Sae | Sai  | A    | Sae | Sai  | A    | Sae | Sai  |
|    |     |     |      |     |     |      |     |     |      |      |     |      |      |     |      |      |     |      |
| 5  | 8   | 8   | 23,5 | 11  | 8   | 28   | 15  | 8   | 34   | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 10 | 8   | 8   | 22   | 10  | 8   | 26,5 | 13  | 8   | 31,5 | 18   | 8   | 37,5 | 6    | 0   | 0    | 6    | 0   | 0    |
| 15 | 8   | 8   | 21   | 9   | 8   | 25   | 12  | 8   | 29,5 | 16   | 8   | 35   | 6    | 0   | 0    | 6    | 0   | 0    |
| 20 | 8   | 7,5 | 20   | 8   | 8   | 23,5 | 10  | 8   | 27,5 | 14   | 8   | 32   | 18   | 8   | 37,5 | 6    | 0   | 0    |
| 25 | 7   | 7   | 19   | 8   | 8   | 22   | 9   | 8   | 25   | 12   | 8   | 29   | 15   | 8   | 34   | 6    | 0   | 0    |
| 30 | 7   | 6,5 | 17,5 | 8   | 7,5 | 20,5 | 8   | 8   | 23   | 10   | 8   | 26   | 11   | 8   | 31   | 16   | 8,5 | 33   |
| 35 | 7   | 6,5 | 16,5 | 7   | 7   | 19   | 8   | 8   | 21   | 8    | 8   | 23,5 | 11   | 8   | 30,5 | 12   | 8,5 | 28   |
| 40 | 7   | 6   | 15,5 | 7   | 7   | 17,5 | 7   | 7,5 | 19   | 8    | 8   | 22   | 10   | 8   | 28   | 8    | 8,5 | 23   |
| 45 | 7   | 5,5 | 14,5 | 7   | 6   | 16   | 7   | 7   | 18   | 8    | 8   | 21   | 7    | 7,5 | 18,5 | 7    | 7,5 | 18,5 |
| 50 | 7   | 5   | 13,5 | 7   | 5,5 | 14,5 | 7   | 6   | 17   | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 |
| 55 | 7   | 4,5 | 12,5 | 7   | 5   | 13   | 7   | 5,5 | 16   | 7    | 5,5 | 13   | 7    | 5,5 | 13   | 7    | 5,5 | 13   |
| 60 | 6   | 4,5 | 11   | 6   | 4,5 | 11   | 6   | 5,5 | 11,5 | 6    | 5   | 11,5 | 6    | 5   | 11,5 | 6    | 5   | 11,5 |
| 65 | 6   | 4   | 10   | 6   | 4   | 10   | 6   | 4   | 10   | 6    | 4   | 10   | 6    | 4   | 10   | 6    | 4   | 10   |
| 70 | 6   | 3,5 | 9    | 6   | 3,5 | 9    | 6   | 3,5 | 9    | 6    | 3,5 | 9    | 6    | 3,5 | 9    | 6    | 3,5 | 9    |
| 75 | 6   | 3   | 8,5  | 6   | 3   | 8,5  | 6   | 3   | 8,5  | 6    | 3   | 8,5  | 6    | 3   | 8,5  | 6    | 3   | 8,5  |
| 80 | 6   | 2,5 | 7,5  | 6   | 2,5 | 7,5  | 6   | 2,5 | 7,5  | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  |
| 85 | 6   | 2   | 7    | 6   | 2   | 7    | 6   | 2   | 7    | 6    | 2   | 7    | 6    | 2   | 7    | 6    | 2   | 7    |
| 90 | 6   | 1,5 | 6,5  | 6   | 1,5 | 6,5  | 6   | 1,5 | 6,5  | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  |

|    | 130° |     |      | 140° |     |      | 150° |     |      | 160° |     |      | 170° |     |      | 180° |     |      |
|----|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|
|    | A    | Sae | Sai  | A    | Sae | Sai  | A    | Sae | Sai  | A    | Sae | Sai  | A    | Sae | Sai  | A    | Sae | Sai  |
|    |      |     |      |      |     |      |      |     |      |      |     |      |      |     |      |      |     |      |
| 5  | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 10 | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 15 | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 20 | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 25 | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 30 | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 35 | 15   | 8,5 | 31   | 19   | 8,5 | 35   | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    | 6    | 0   | 0    |
| 40 | 9    | 8,5 | 24   | 11   | 8,5 | 25,5 | 12   | 8,5 | 26   | 11   | 8,5 | 25,5 | 16   | 8,5 | 29   | 18   | 8,5 | 31   |
| 45 | 7    | 7,5 | 18,5 | 7    | 7,5 | 18,5 | 8    | 7,5 | 18,5 | 8    | 7,5 | 18,5 | 8    | 7,5 | 18,5 | 8    | 7,5 | 18,5 |
| 50 | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 | 7    | 6,5 | 15,5 |
| 55 | 7    | 5,5 | 13   | 7    | 5,5 | 13   | 7    | 5,5 | 13   | 7    | 5,5 | 13   | 7    | 5,5 | 13   | 7    | 5,5 | 13   |
| 60 | 6    | 5   | 11,5 | 6    | 5   | 11,5 | 6    | 5   | 11,5 | 6    | 5   | 11,5 | 6    | 5   | 11,5 | 6    | 5   | 11,5 |
| 65 | 6    | 4   | 10   | 6    | 4   | 10   | 6    | 4   | 10   | 6    | 4   | 10   | 6    | 4   | 10   | 6    | 4   | 10   |
| 70 | 6    | 3,5 | 9    | 6    | 3,5 | 9    | 6    | 3,5 | 9    | 6    | 3,5 | 9    | 6    | 3,5 | 9    | 6    | 3,5 | 9    |
| 75 | 6    | 3   | 8,5  | 6    | 3   | 8,5  | 6    | 3   | 8,5  | 6    | 3   | 8,5  | 6    | 3   | 8,5  | 6    | 3   | 8,5  |
| 80 | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  | 6    | 2,5 | 7,5  |
| 85 | 6    | 2   | 7    | 6    | 2   | 7    | 6    | 2   | 7    | 6    | 2   | 7    | 6    | 2   | 7    | 6    | 2   | 7    |
| 90 | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  | 6    | 1,5 | 6,5  |

VEHICLE: SG170, RIGHT TURN

|    | 10º |     |     | 20º |     |     | 30º |     |     | 40º |     |      | 50º |     |      | 60º |      |      |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|------|-----|------|------|
|    | A   | Sae | Sai | A   | Sae | Sai | A   | Sae | Sai | A   | Sae | Sai  | A   | Sae | Sai  | A   | Sae  | Sai  |
|    |     |     |     |     |     |     |     |     |     |     |     |      |     |     |      |     |      |      |
| 5  | 5   | 4   | 2,5 | 6   | 6   | 5,5 | 6   | 7,5 | 8,5 | 6   | 9   | 11,5 | 7   | 10  | 15,5 | 7   | 10,5 | 19   |
| 10 | 5   | 4   | 2,5 | 6   | 6   | 5,5 | 6   | 7,5 | 8,5 | 6   | 8,5 | 11,5 | 7   | 9,5 | 15   | 7   | 10,5 | 18   |
| 15 | 5   | 4   | 2,5 | 6   | 5,5 | 5   | 6   | 7,5 | 8,5 | 6   | 8,5 | 11   | 7   | 9,5 | 14   | 7   | 10,5 | 17,5 |
| 20 | 5   | 4   | 2   | 6   | 5,5 | 5   | 6   | 7,5 | 8   | 6   | 8,5 | 11   | 7   | 9,5 | 14   | 7   | 10   | 16,5 |
| 25 | 5   | 4   | 2   | 6   | 5,5 | 5   | 6   | 7,5 | 8   | 6   | 8,5 | 10,5 | 7   | 9,5 | 13,5 | 7   | 10   | 16   |
| 30 | 5   | 4   | 2   | 5   | 5,5 | 5   | 6   | 7   | 7,5 | 6   | 8,5 | 10,5 | 7   | 9,5 | 13   | 7   | 10   | 15,5 |
| 35 | 5   | 4   | 2   | 5   | 5,5 | 5   | 6   | 7   | 7,5 | 6   | 8,5 | 10   | 6   | 9   | 12,5 | 7   | 9,5  | 14,5 |
| 40 | 5   | 4   | 2   | 5   | 5,5 | 5   | 6   | 7   | 7,5 | 6   | 8,5 | 9,5  | 6   | 9   | 12   | 7   | 9,5  | 14   |
| 45 | 5   | 4   | 2   | 5   | 5,5 | 5   | 6   | 7   | 7,5 | 6   | 8   | 9,5  | 6   | 8,5 | 11,5 | 7   | 9,5  | 13,5 |
| 50 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 6   | 7   | 7,5 | 6   | 8   | 9    | 6   | 8,5 | 11   | 6   | 9    | 12,5 |
| 55 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 6   | 7   | 7,5 | 6   | 8   | 9    | 6   | 8,5 | 10,5 | 6   | 9    | 11,5 |
| 60 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 6   | 6,5 | 6,5 | 6   | 7,5 | 8,5  | 6   | 8,5 | 10   | 6   | 9    | 11   |
| 65 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 6   | 6,5 | 6,5 | 6   | 7,5 | 8    | 6   | 8   | 9,5  | 6   | 8,5  | 10,5 |
| 70 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 6   | 6,5 | 6,5 | 6   | 7,5 | 8    | 6   | 8   | 9    | 6   | 8,5  | 9,5  |
| 75 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 6   | 6,5 | 6   | 6   | 7   | 7,5  | 6   | 7,5 | 8,5  | 6   | 8    | 9    |
| 80 | 5   | 4   | 2   | 5   | 5,5 | 4,5 | 5   | 6,5 | 6   | 5   | 7   | 7,5  | 6   | 7,5 | 8    | 6   | 7,5  | 8    |
| 85 | 5   | 4   | 2   | 5   | 5,5 | 4   | 5   | 6,5 | 6   | 5   | 7   | 7    | 6   | 7,5 | 7,5  | 6   | 7,5  | 7,5  |
| 90 | 5   | 4   | 2   | 5   | 5,5 | 4   | 5   | 6,5 | 5,5 | 5   | 7   | 6,5  | 6   | 7   | 7    | 6   | 7    | 7    |

|    | Radios (m) |      |      |     |      |      |     |      |      |      |      |      |      |      |      |      |      |      |    |
|----|------------|------|------|-----|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|----|
|    | 70º        |      |      | 80º |      |      | 90º |      |      | 100º |      |      | 110º |      |      | 120º |      |      |    |
|    | A          | Sae  | Sai  | A   | Sae  | Sai  | A   | Sae  | Sai  | A    | Sae  | Sai  | A    | Sae  | Sai  | A    | Sae  | Sai  |    |
| 5  | 8          | 11   | 23,5 | 11  | 11   | 28   | 15  | 11   | 34   |      |      |      |      |      |      |      |      |      |    |
| 10 | 8          | 11   | 22   | 10  | 11   | 26,5 | 13  | 11   | 31,5 | 18   | 11   | 37,5 |      |      |      |      |      |      |    |
| 15 | 8          | 10,5 | 21   | 9   | 11   | 25   | 12  | 11   | 29,5 | 16   | 11   | 35   |      |      |      |      |      |      |    |
| 20 | 8          | 10,5 | 20   | 8   | 11   | 23,5 | 10  | 11   | 27,5 | 14   | 11   | 31,5 | 18   | 11   | 37,5 |      |      |      |    |
| 25 | 7          | 10,5 | 19   | 8   | 11   | 22   | 9   | 11   | 25   | 12   | 11   | 29,5 | 15   | 11   | 33   |      |      |      |    |
| 30 | 7          | 10,5 | 17,5 | 8   | 10,5 | 20,5 | 8   | 11   | 23   | 10   | 11   | 27,5 | 14   | 11   | 31,5 | 16   | 11   | 33   |    |
| 35 | 7          | 10   | 16,5 | 7   | 10,5 | 19   | 8   | 11   | 22   | 10   | 11   | 26,5 | 13,5 | 10   | 11   | 26   | 12   | 11   | 28 |
| 40 | 7          | 10   | 15,5 | 7   | 10,5 | 17,5 | 7   | 10,5 | 19   | 11   | 10,5 | 20,5 | 8    | 11   | 22   | 8    | 11   | 23   |    |
| 45 | 7          | 9,5  | 14,5 | 7   | 10   | 16   | 7   | 10,5 | 17,5 | 7    | 10,5 | 18   | 7    | 10,5 | 18,5 | 7    | 10,5 | 18,5 |    |
| 50 | 7          | 9,5  | 13,5 | 7   | 9,5  | 14,5 | 7   | 10   | 15,5 | 7    | 10   | 15,5 | 7    | 10   | 15,5 | 7    | 10   | 15,5 |    |
| 55 | 7          | 9,5  | 12,5 | 7   | 9,5  | 13,5 | 7   | 9,5  | 13,5 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 |    |
| 60 | 6          | 9    | 11,5 | 6   | 9    | 12   | 6   | 9    | 12   | 6    | 9    | 12   | 6    | 9    | 12   | 6    | 9    | 12   |    |
| 65 | 6          | 8,5  | 10,5 | 6   | 8,5  | 10,5 | 6   | 9    | 10,5 | 6    | 9    | 10,5 | 6    | 9    | 10,5 | 6    | 9    | 10,5 |    |
| 70 | 6          | 8,5  | 9,5  | 6   | 8,5  | 9,5  | 6   | 8,5  | 9,5  | 6    | 8,5  | 9,5  | 6    | 8,5  | 9,5  | 6    | 8,5  | 9,5  |    |
| 75 | 6          | 8    | 9    | 6   | 8    | 9    | 6   | 8    | 9    | 6    | 8    | 9    | 6    | 8    | 9    | 6    | 8    | 9    |    |
| 80 | 6          | 7,5  | 8,5  | 6   | 8    | 8,5  | 6   | 8    | 8,5  | 6    | 8    | 8,5  | 6    | 8    | 8,5  | 6    | 8    | 8,5  |    |
| 85 | 6          | 7,5  | 7,5  | 6   | 7,5  | 7,5  | 6   | 7,5  | 7,5  | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  |    |
| 90 | 6          | 7    | 7    | 6   | 7    | 7    | 6   | 7    | 7    | 6    | 7    | 7    | 6    | 7    | 7    | 6    | 7    | 7    |    |

|    | 130º |      |      | 140º |      |      | 150º |      |      | 160º |      |      | 170º |      |      | 180º |      |      |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|    | A    | Sae  | Sai  | A    | Sae  | Sai  | A    | Sae  | Sai  | A    | Sae  | Sai  | A    | Sae  | Sai  | A    | Sae  | Sai  |
|    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 5  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 10 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 15 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 20 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 25 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 30 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 35 | 15   | 11   | 31   | 19   | 11   | 35   |      |      |      |      |      |      |      |      |      |      |      |      |
| 40 | 9    | 11   | 24   | 11   | 11   | 25,5 | 11   | 11   | 27,5 | 11   | 11   | 27   | 16   | 11   | 29   | 18   | 11   | 31   |
| 45 | 7    | 10,5 | 18,5 | 7    | 10,5 | 18,5 | 7    | 10,5 | 18,5 | 8    | 10,5 | 18,5 | 8    | 10,5 | 18,5 | 8    | 10,5 | 18,5 |
| 50 | 7    | 10   | 15,5 | 7    | 10   | 15,5 | 7    | 10   | 15,5 | 7    | 10   | 15,5 | 7    | 10   | 15,5 | 7    | 10   | 15,5 |
| 55 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 | 7    | 9,5  | 13,5 |
| 60 | 6    | 9    | 12   | 6    | 9    | 12   | 6    | 9    | 12   | 6    | 9    | 12   | 6    | 9    | 12   | 6    | 9,5  | 12   |
| 65 | 6    | 9    | 10,5 | 6    | 9    | 10,5 | 6    | 9    | 10,5 | 6    | 9    | 10,5 | 6    | 9    | 10,5 | 6    | 9    | 10,5 |
| 70 | 6    | 8,5  | 9,5  | 6    | 8,5  | 9,5  | 6    | 8,5  | 9,5  | 6    | 8,5  | 9,5  | 6    | 8,5  | 9,5  | 6    | 8,5  | 10   |
| 75 | 6    | 8    | 9    | 6    | 8    | 9    | 6    | 8    | 9    | 6    | 8    | 9    | 6    | 8    | 9    | 6    | 8    | 9    |
| 80 | 6    | 8    | 8,5  | 6    | 8    | 8,5  | 6    | 8    | 8,5  | 6    | 8    | 8,5  | 6    | 8    | 8,5  | 6    | 8    | 8,5  |
| 85 | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  | 6    | 7,5  | 7,5  |
| 90 | 6    | 7    | 7    | 6    | 7    | 7    | 6    | 7    | 7    | 6    | 7    | 7    | 6    | 7    | 7    | 6    | 7,5  | 7    |

## 5.2. Quality tests and requirements for civil works projects

The quality control and the requirements for the civil works design is defined according to the ***GD483525-EN, Quality Test Plan for Roads and Hardstands.***



**This text (5.2.) must be kept intact in the project specific requirements and can only be adapted to the local standard, if any, for these specific low volume roads.**

## 5.3. Legislations

Siemens Gamesa and its affiliates reserve the right to change the above specifications without prior notice.

## 5.4. Additional documentation

The following additional documentation is subject to customer requirement:

- ***GD483525-EN, Quality Test Plan for Roads and Hardstands.***



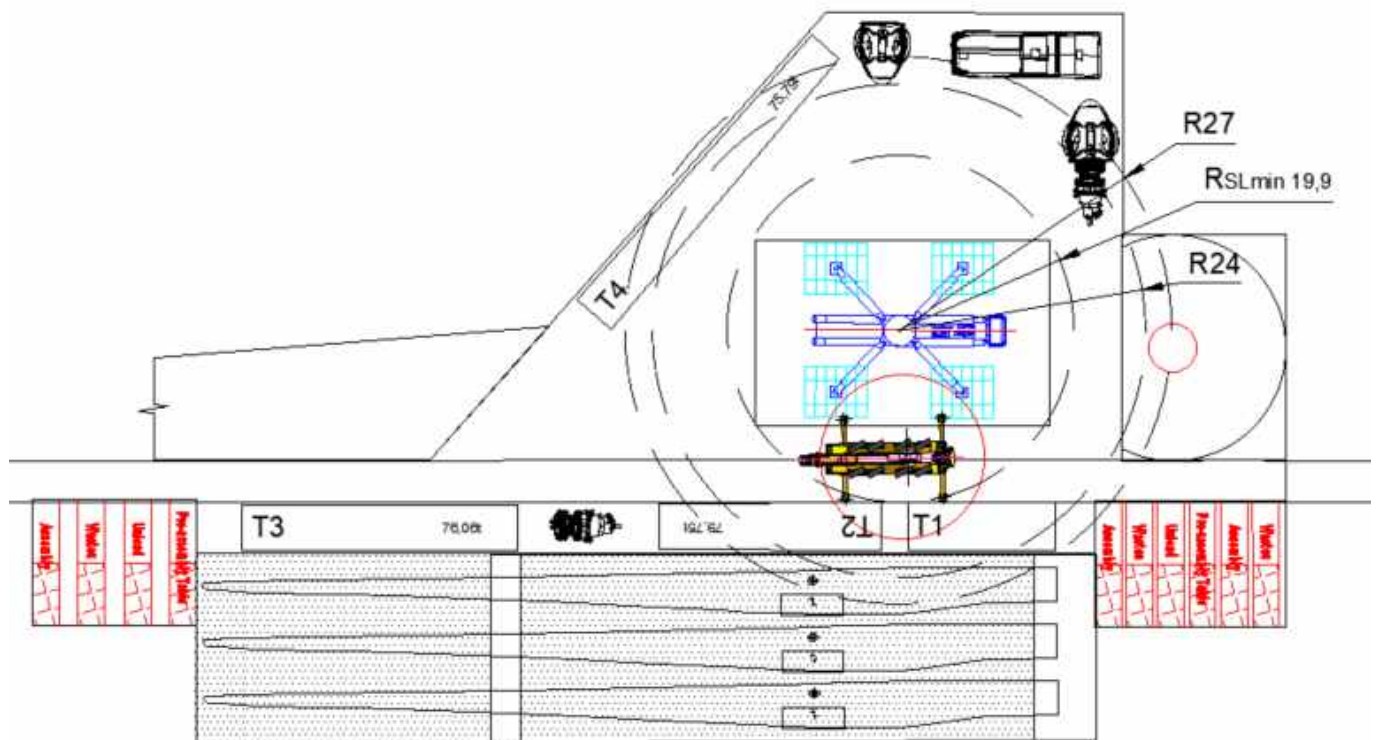
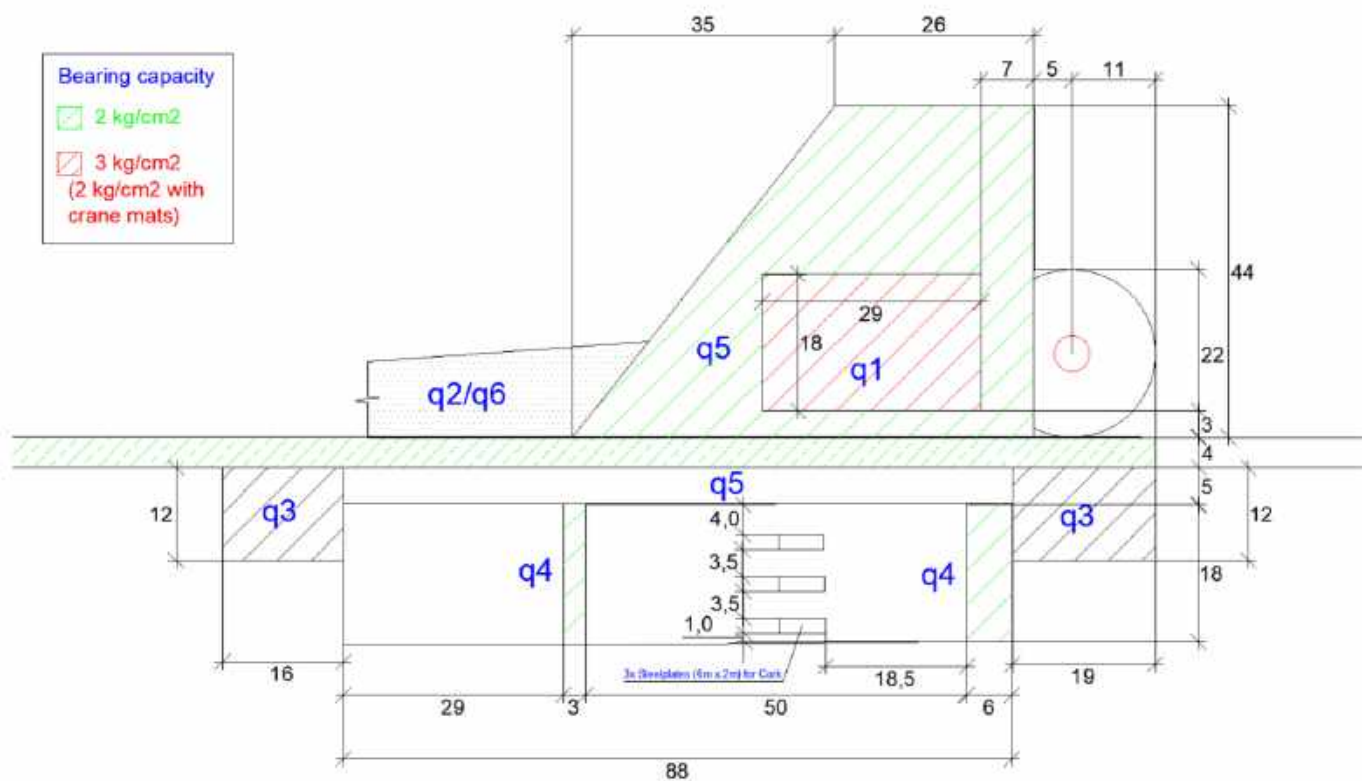


Figure 10 Model T100m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE Standard)





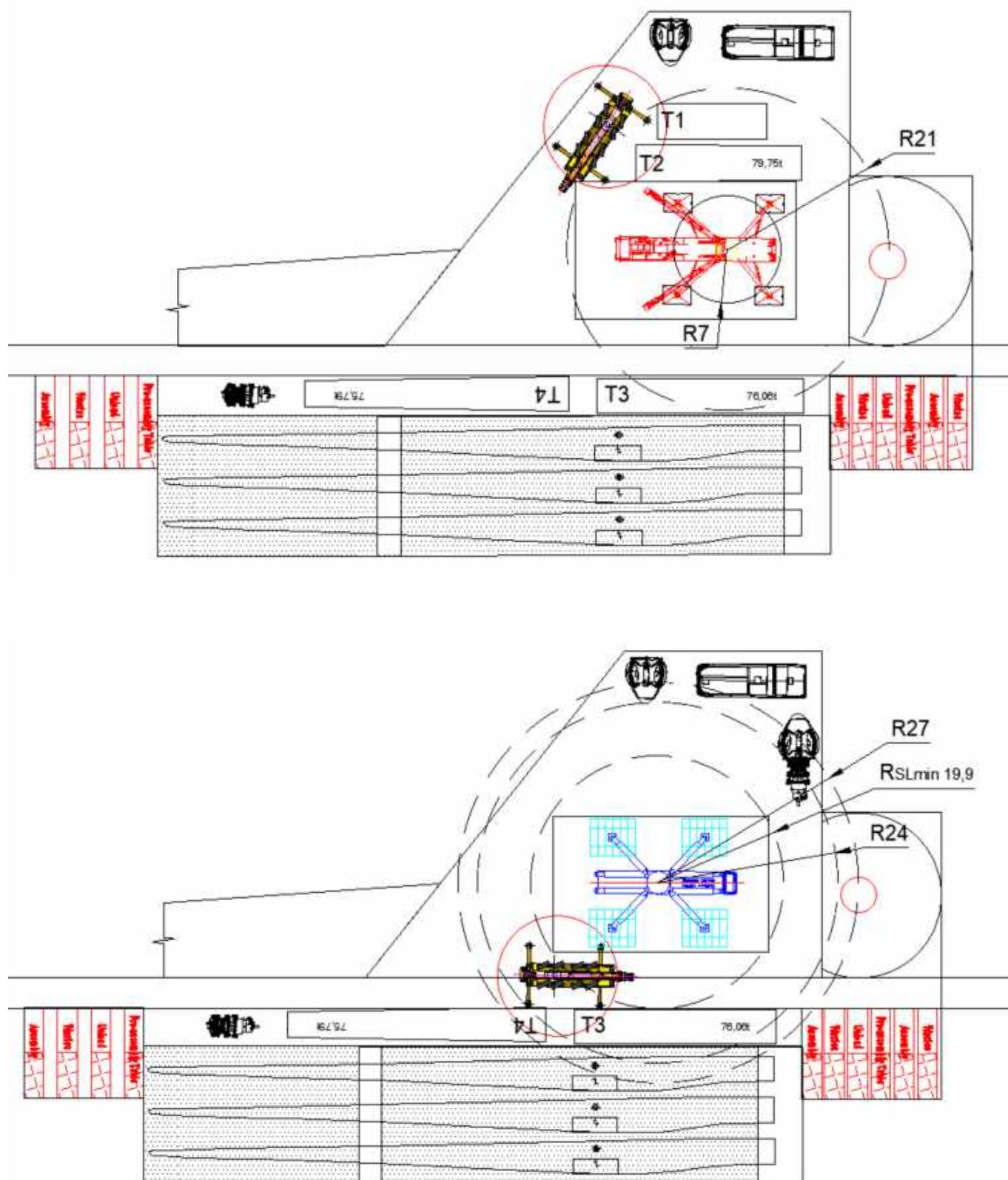


Figure 11 Model T100m – Partial storage assembling with strategy 3 in 2 phases

### 5.5.2. T100m tubular steel tower Hardstand with strategy 4

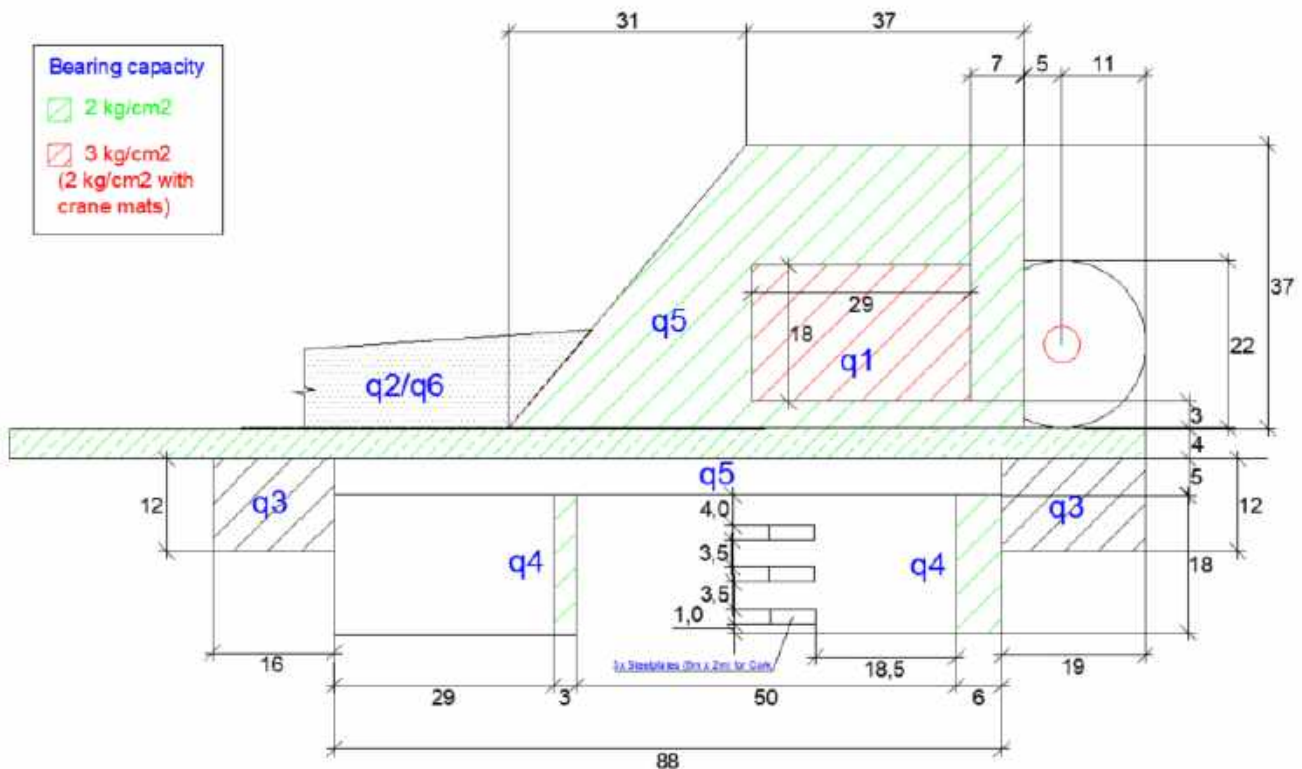
- Tailing crane offloading T100m

| Storage conditions                     | Width x length   |
|--|--|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 37m x 37m + (31m x 37m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane    |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 ....hardstand 3m x 18m + 6m x 18m)<br>q5: 29m x 39m + (32m x 39m)/2 – q1+ 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 28. Dimensions of the areas of model T100m with strategy 4 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – Assembly in 1 phase



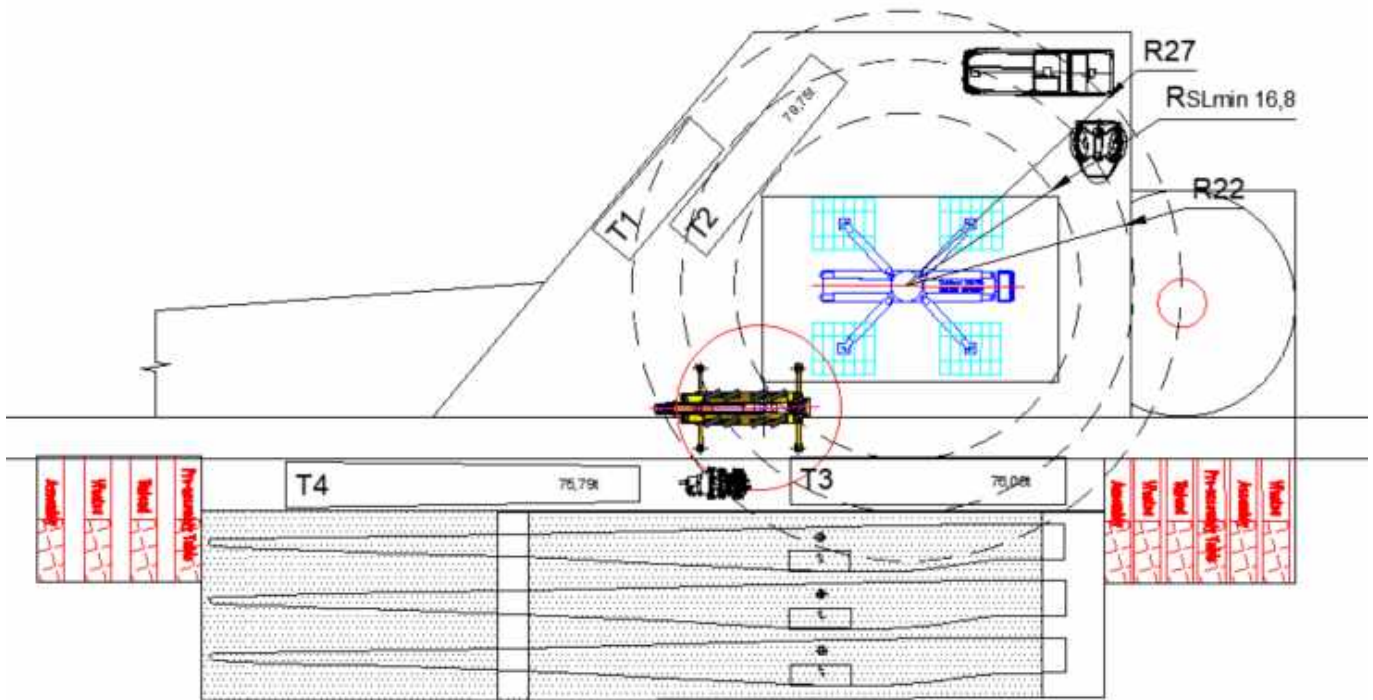
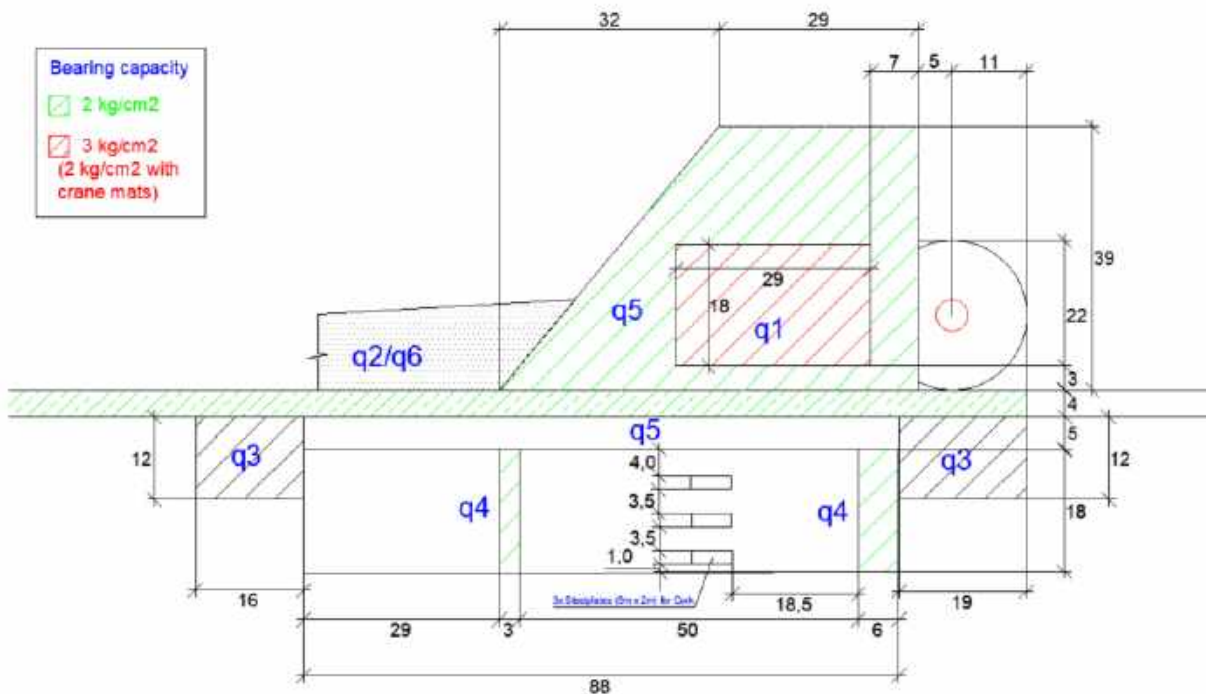


Figure 12 Model T100m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)





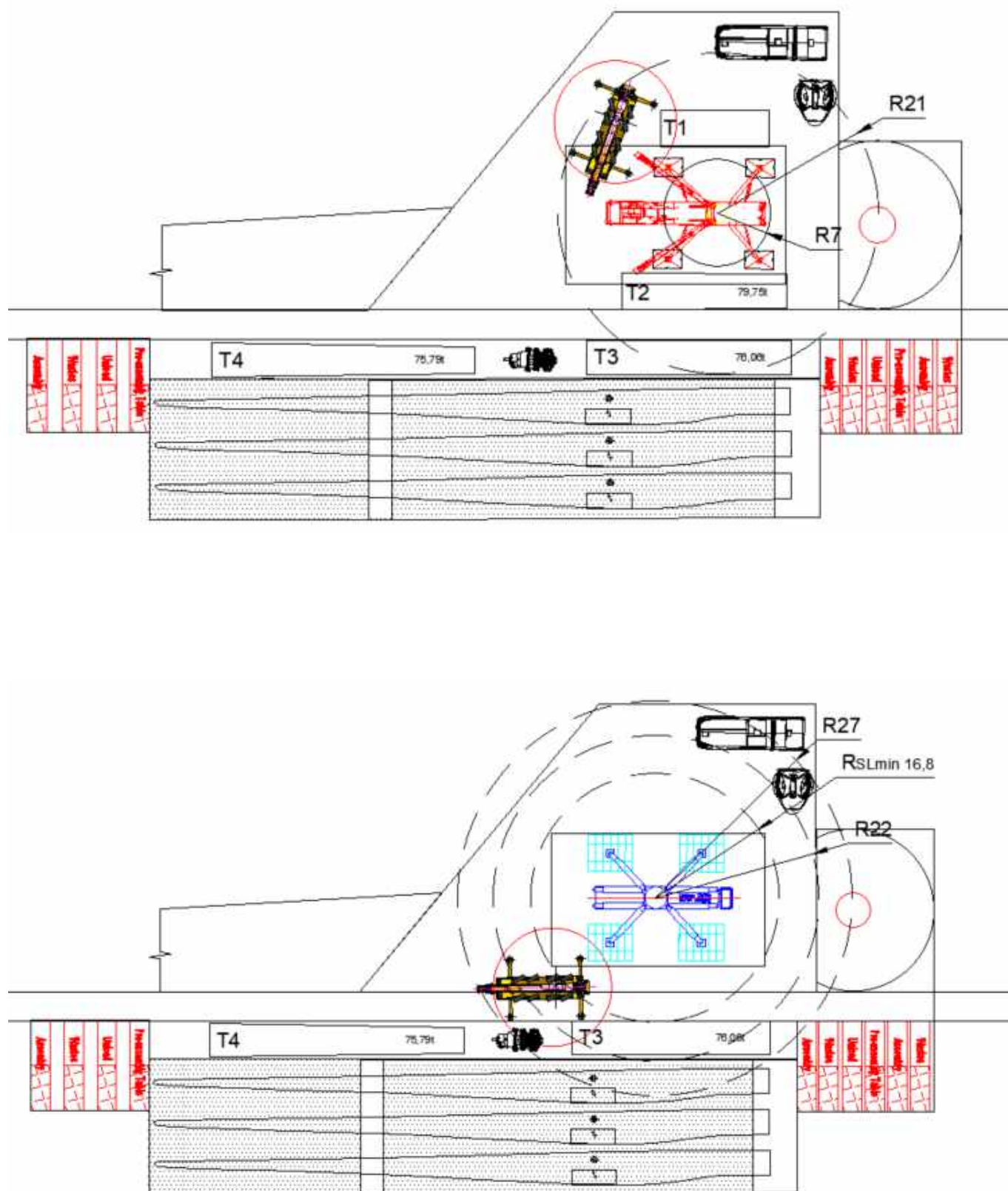


Figure 13 Model T100m – Partial storage assembling with strategy 4 in 2 phases

### 5.5.3. T110.5m tubular steel tower Hardstand with strategy 3

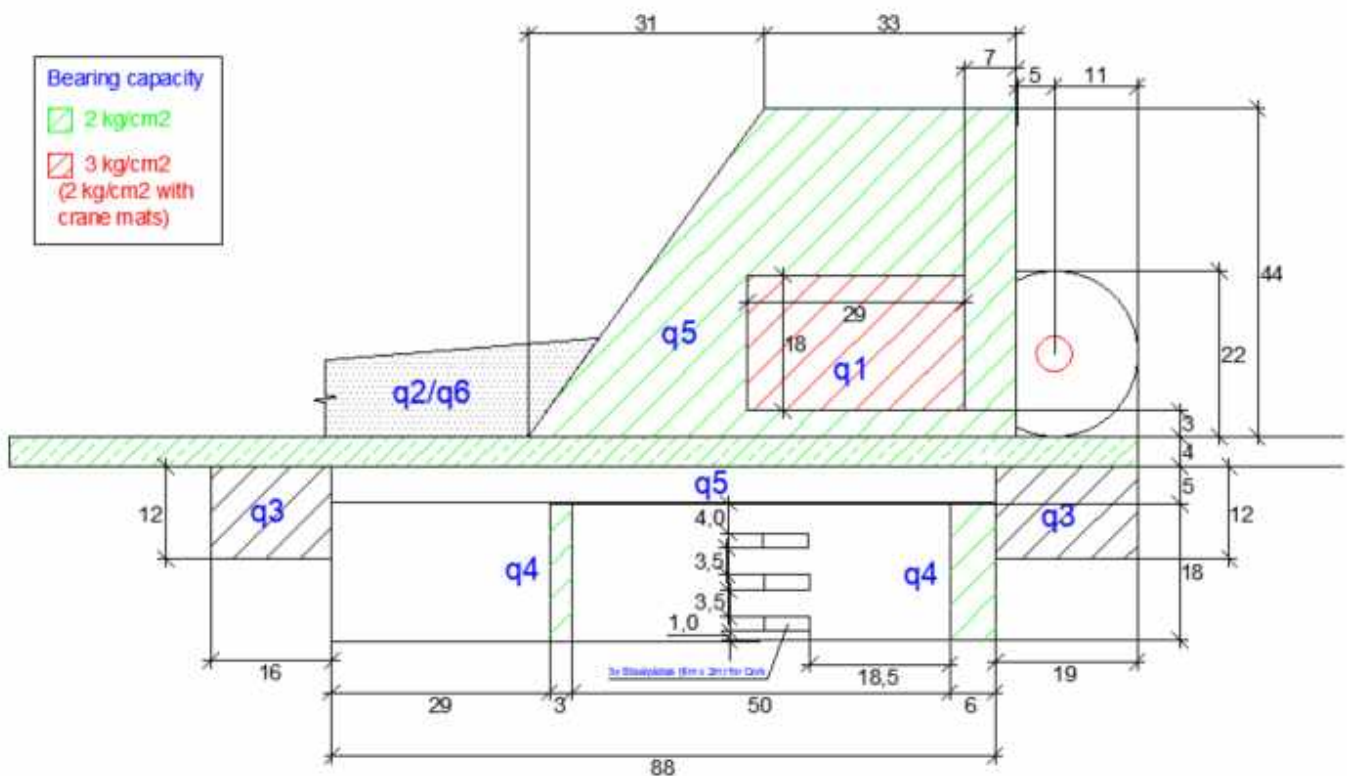
- Tailing crane offloading 110.5m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 ....hardstand 3m x 18m + 6m x 18m)<br>q5: 33m x 44m + (31m x 44m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 ....hardstand 3m x 18m + 6m x 18m)<br>q5: 27m x 44m + (30m x 44m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 29. Dimensions of the areas of model T110.5m with strategy 3 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – Assembly in 1 phase



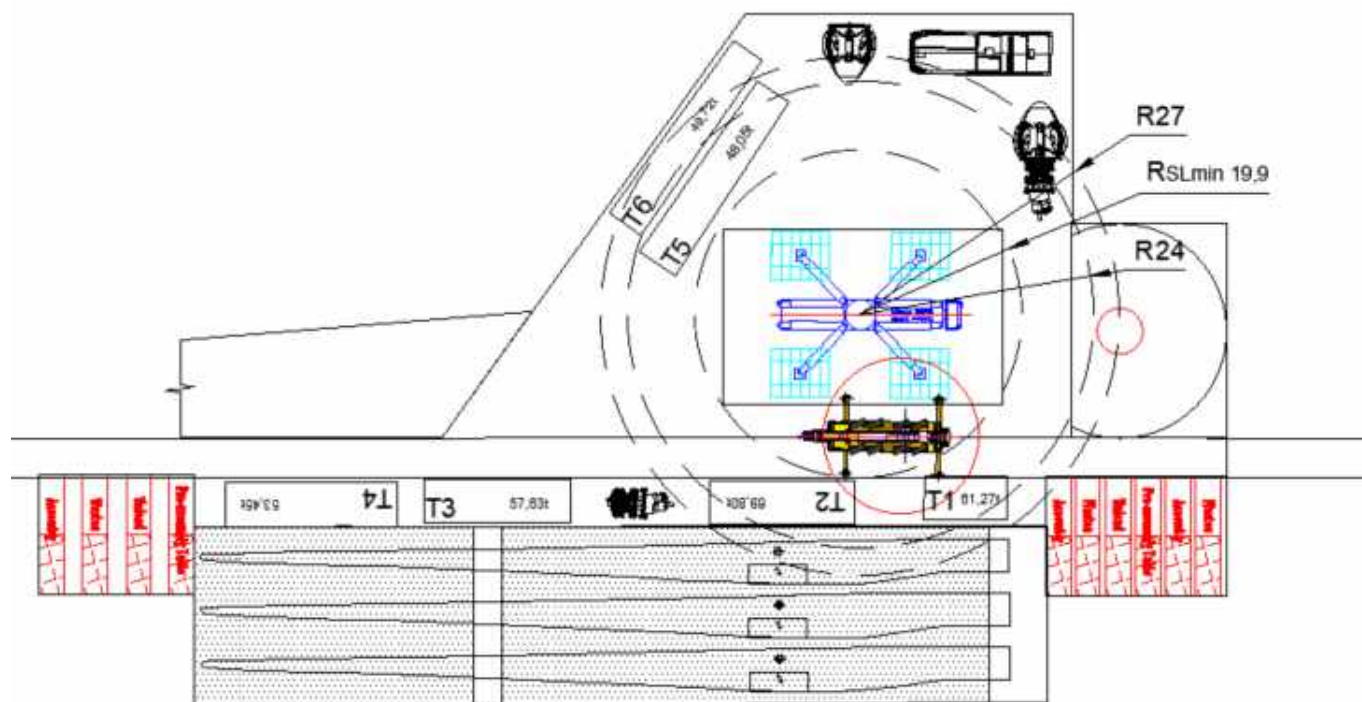
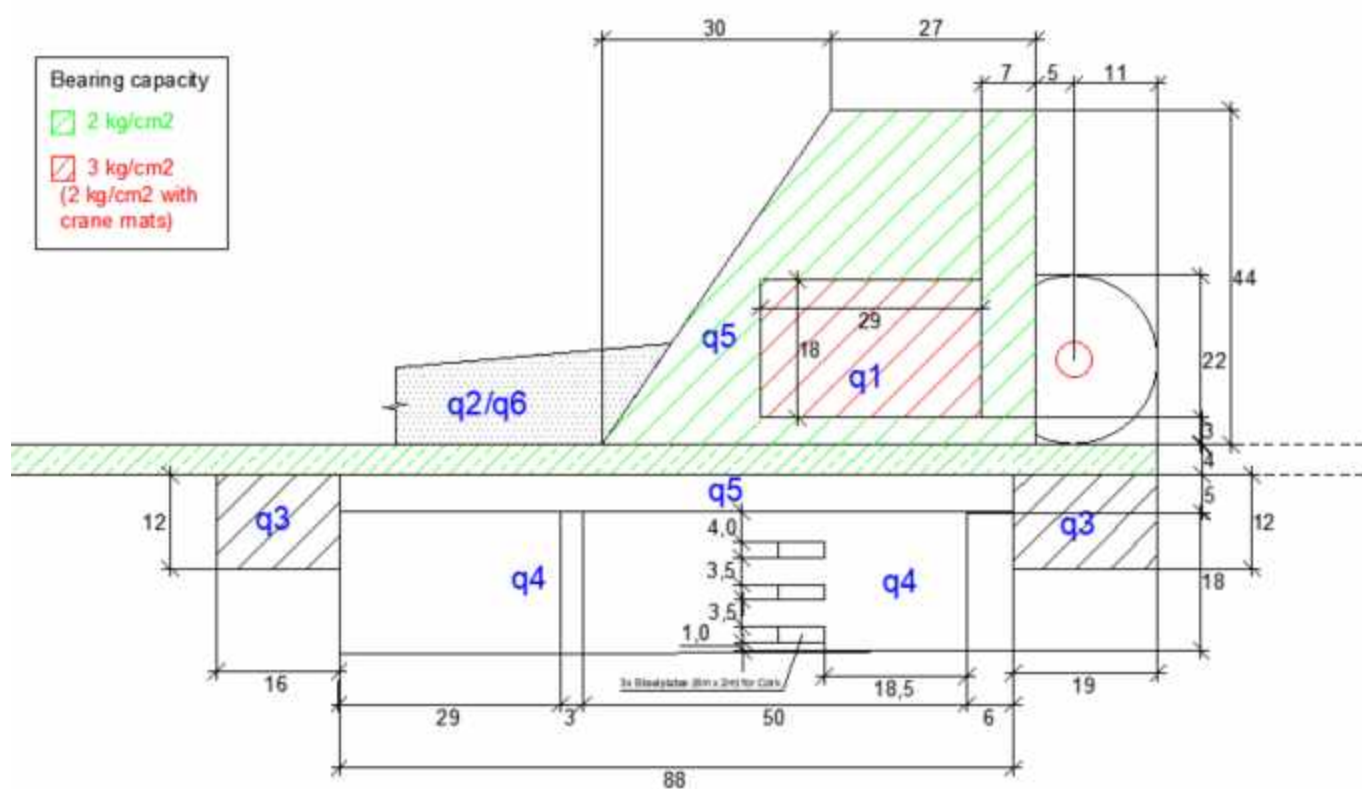


Figure 14 Model T110.5m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE Standard)





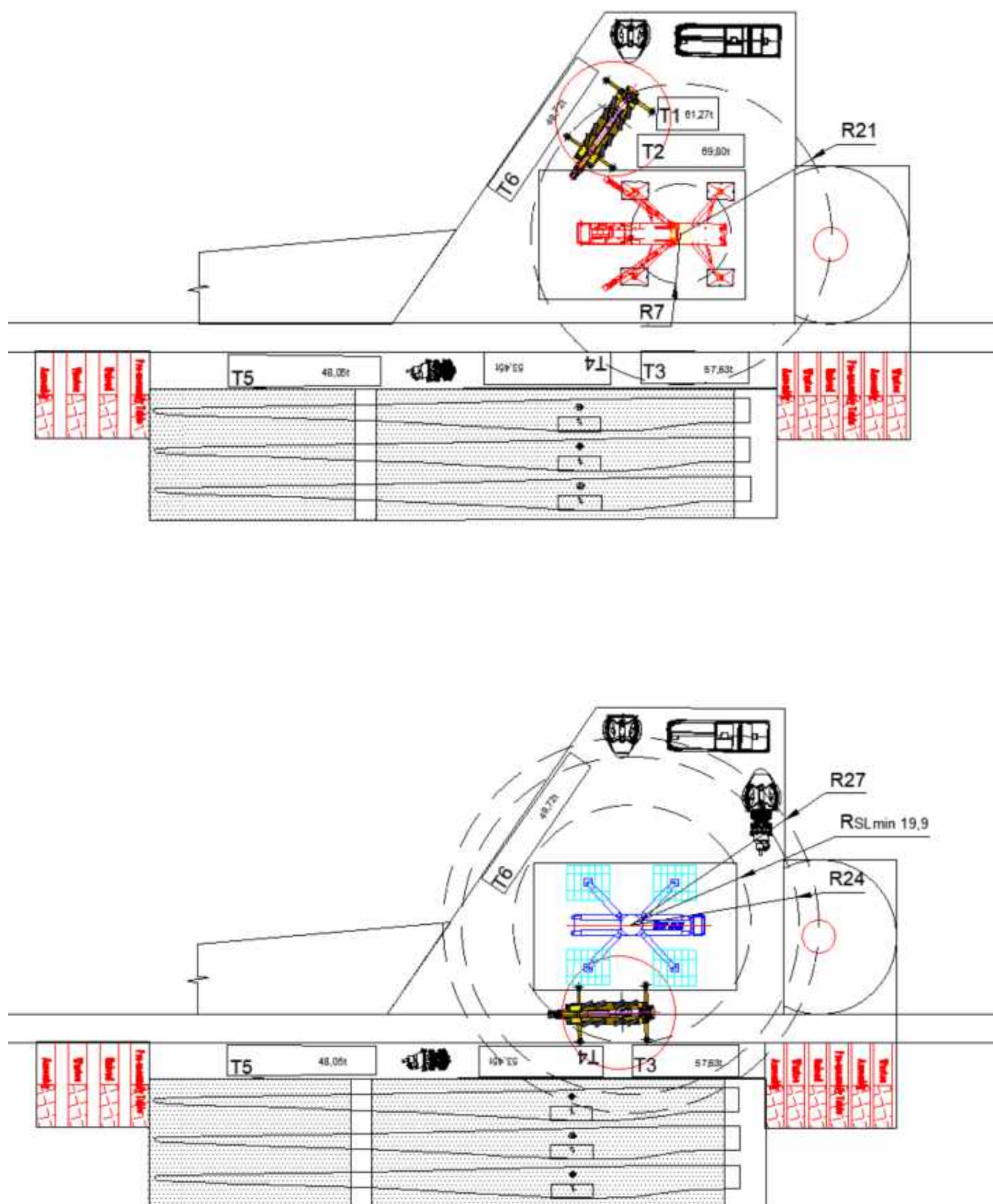


Figure 15 Model T110.5m – Partial storage assembling with strategy 3 in 2 phases

#### 5.5.4. T110.5m tubular steel tower Hardstand with strategy 4

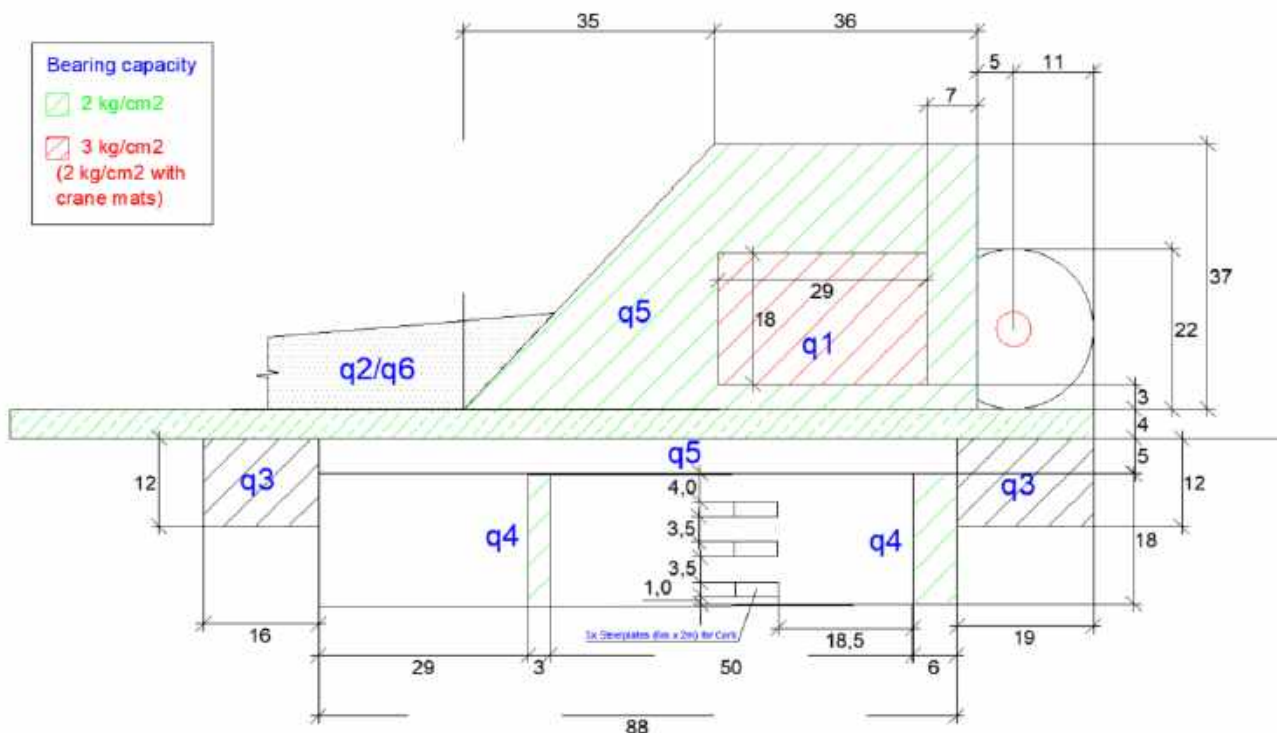
- Tailing crane offloading T110.5m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 36m x 37m + (35m x 37m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 28m x 37m + (35m x 37m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 30.12 Dimensions of the areas of model T110.5m with strategy 4 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – Assembly in 1 phase



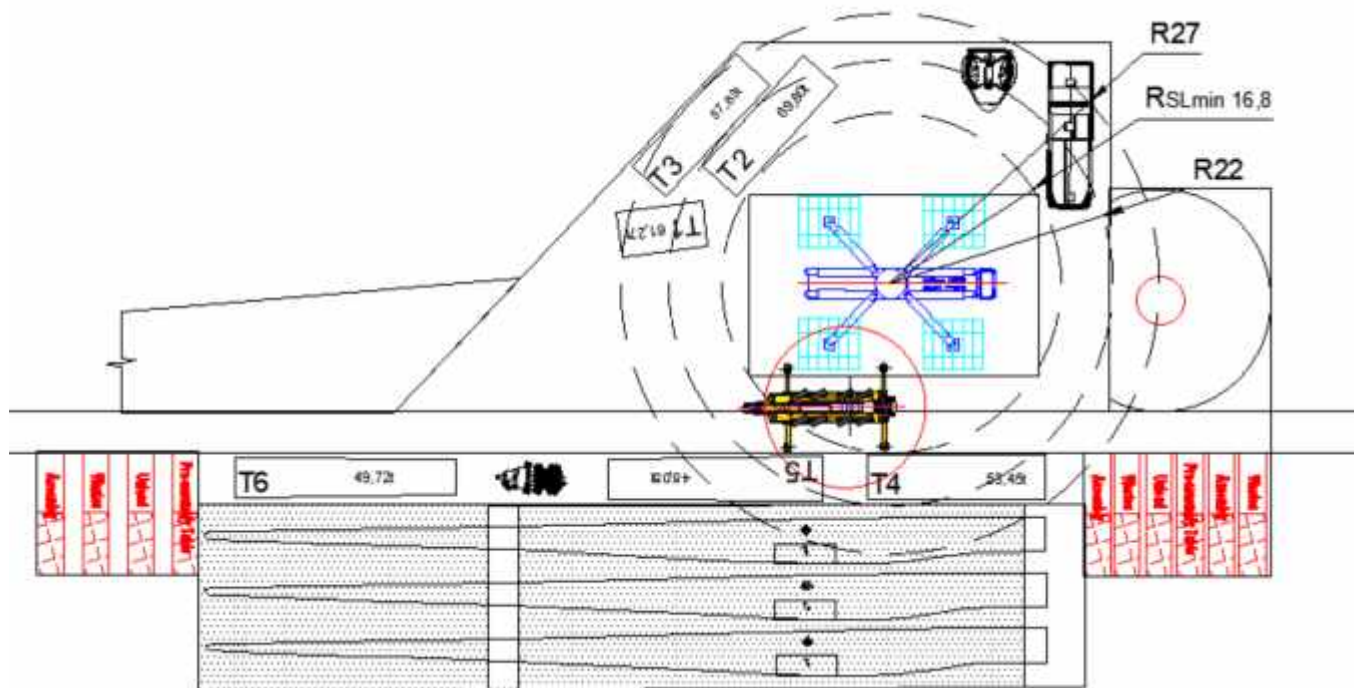
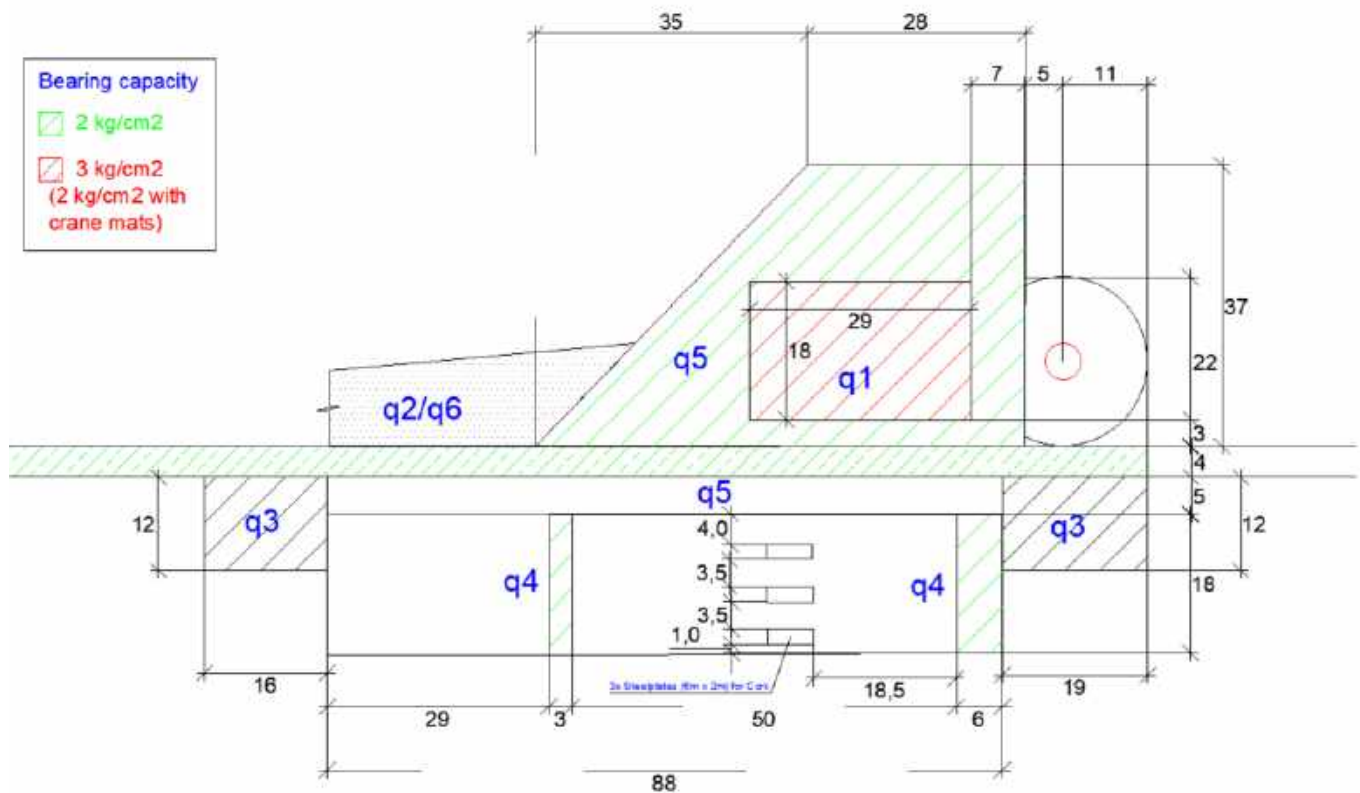


Figure 16 Model T110.5m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)





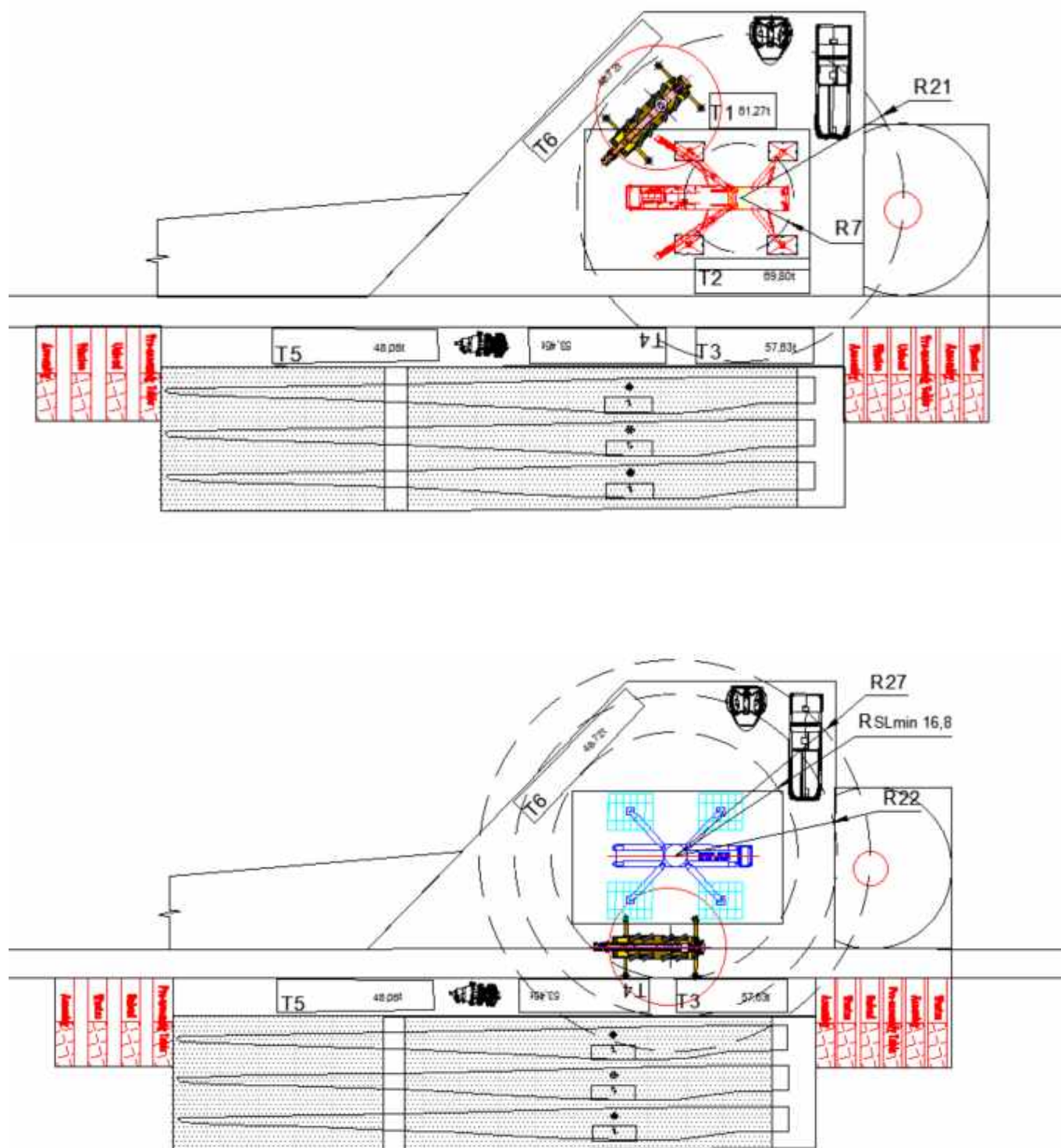


Figure 17 Model T110.5m – Partial storage assembling with strategy 4 in 2 phases

### 5.5.5. T115m tubular steel tower Hardstand with strategy 3

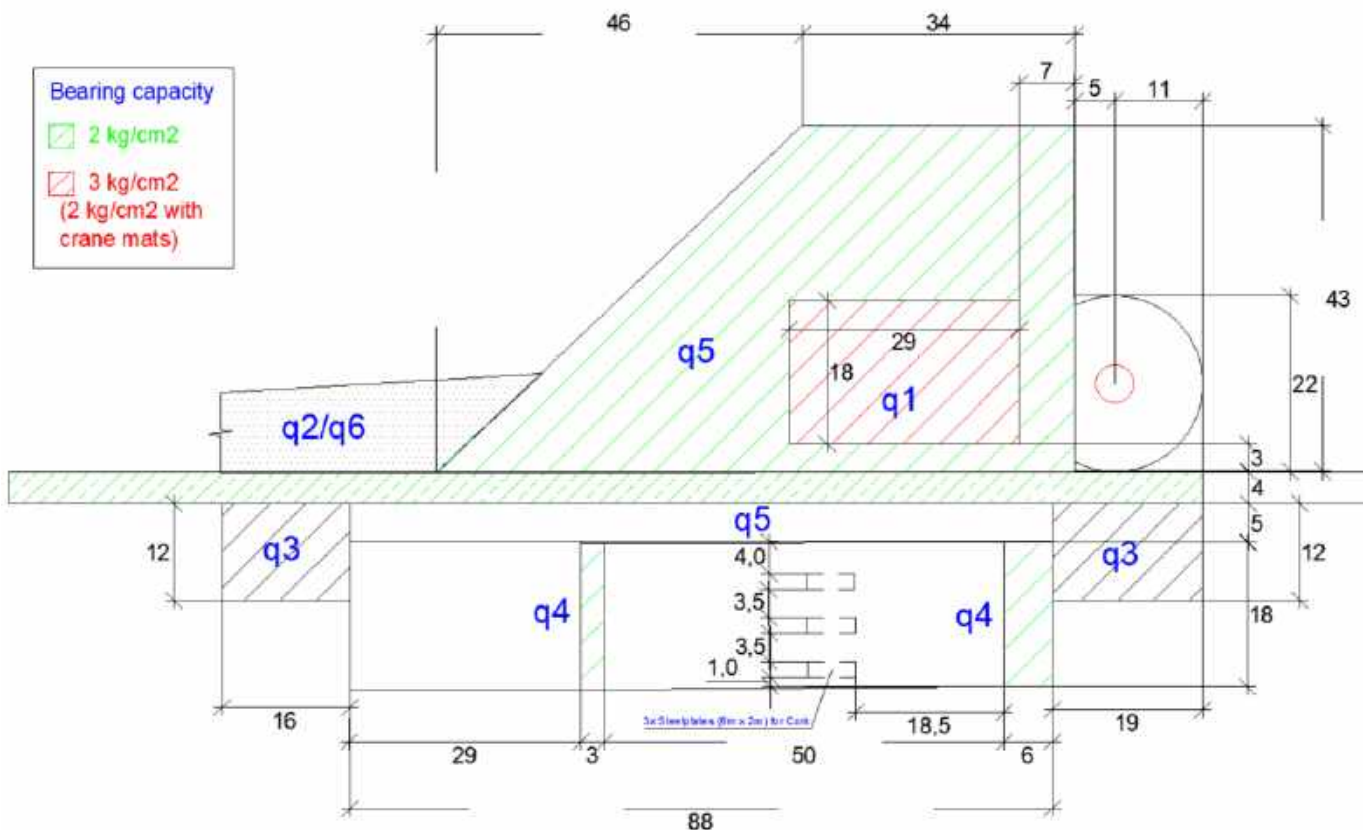
- Tailing crane offloading T115m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 34m x 43m + (46m x 43m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6 dimensions according to the 3.2.7. Requirements for assembly the main crane  |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 33m x 43m + (36m x 43m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |

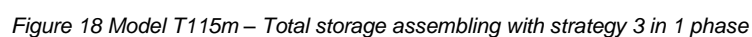
Table 31. Dimensions of the areas of model T115m with strategy 3 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – assembly in 1 phase







- 
- Bearing capacity**
- 2 kg/cm<sup>2</sup>
  - 3 kg/cm<sup>2</sup>  
(2 kg/cm<sup>2</sup> with crane mats)
- Dimensions (m): 36, 33, 7, 5, 11, 43, 22, 3, 4, 5, 12, 16, 29, 3, 50, 18.5, 6, 19, 88, 4.0, 3.5, 3.5, 1.0.
- Areas: q1, q2/q6, q3, q4, q5.
- Note: 3x Streifengates (50m x 20m) für Crane

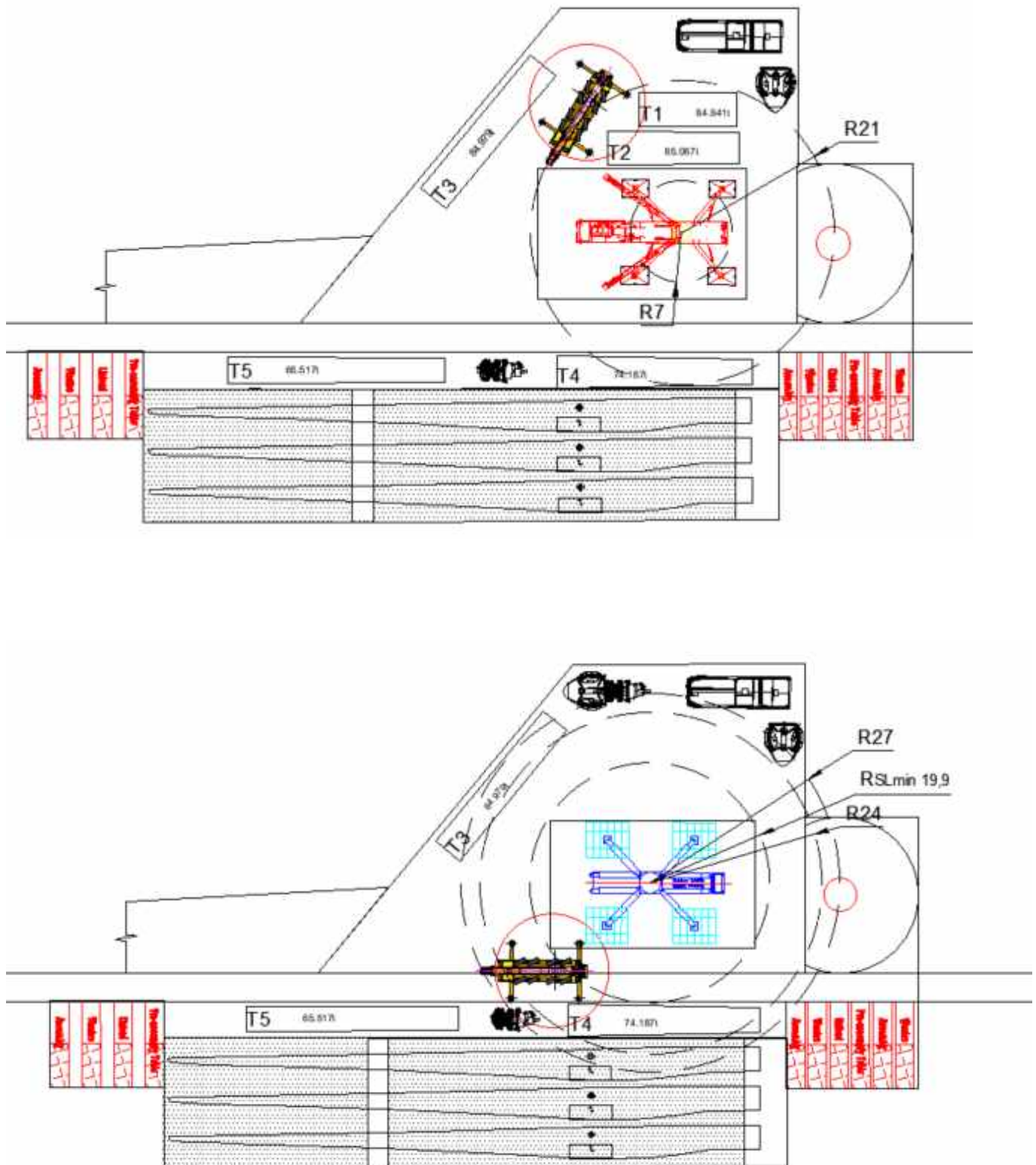


Figure 19 Model T115m – Partial storage assembling with strategy 3 in 2 phases

#### 5.5.6. T115m tubular steel tower Hardstand with strategy 4

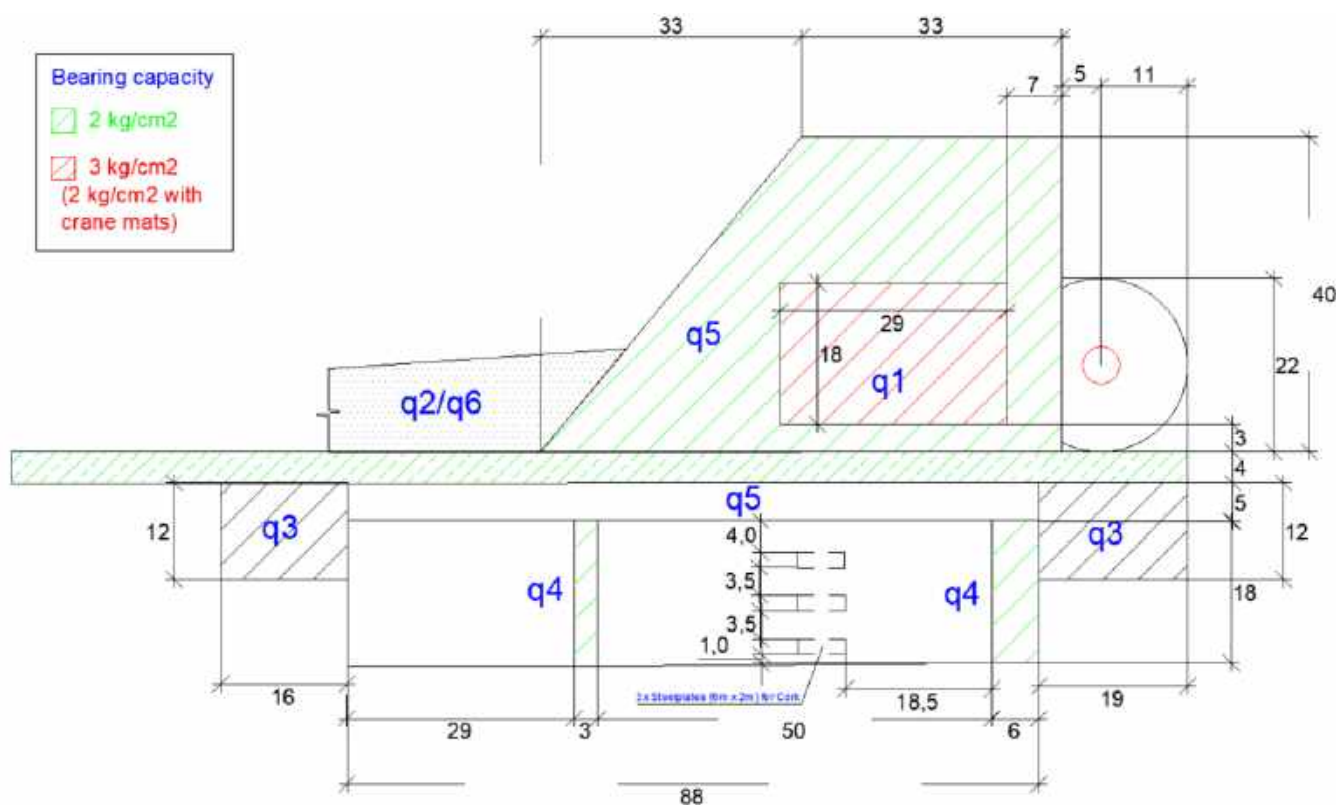
- Tailing crane offloading T115m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 33m x 40m + (33m x 40m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 30m x 38m + (31m x 38m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 32. Dimensions of the areas of model T115m with strategy 4 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – Assembly strategy in 1 phase





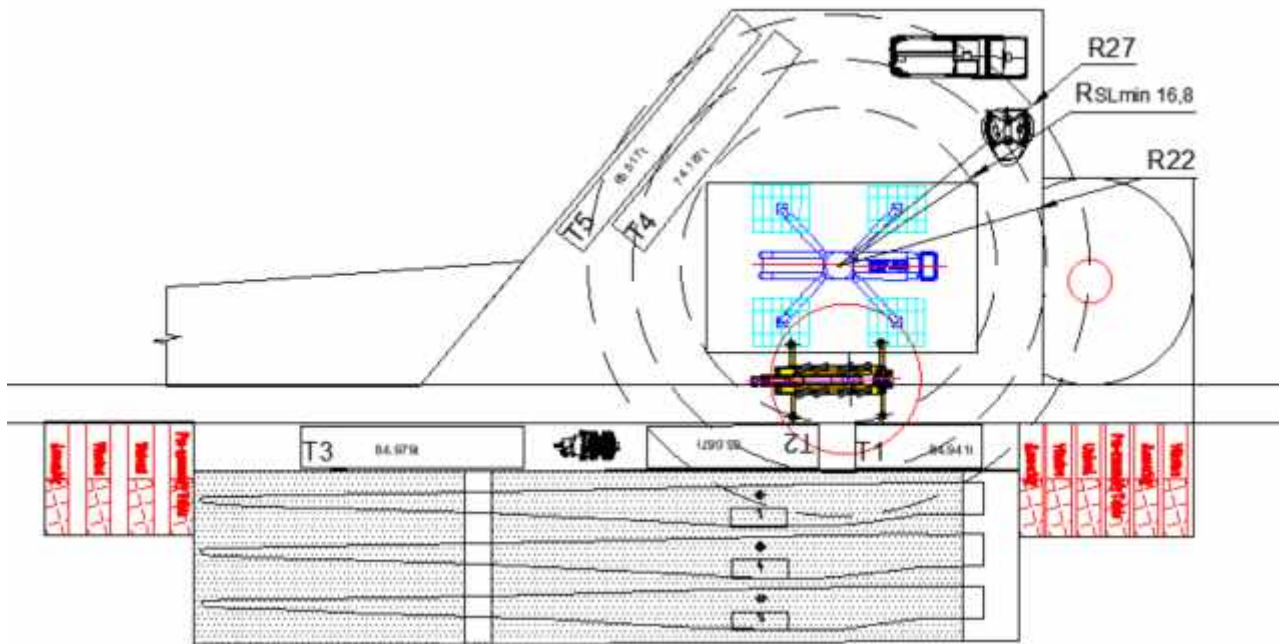
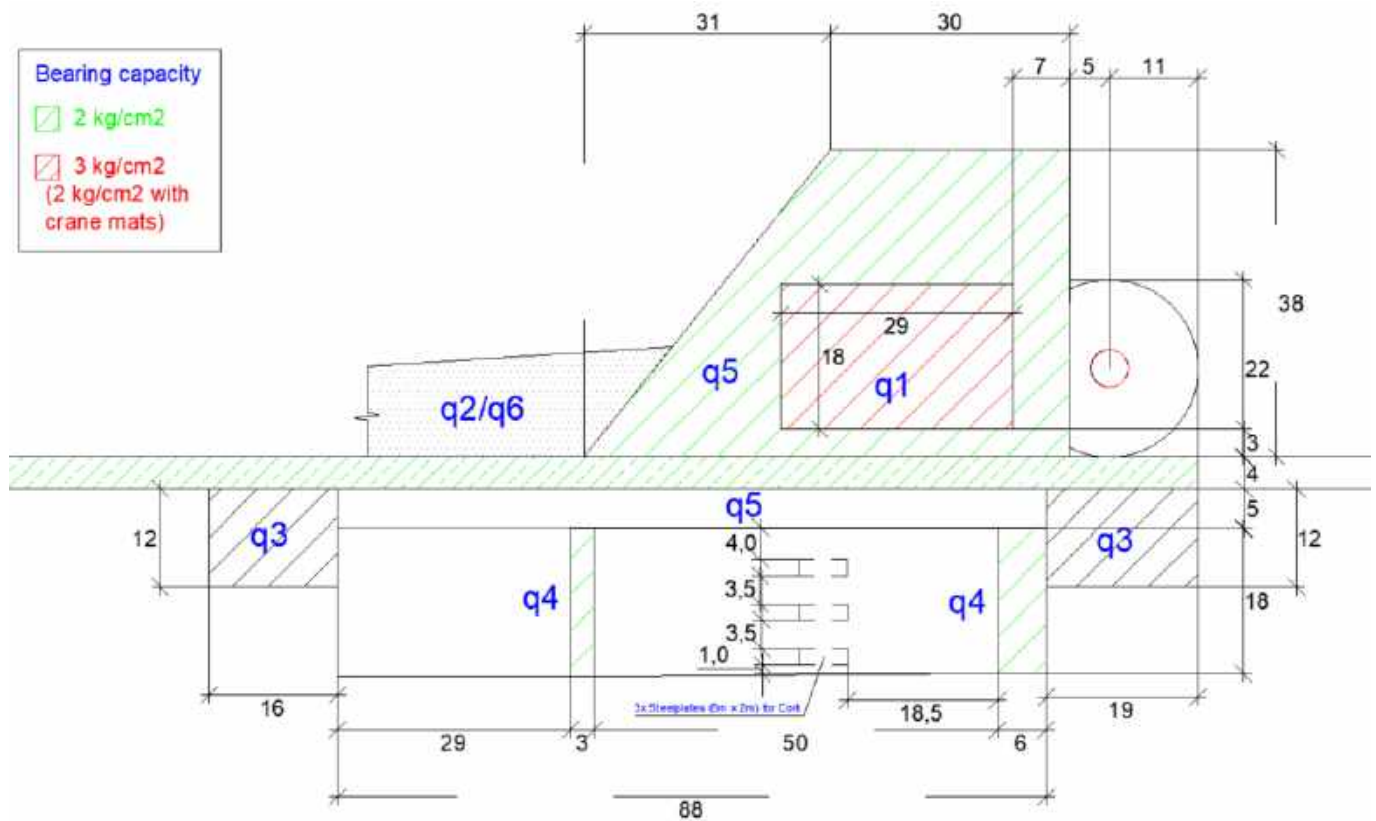


Figure 20 Model T115m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)



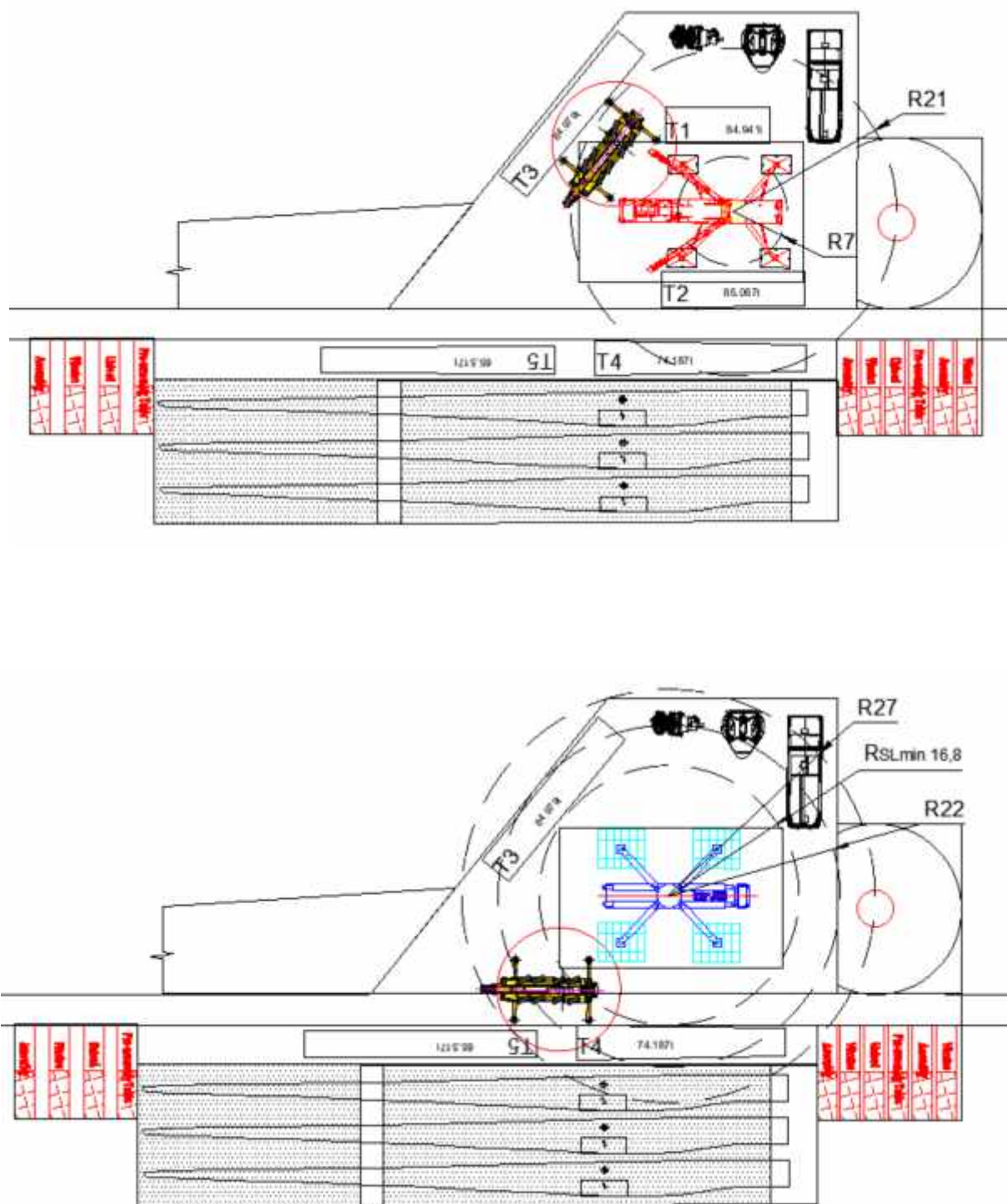


Figure 21 Model T115m – Partial storage assembling with strategy 4 in 2 phases

### 5.5.7. T135m (52A) tubular steel tower Hardstand with strategy 3

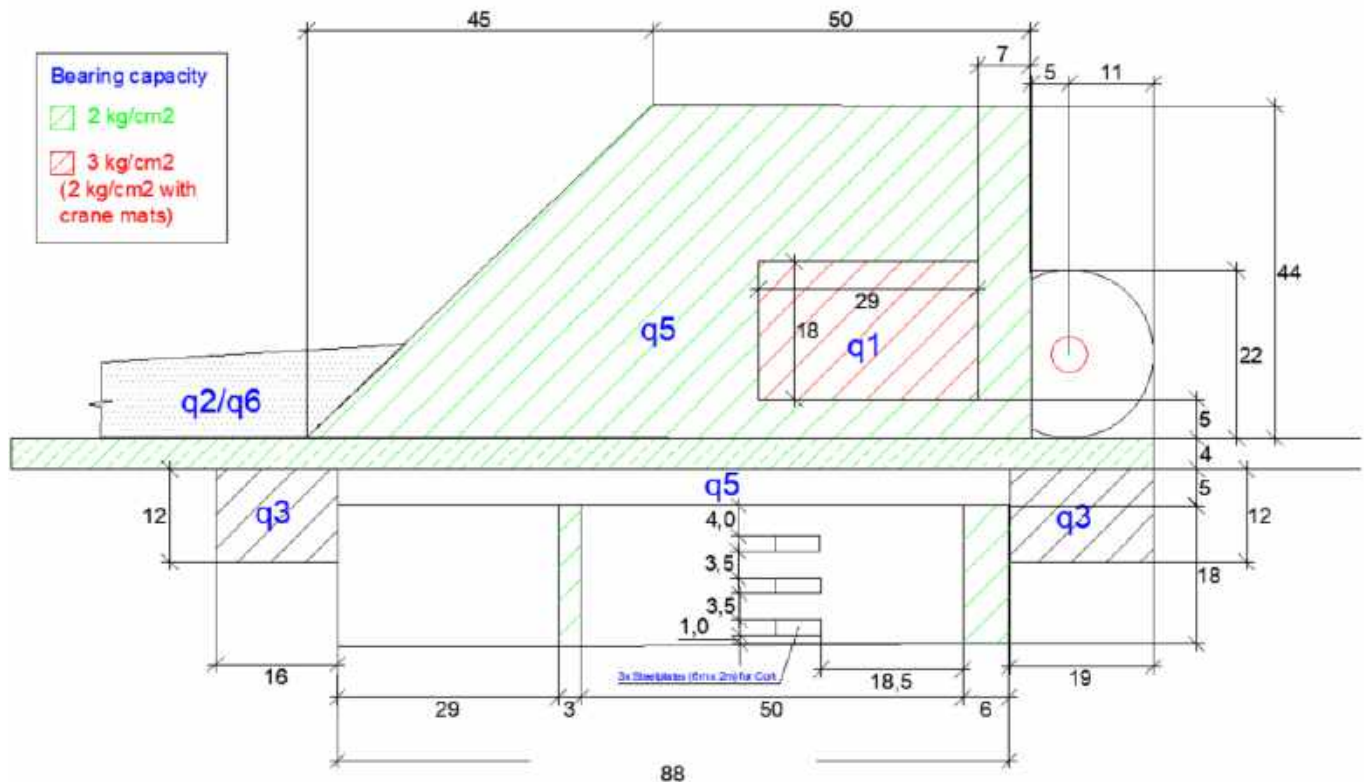
- Tailing crane offloading T135m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 50m x 44m + (45m x 44m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6 dimensions according to the 3.2.7. Requirements for assembly the main crane  |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 41m x 45m + (28m x 45m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 33. Dimensions of the areas of model T135m (52A) with strategy 3 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – Assembly in 1 phase – STD tower





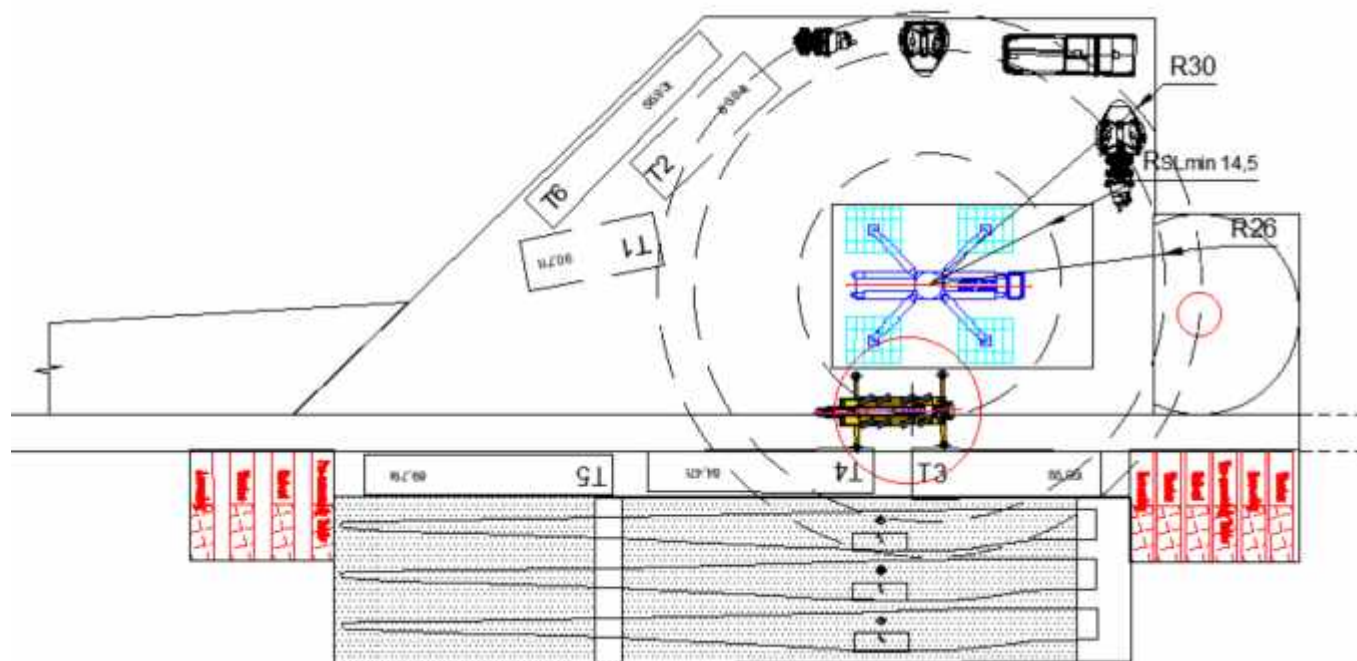
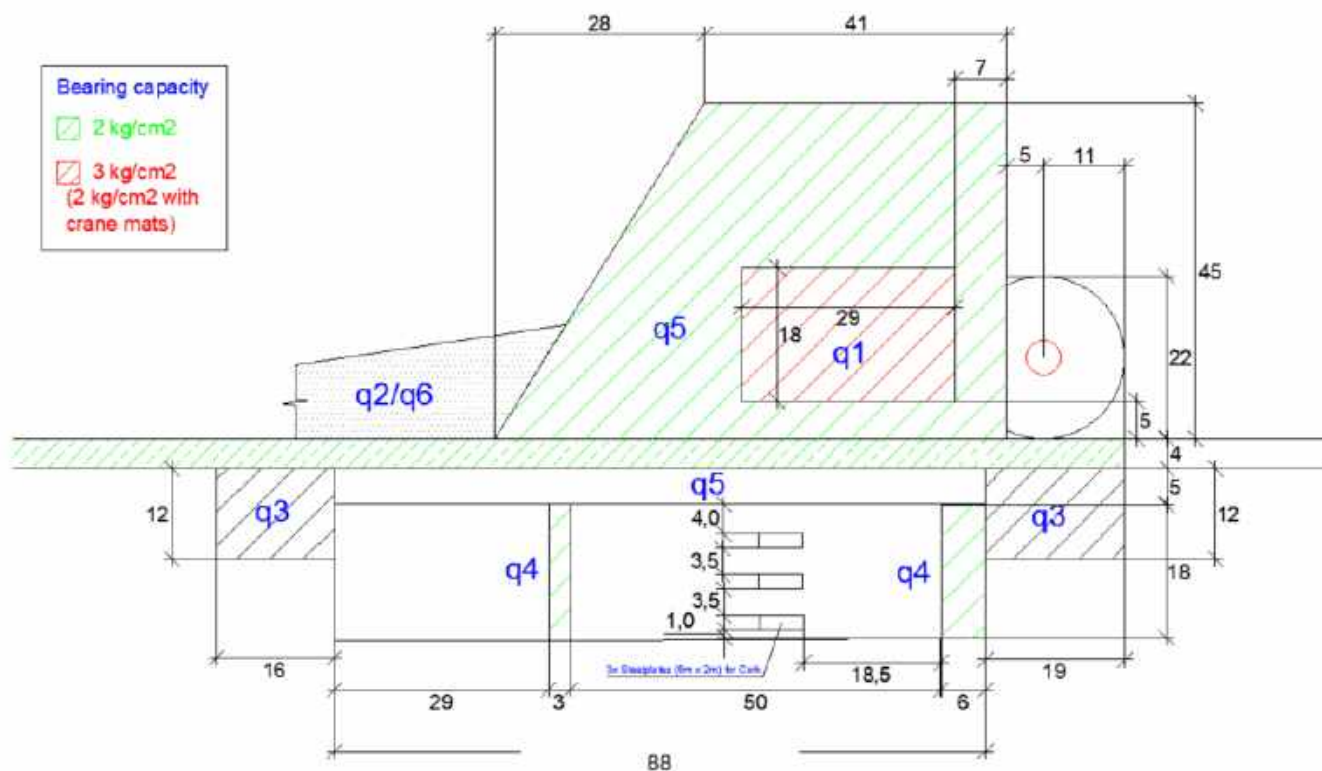


Figure 22. Model T135m (52A) – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower



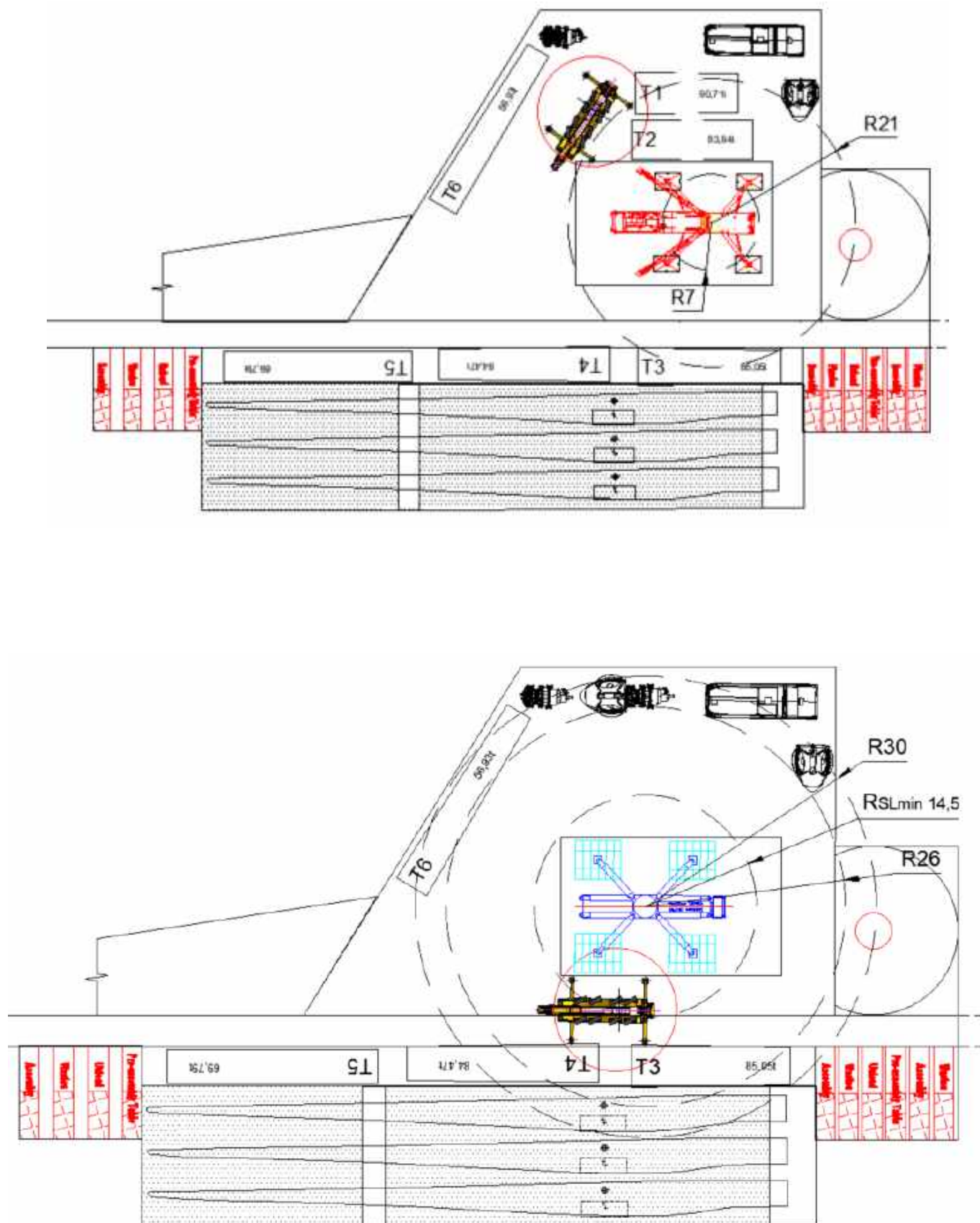


Figure 23. Model T135m (52A) - Partial storage assembling with strategy 3 in 2 phases



### 5.5.8. T135m (52A) tubular steel tower Hardstand with strategy 4

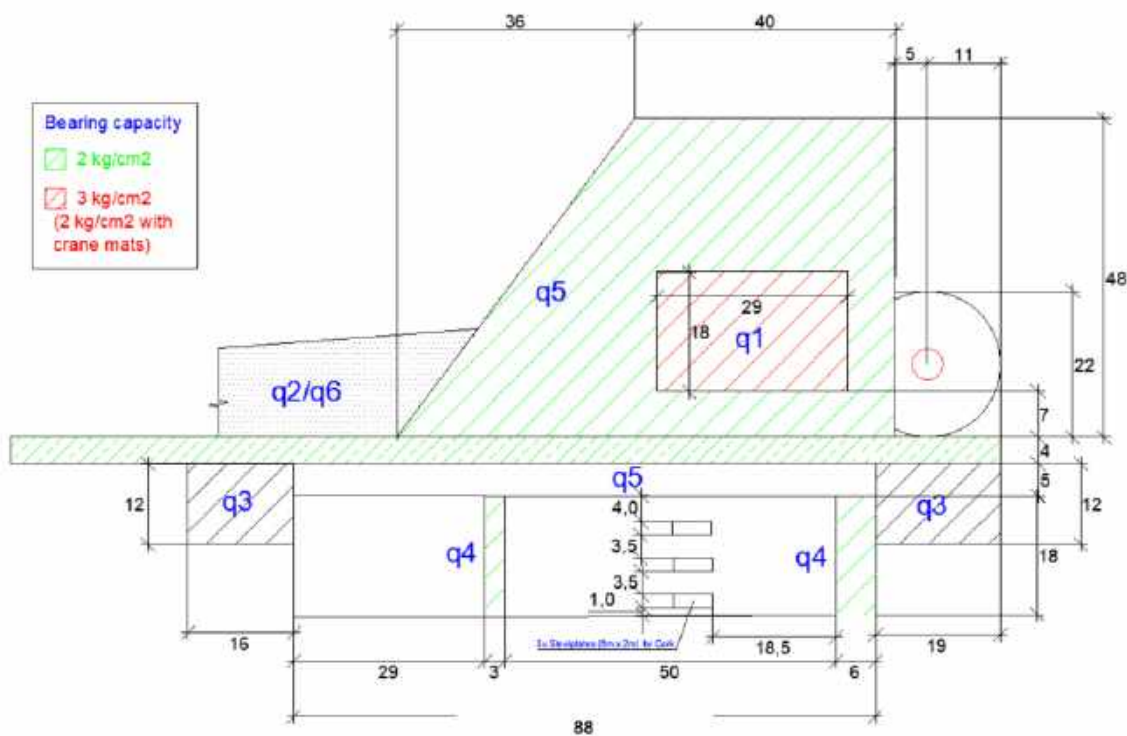
- Tailing crane offloading T135m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 40m x 48m + (36m x 48m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 32m x 48m + (36m x 48m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 34. Dimensions of the areas of model T135m (52A) with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1 phase



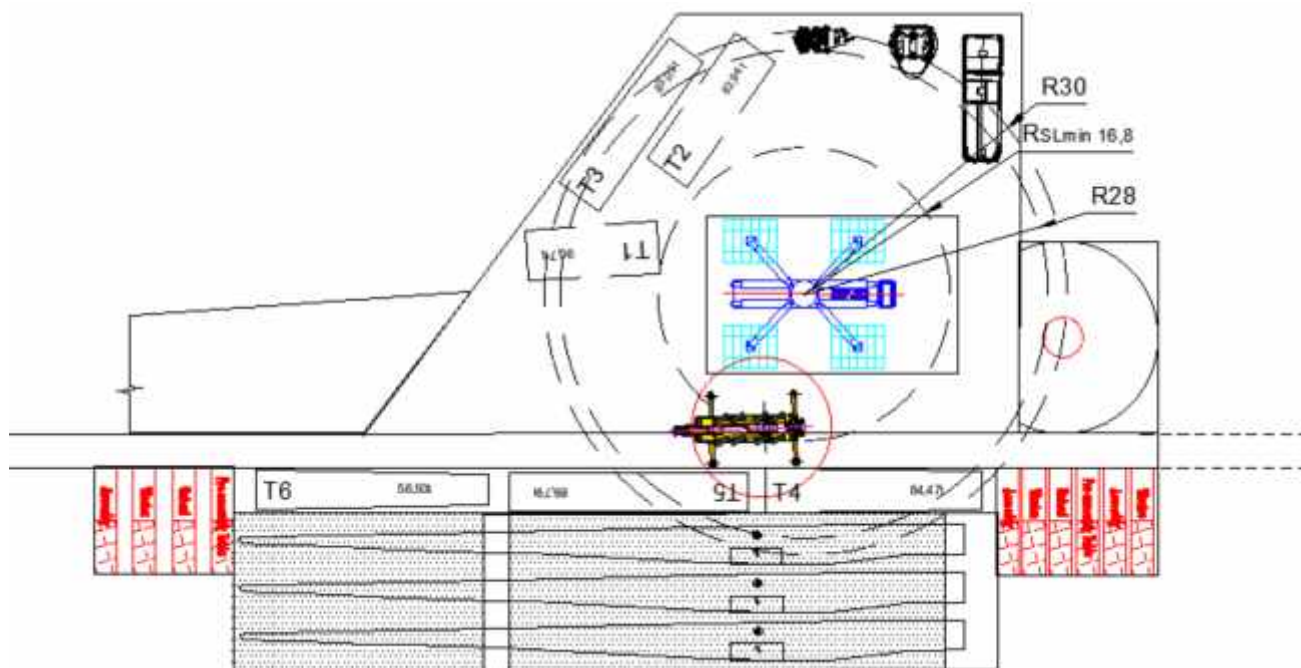
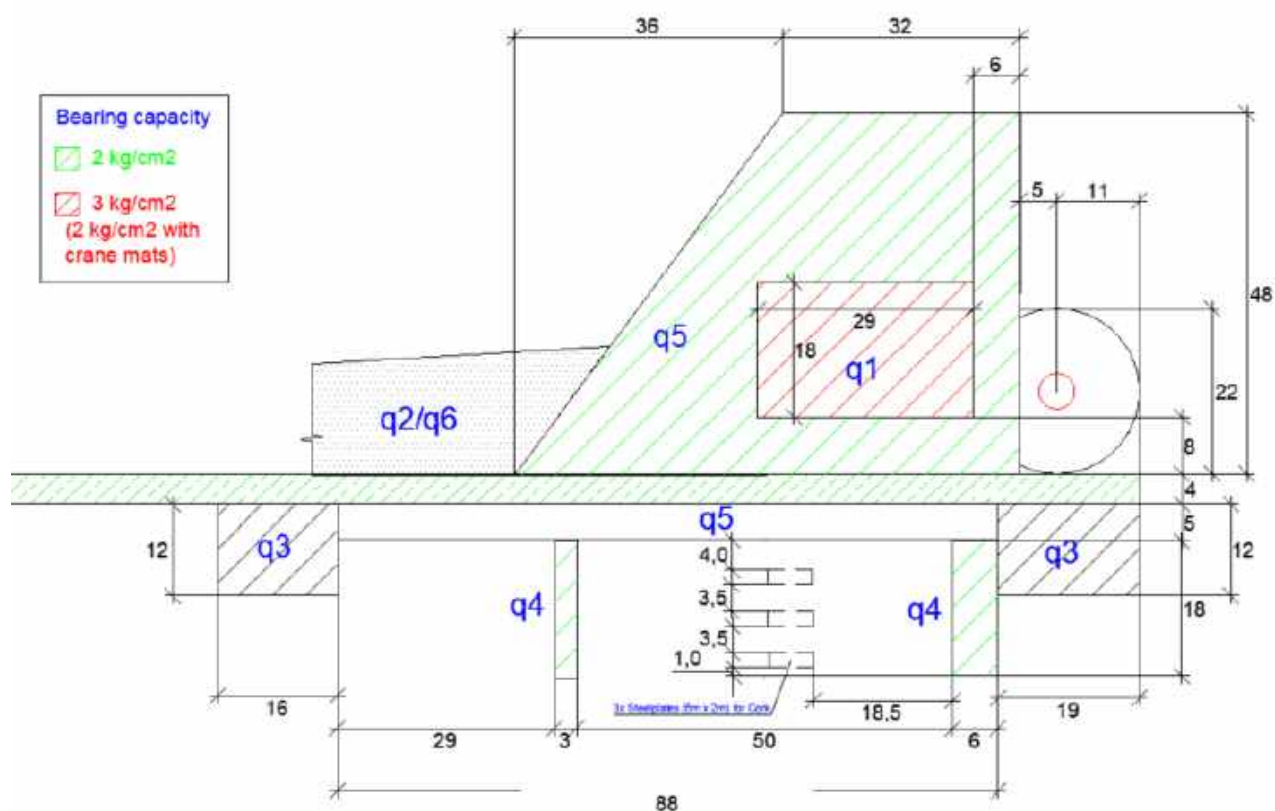


Figure 24. Model T135m (52A) – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)



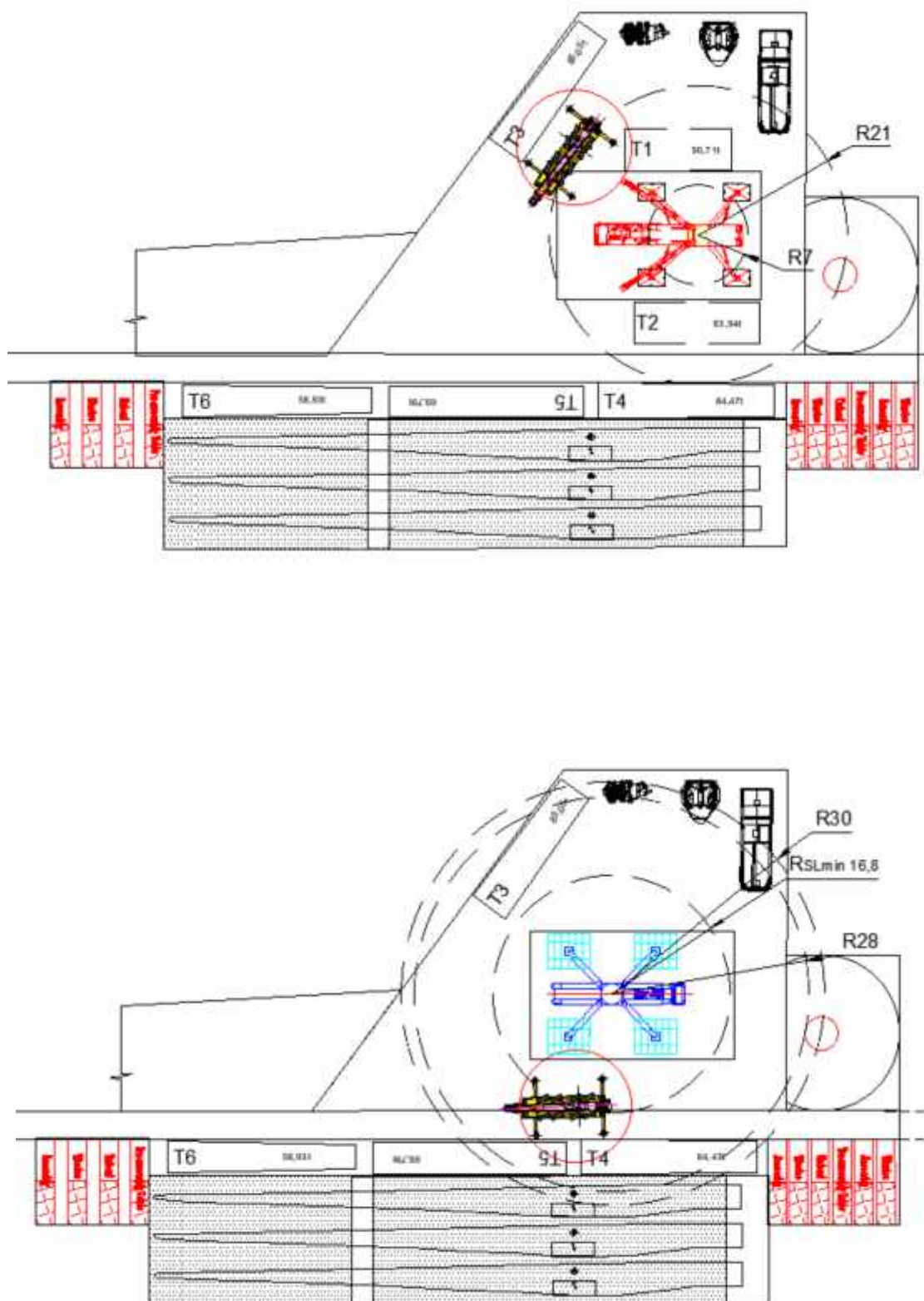


Figure 25. Model T135m (52A) - Partial storage assembling with strategy 4 in 2 phases

### 5.5.9. T135m (54A) tubular steel tower Hardstand with strategy 3

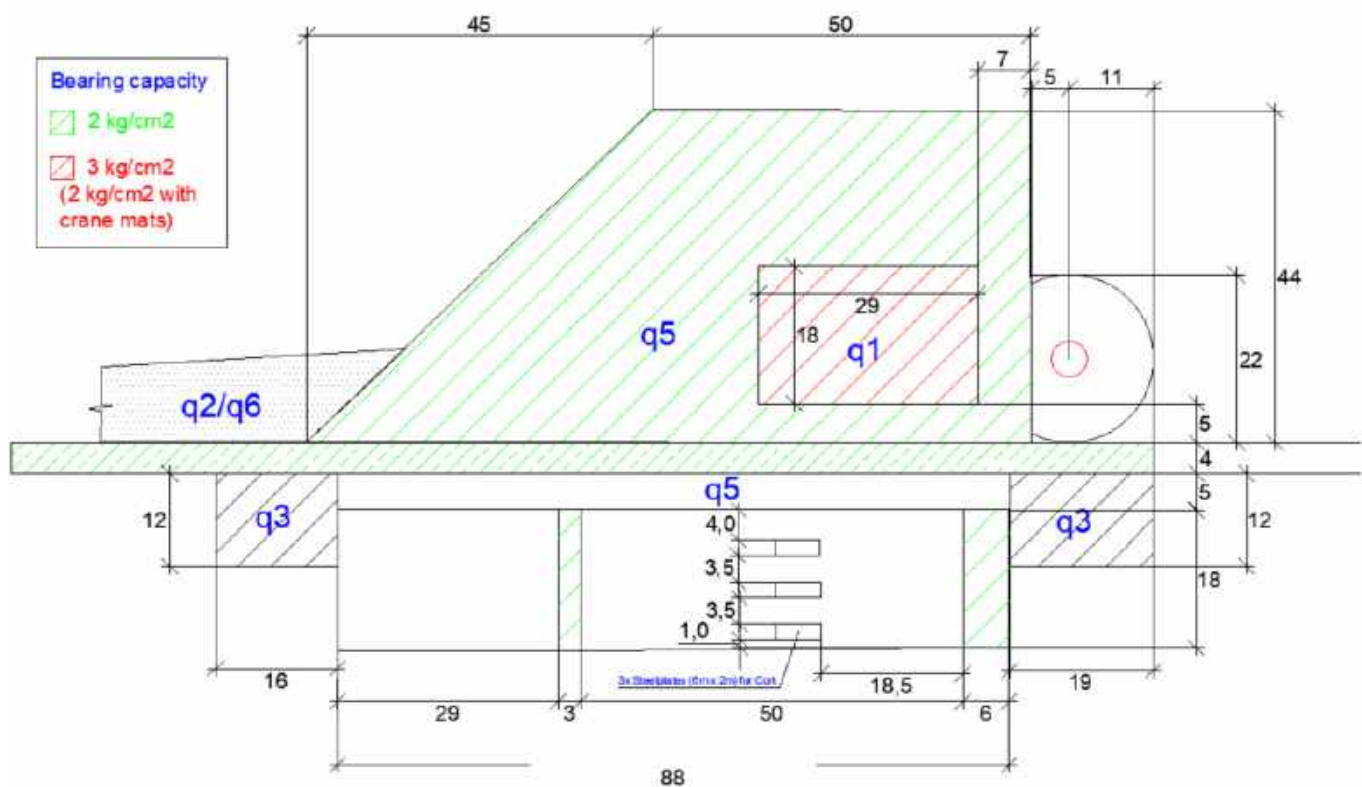
- Tailing crane offloading T135m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 50m x 44m + (45m x 44m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 41m x 45m + (28m x 45m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 35. Dimensions of the areas of model T135m (54A) with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase – STD tower





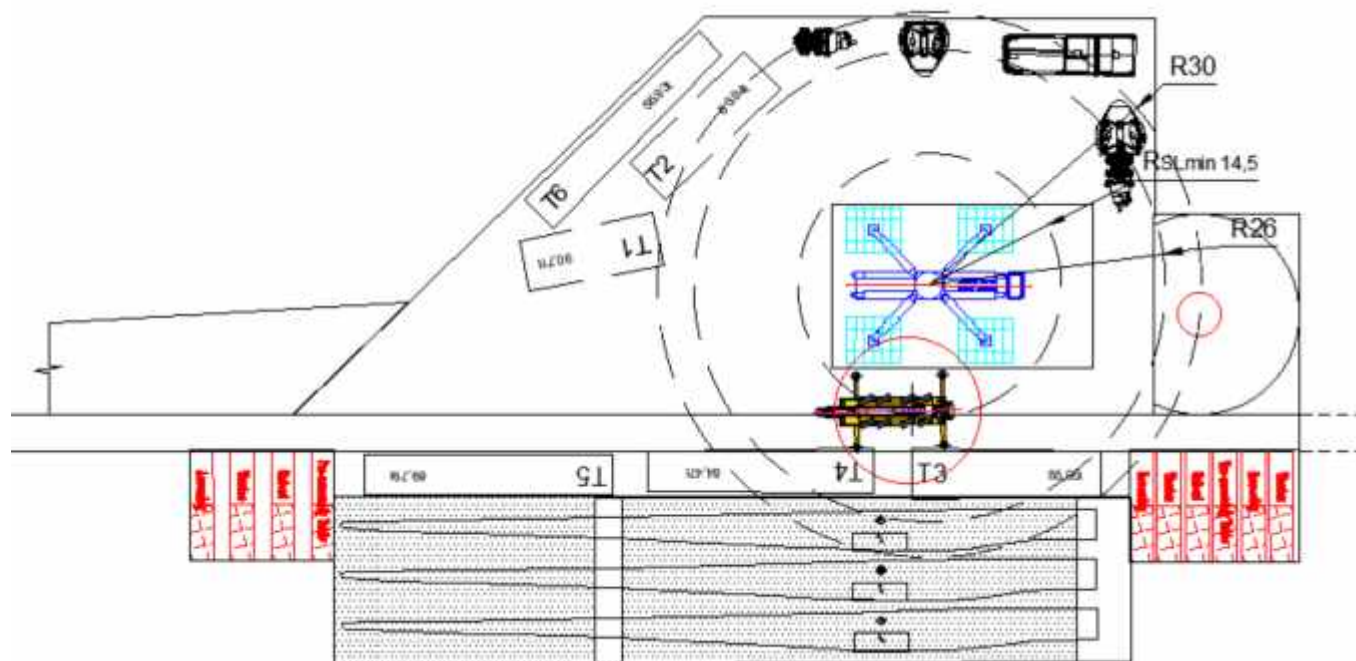
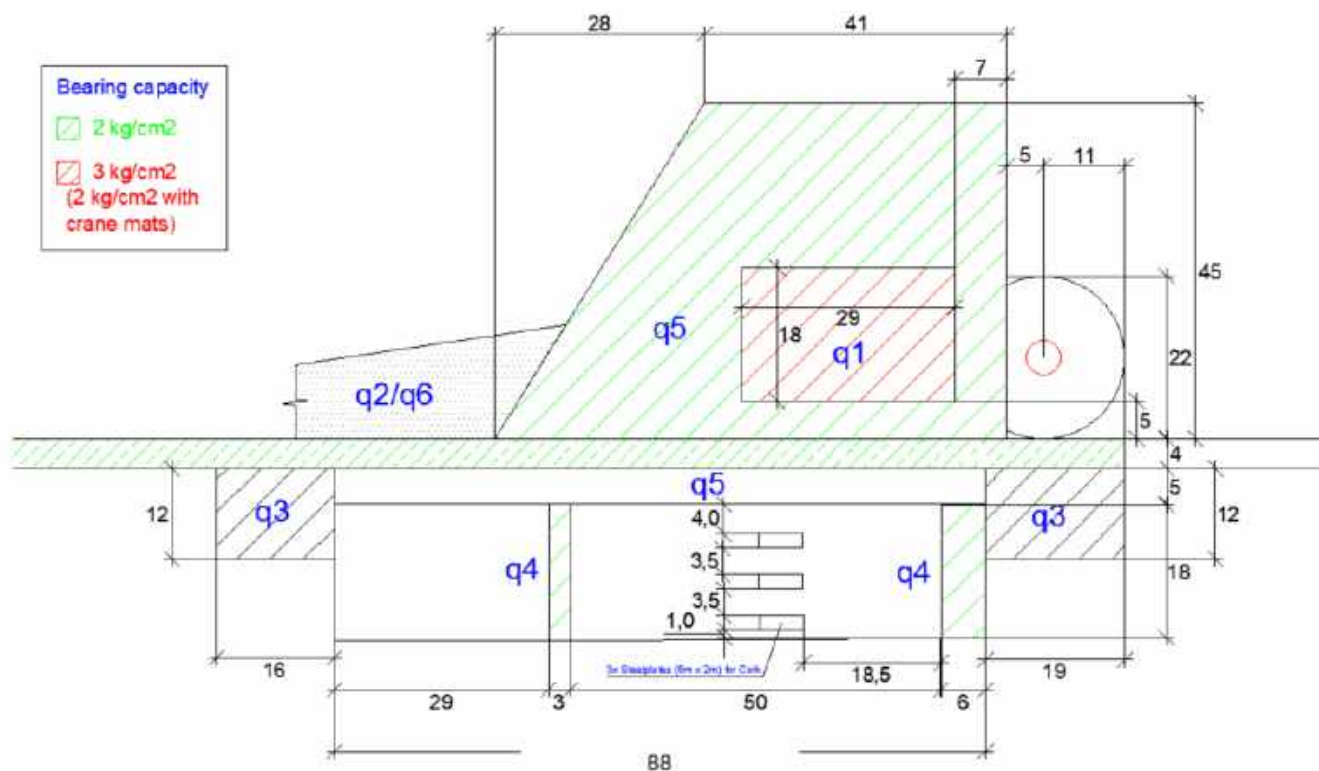
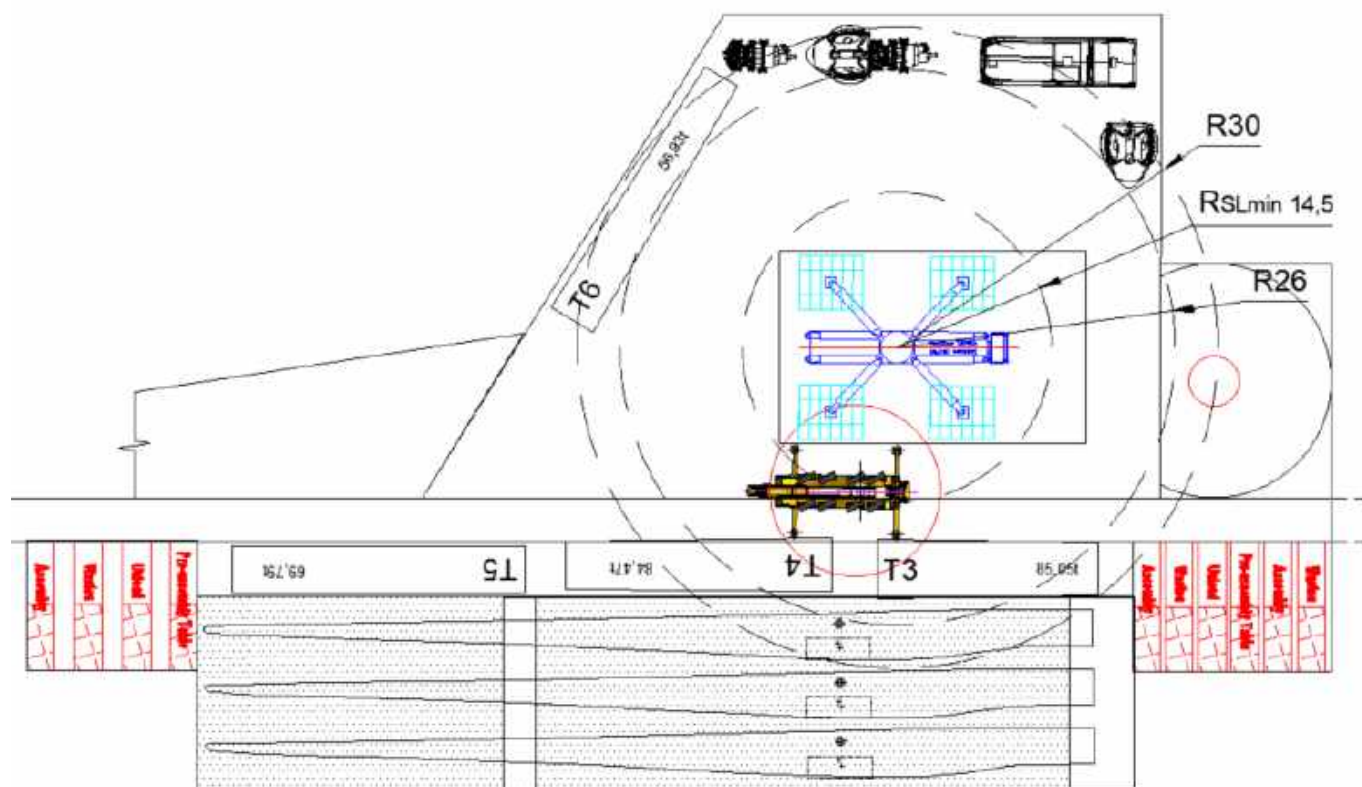


Figure 26. Model T135m (54A) – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower





**D3120697/0024 – Confidential**  
© Siemens Gamesa Renewable Energy S.A., 2022. All rights reserved.

#### 5.5.10. T135m (54A) tubular steel tower Hardstand with strategy 4

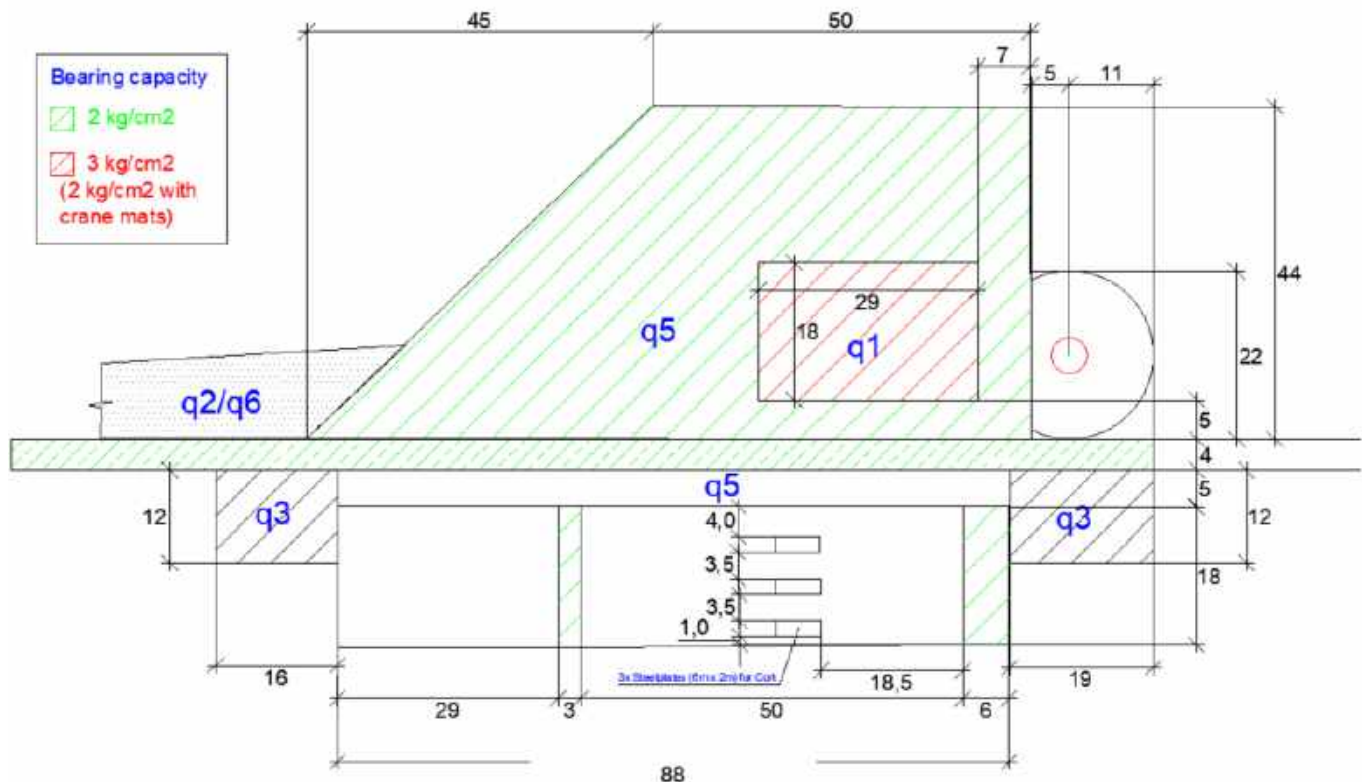
- Tailing crane offloading T135m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 50m x 44m + (45m x 44m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 41m x 45m + (28m x 45m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 36. Dimensions of the areas of model T135m (54A) with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1 phase – STD tower





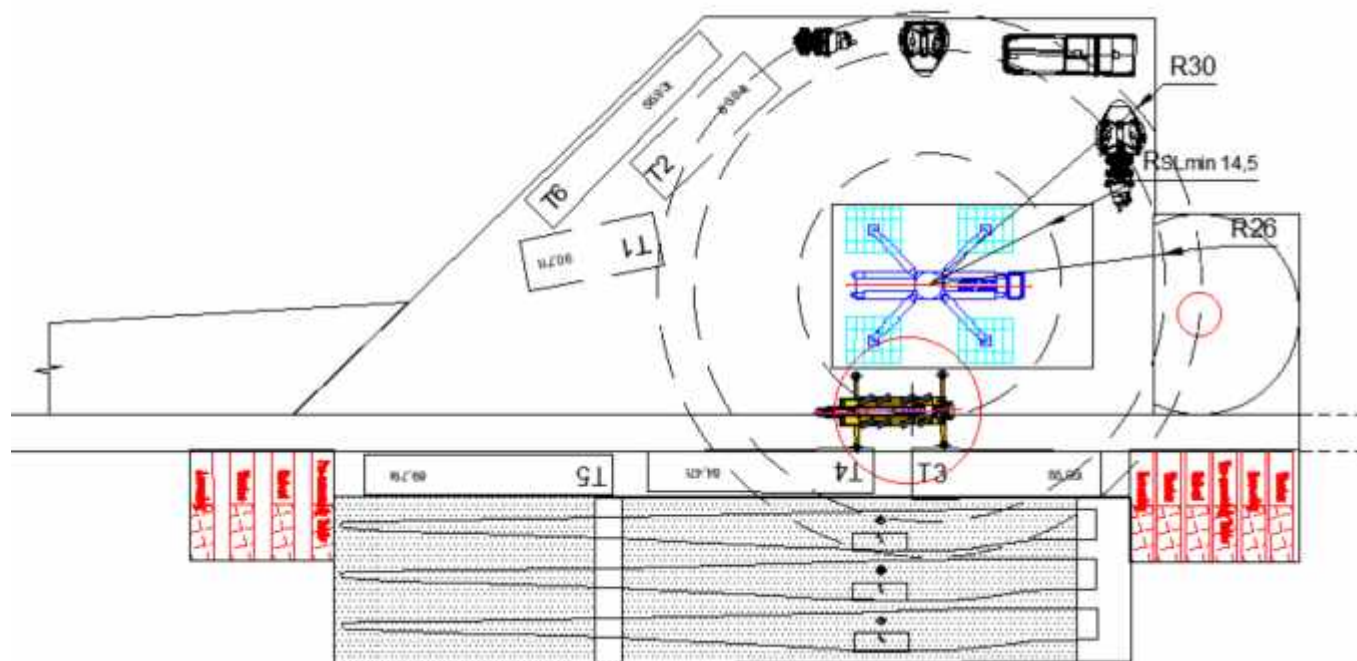
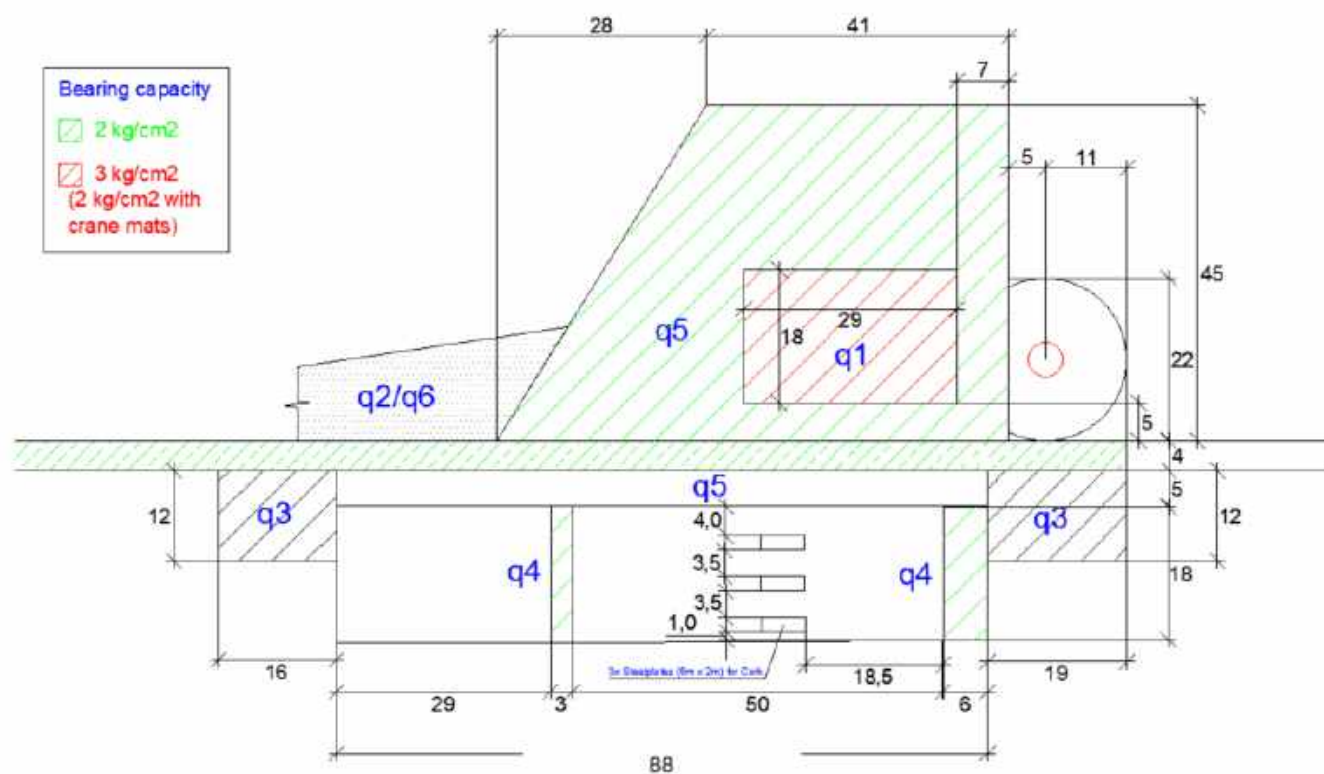


Figure 28. Model T135m (54A) – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower





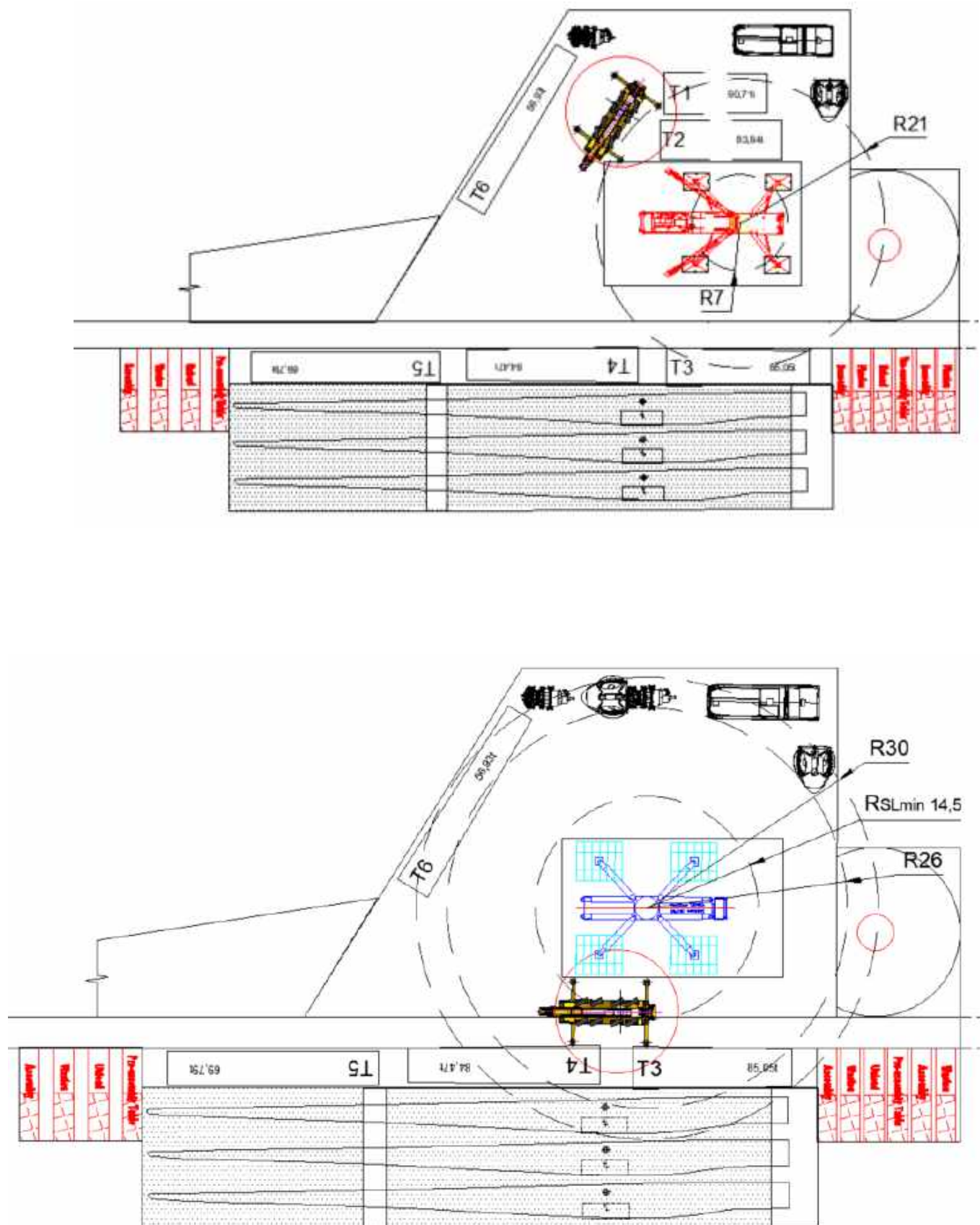


Figure 29. Model T135m (54A) -.Partial storage assembling with strategy 4 in 2 phases

### 5.5.11. T145m and T150m tubular steel tower Hardstand with strategy 3

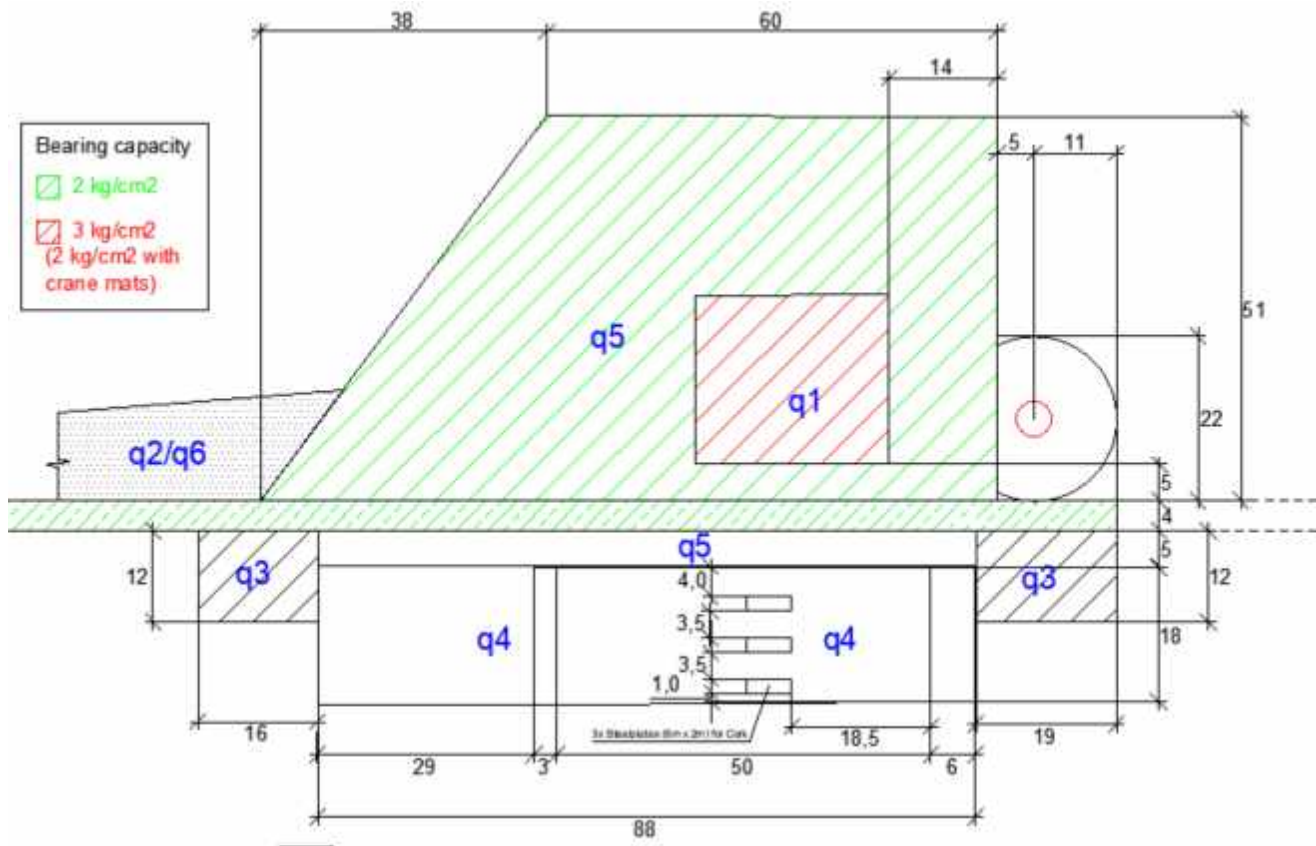
- Tailing crane offloading T145m&T150m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 26m x 23m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 60m x 51m + (38m x 51m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 34m x 23m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 47m x 52m + (44m x 52m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 37. Dimensions of the areas of model T150m with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase – STD tower



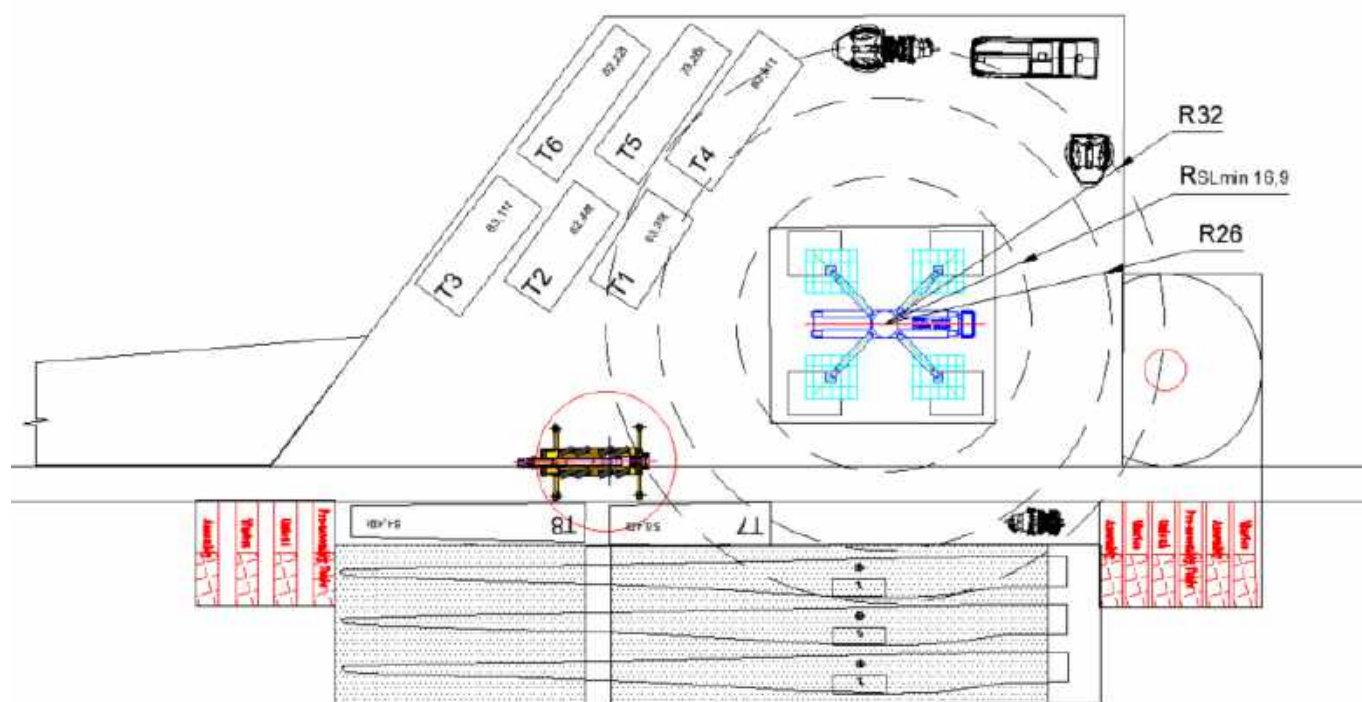
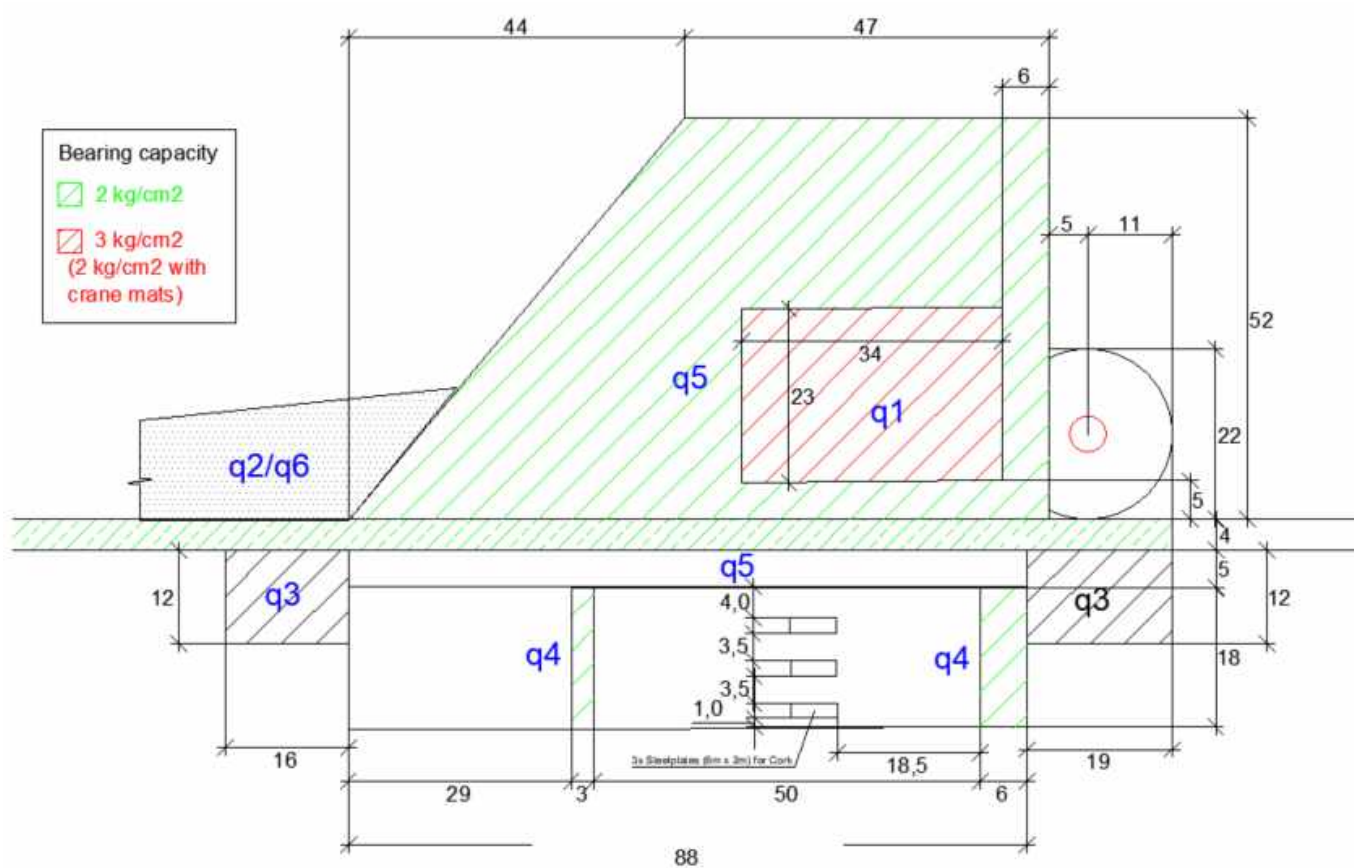


Figure 30. Model T150m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower





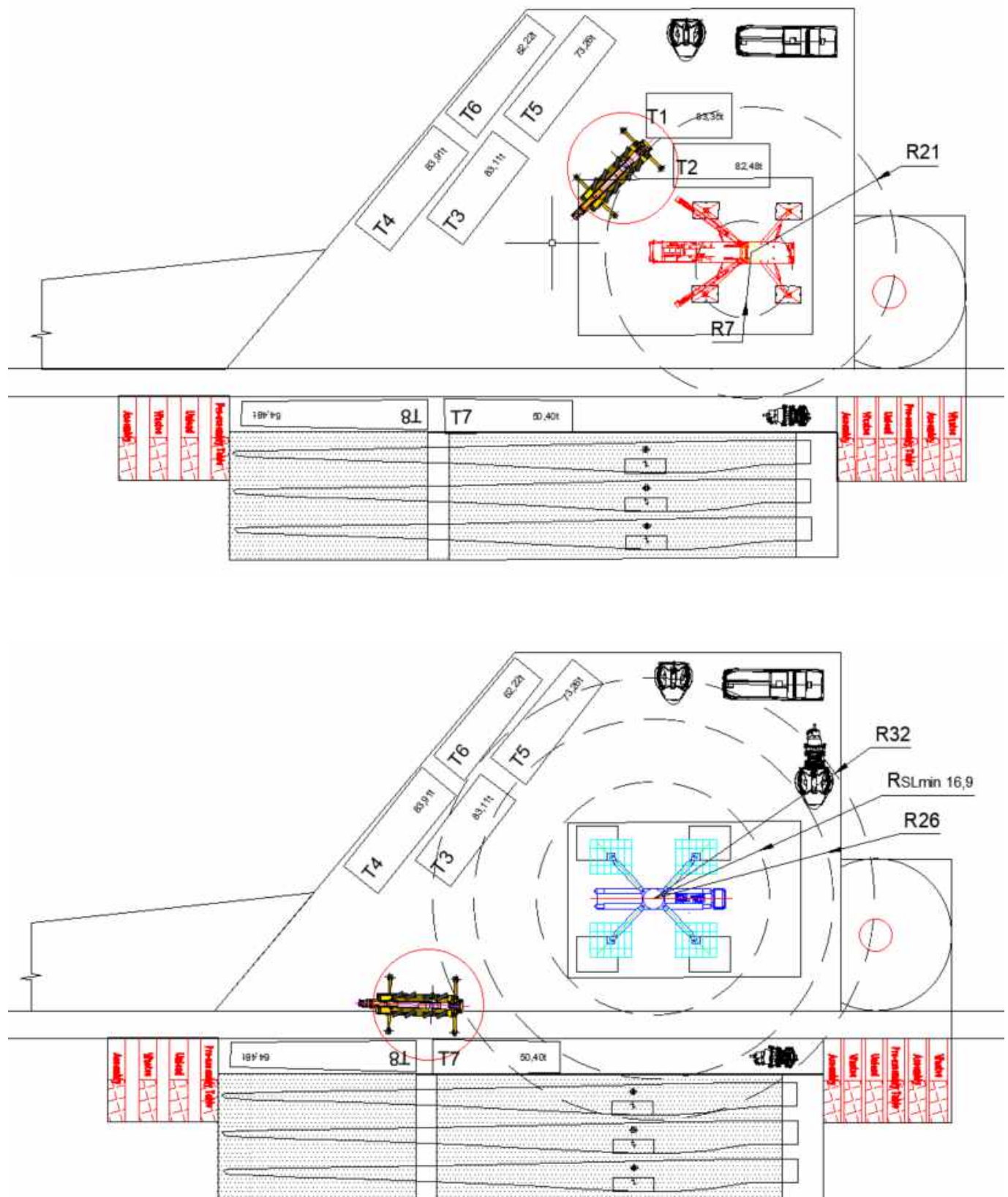


Figure 31. Model T150m - Partial storage assembling with strategy 3 in 2 phases

### 5.5.12. T145m and T150m tubular steel tower Hardstand with strategy 4

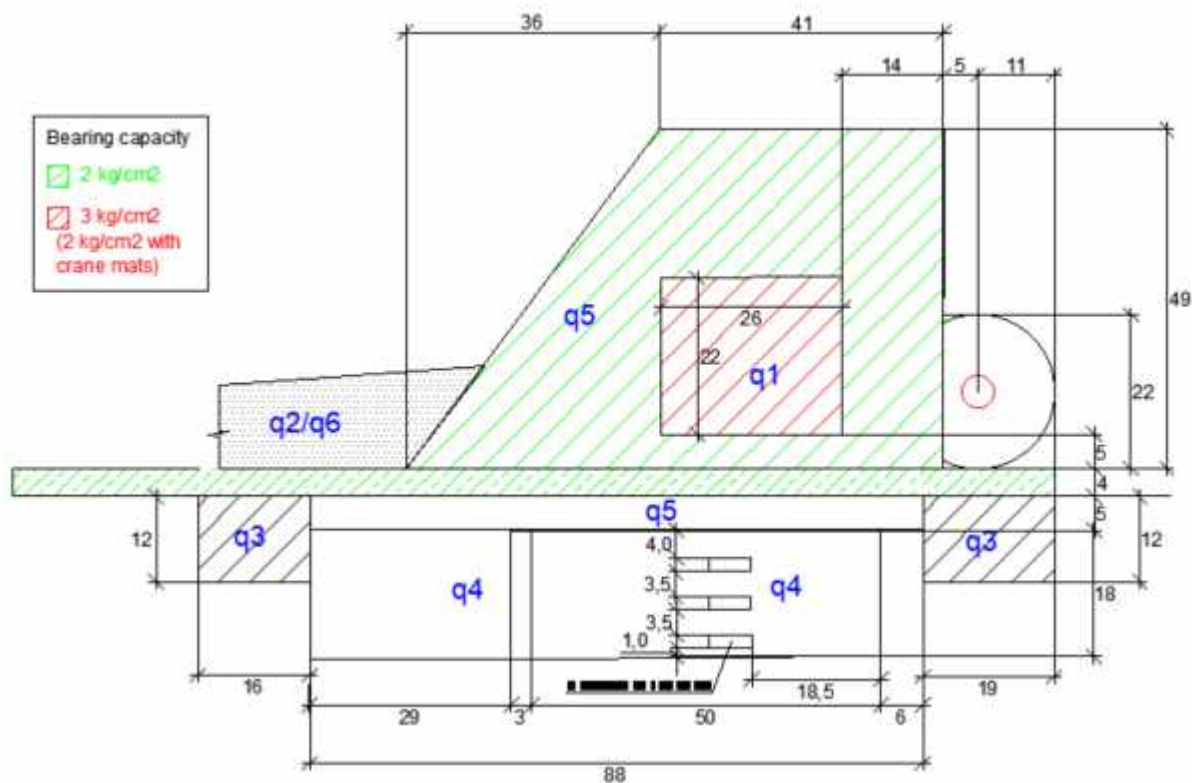
- Tailing crane offloading T145m&T150m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 26m x 22m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 41m x 49m + (36m x 49m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 34m x 23m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 39m x 49m + (41m x 49m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 38. Dimensions of the areas of model T150m with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1 phase – STD tower



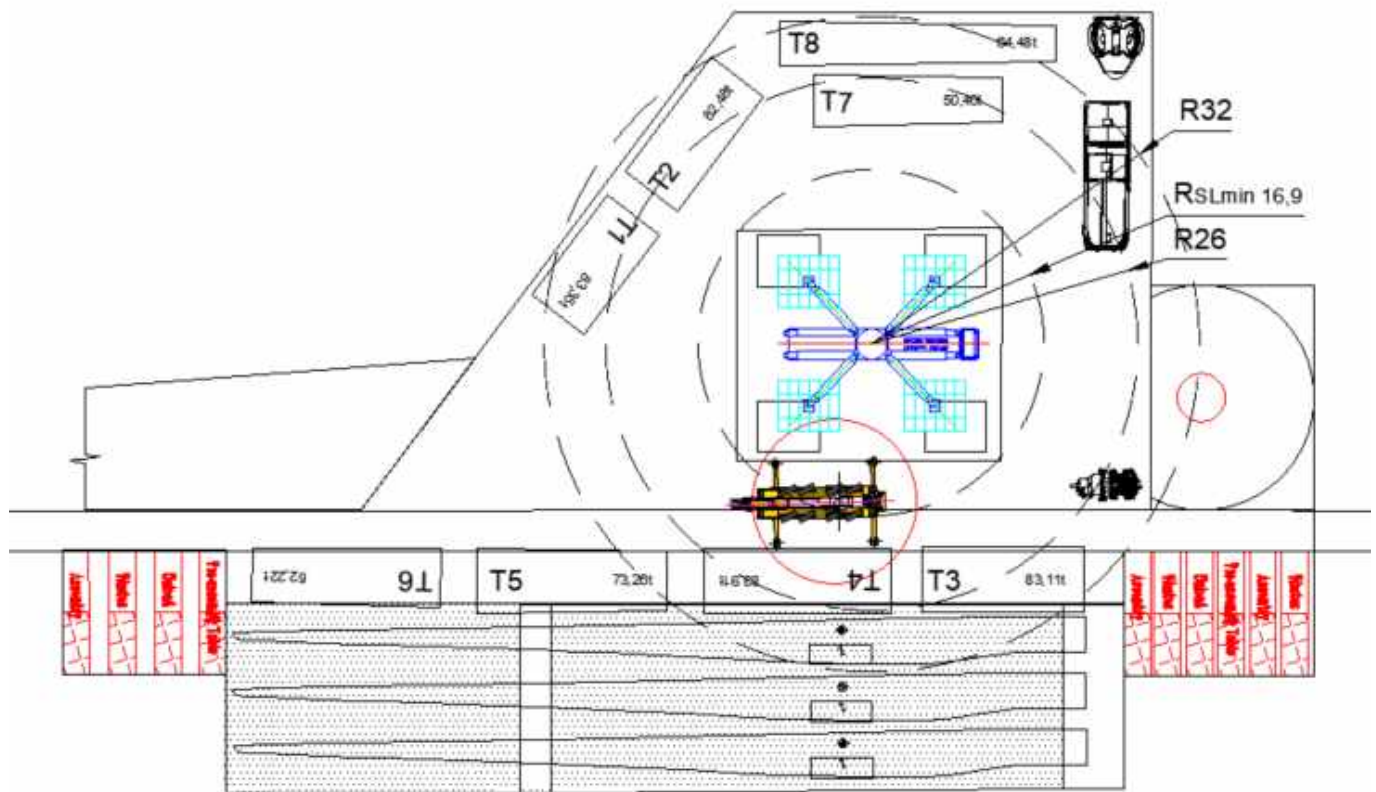
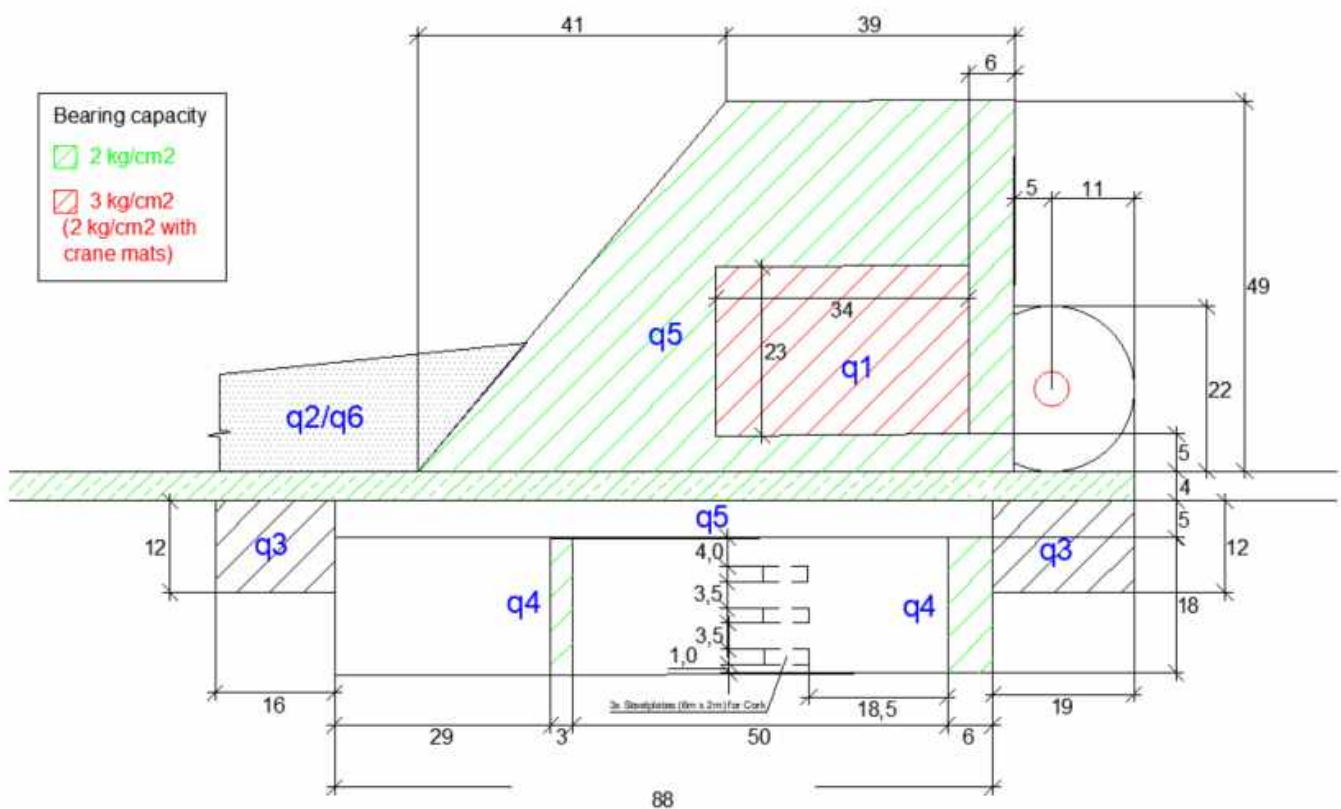


Figure 32. Model T150m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower





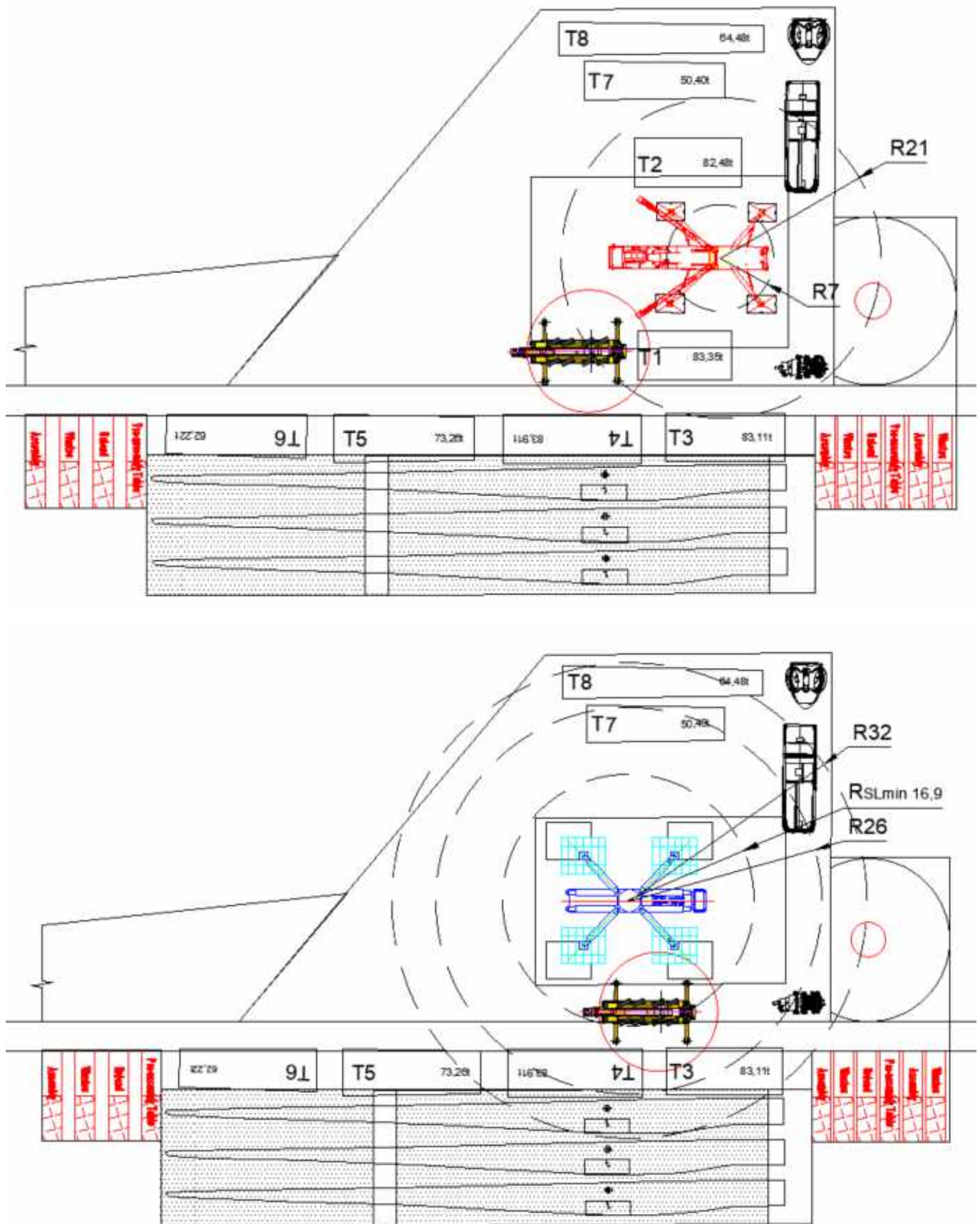


Figure 33. Model T150m - Partial storage assembling with strategy 4 in 2 phases

### 5.5.13. T155m tubular steel tower Hardstand with strategy 3

The sizing of the hardstand corresponds to the use of a large wide track crawler crane and not the standard crane LG1750.

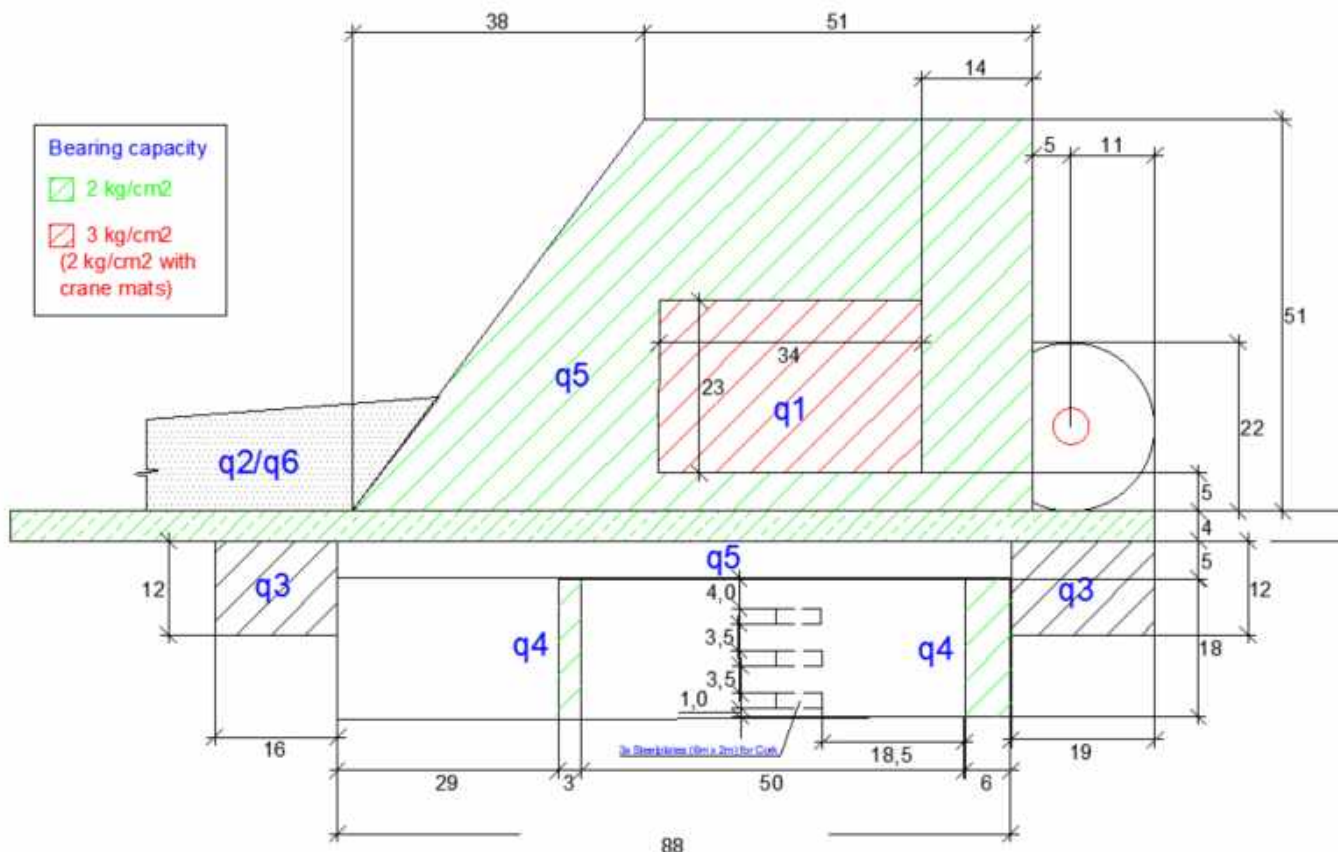
- Tailing crane offloading T155m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 34m x 23m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 51m x 51m + (38m x 51m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 34m x 23m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 53m x 46m + (38m x 56m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 39. Dimensions of the areas of model T155m with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase – STD tower





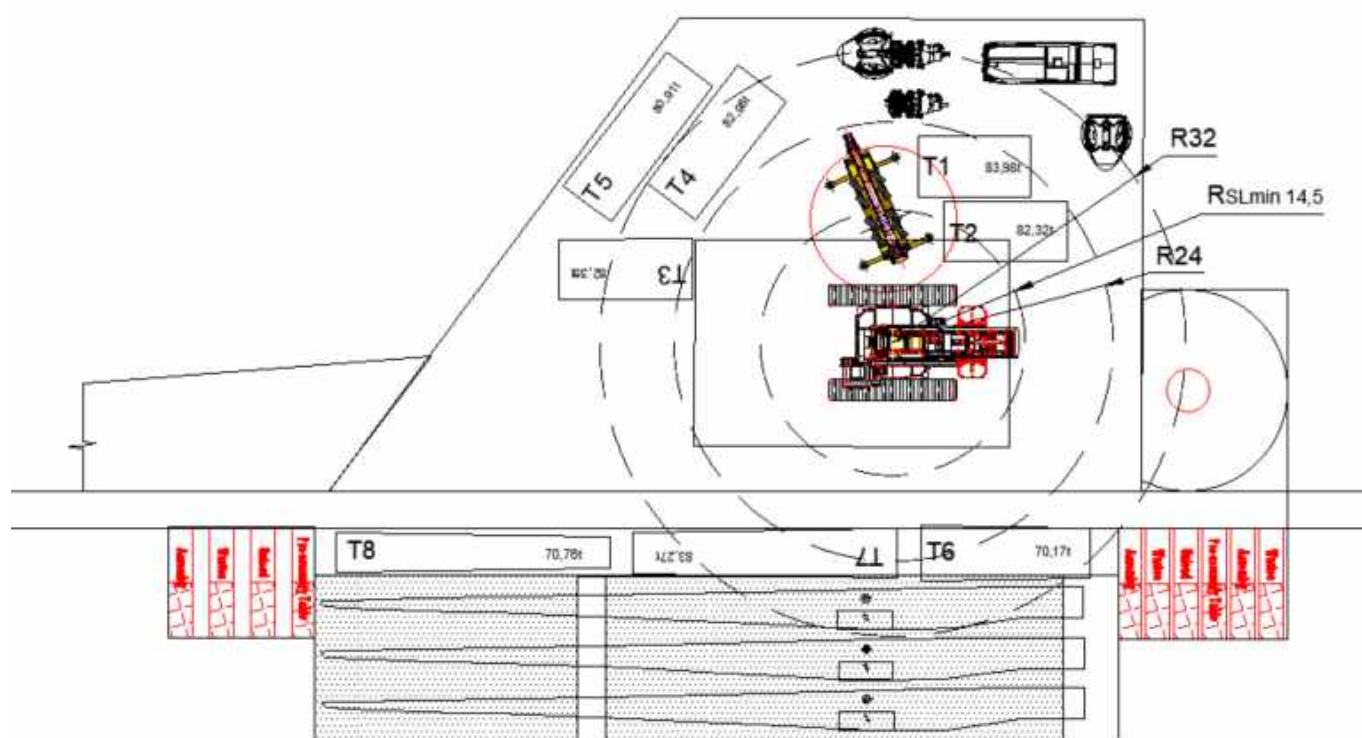
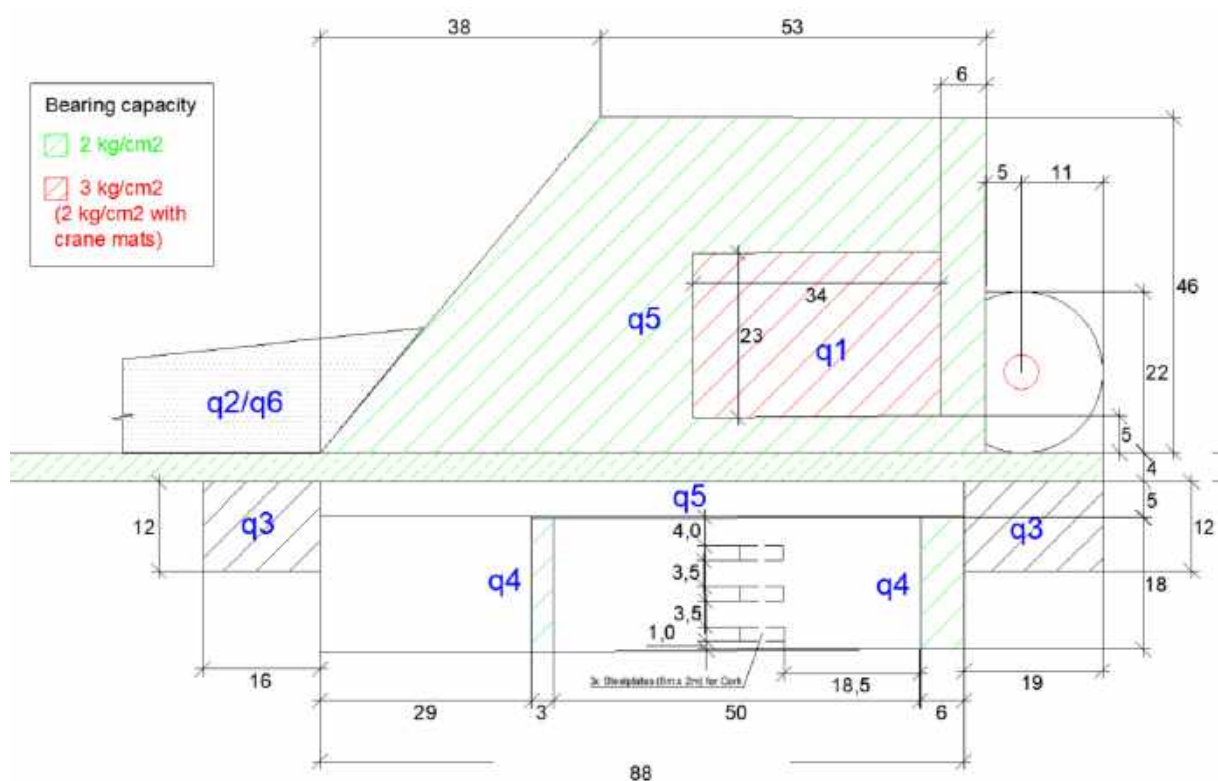
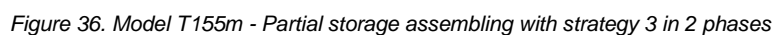


Figure 35. Model T155m – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower





#### 5.5.14. T155m tubular steel tower Hardstand with strategy 4

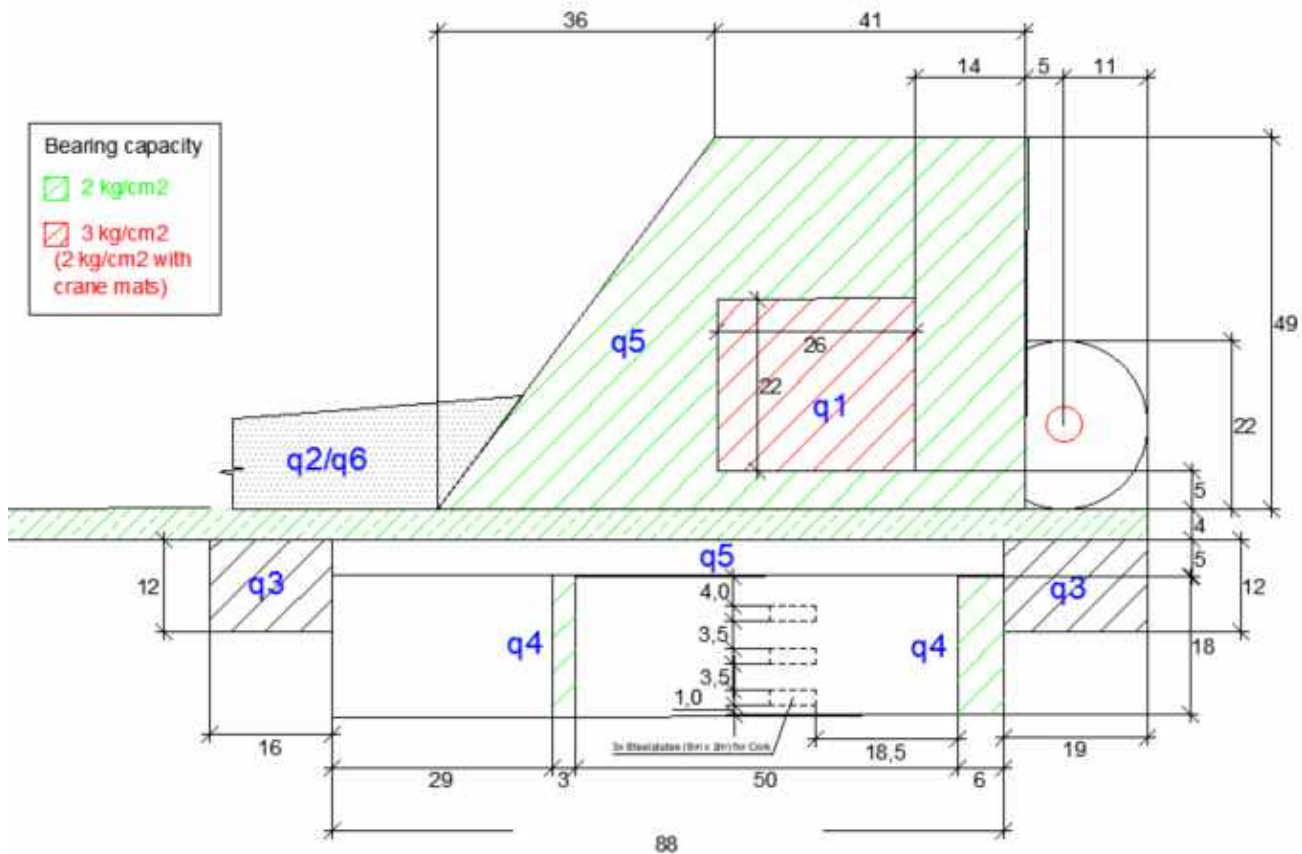
- Tailing crane offloading T155m

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 26m x 22m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 41m x 49m + (36m x 49m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 26m x 22m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 41m x 49m + (36m x 49m)/2 – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 40. Dimensions of the areas of model T155m with strategy 4 – Tailing crane offloading

- Total storage – Assembly in 1 phase – STD tower





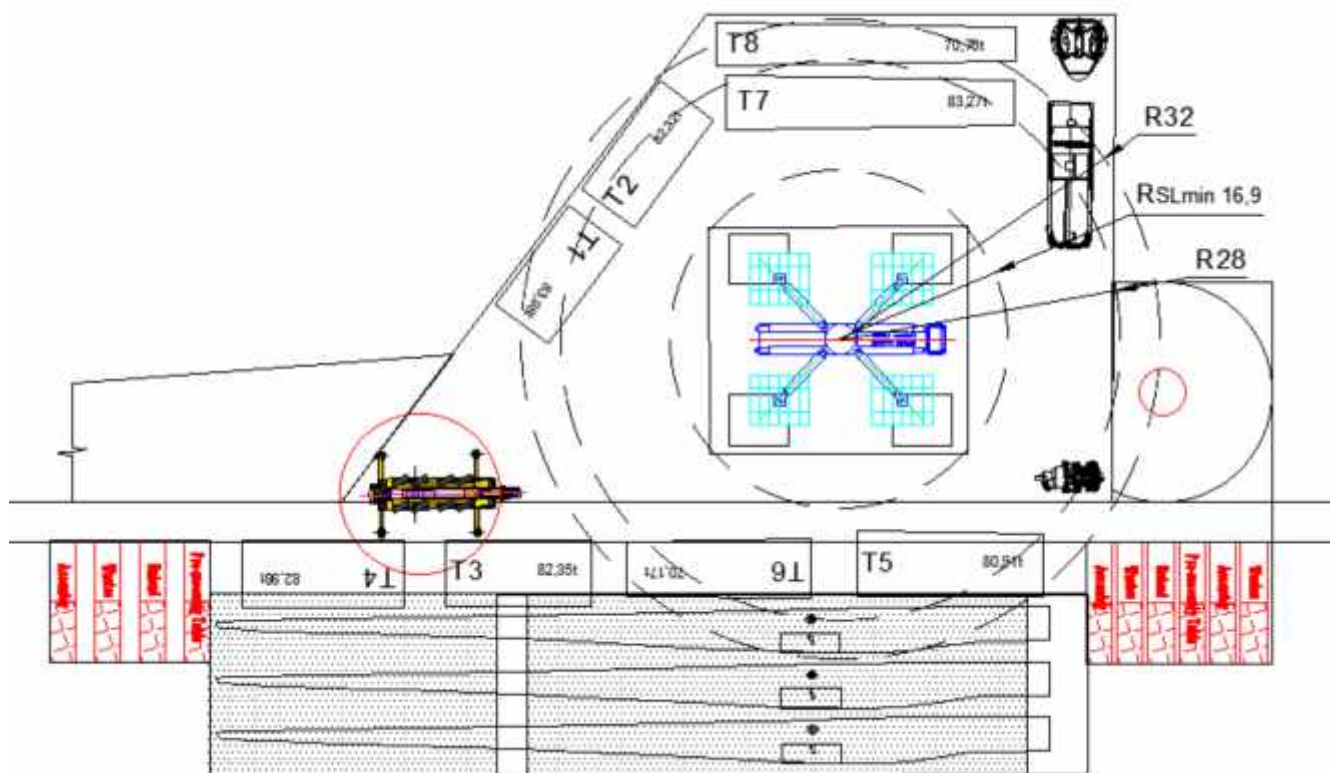
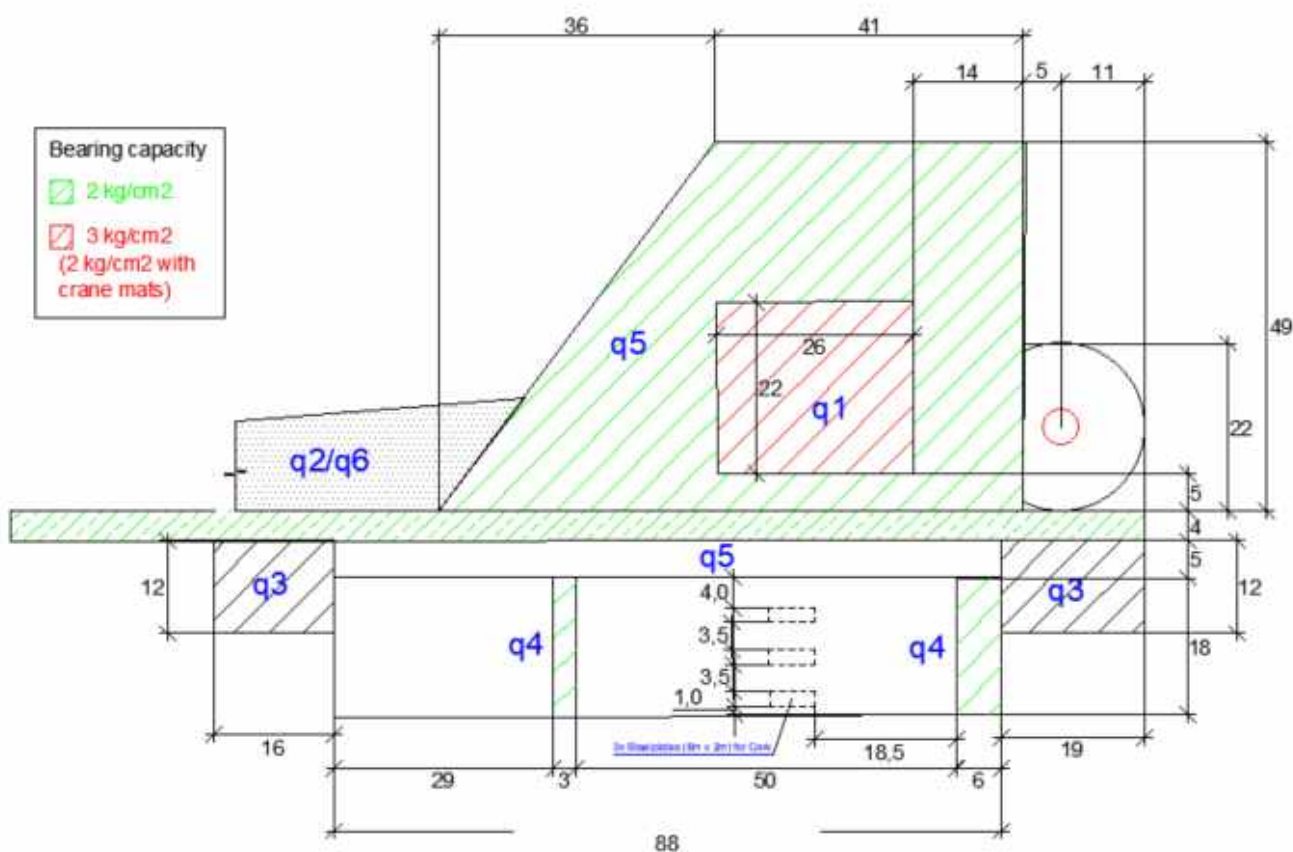


Figure 37. Model T155m – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard) – STD tower



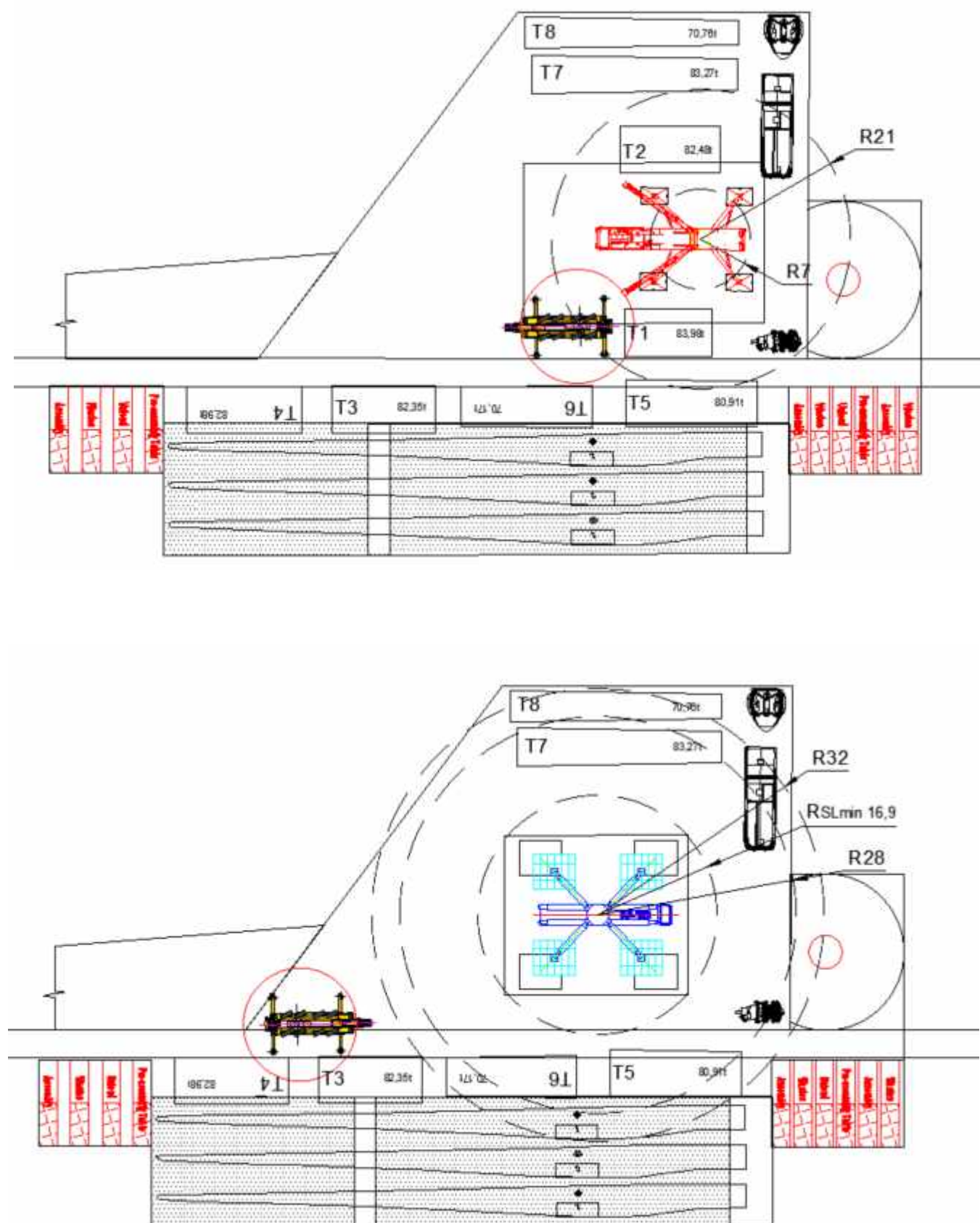


Figure 38. Model T155m - Partial storage assembling with strategy 4 in 2 phases

### 5.5.15. T165m & T165m MB - WT tubular steel tower Hardstand with strategy 3

The sizing of the hardstand corresponds to the use of a large wide track crawler crane and not the standard crane LG1750.

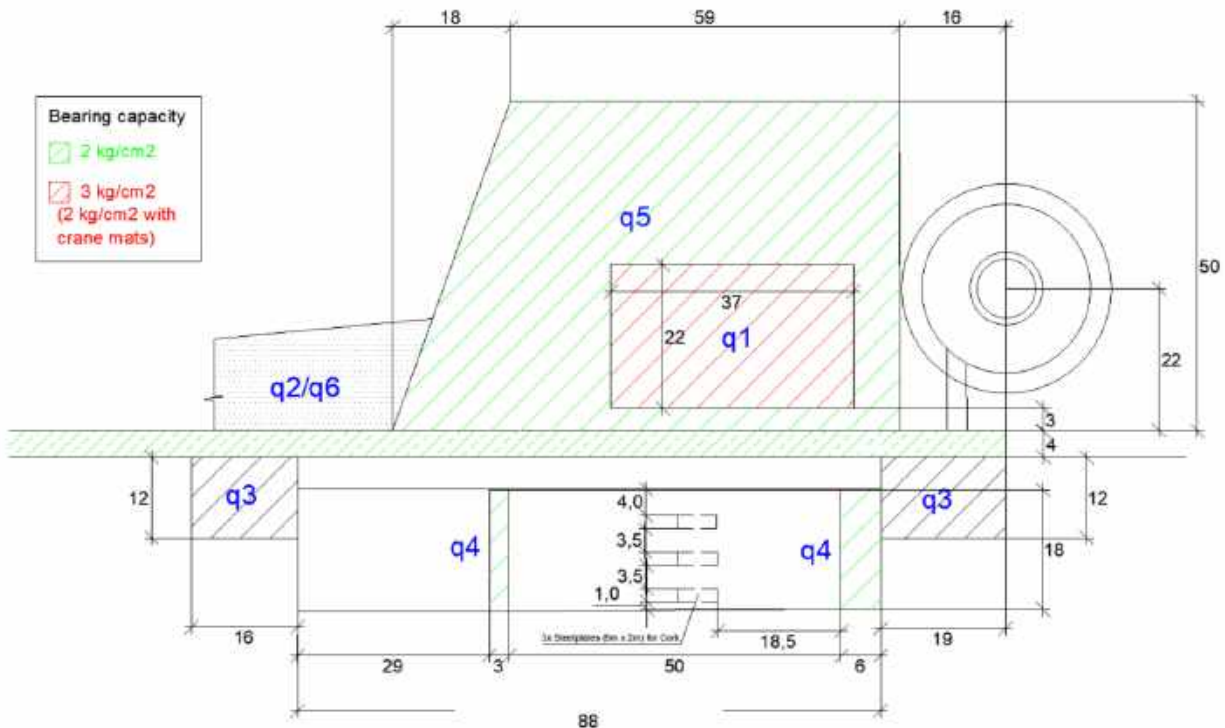
- Tailing crane offloading T165m&T165-MB

| Storage conditions                     | Width x length   |
|--|--|
| <b>Total Storage</b>                   | q1: 51m x 22m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 59m x 50m + (18m x 50m)/2 + 8m x 10m – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
| <b>Partial storage (SGRE standard)</b> | q1: 51m x 22m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 53m x 42m + (14m x 42m)/2 + 8m x 10m – q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

\*Referred to 3.1.3 Road width

Table 43. Dimensions of the areas of model T165m MB – WT with strategy 3 – Tailing crane offloading

- Total storage – Assembly in 1 phase





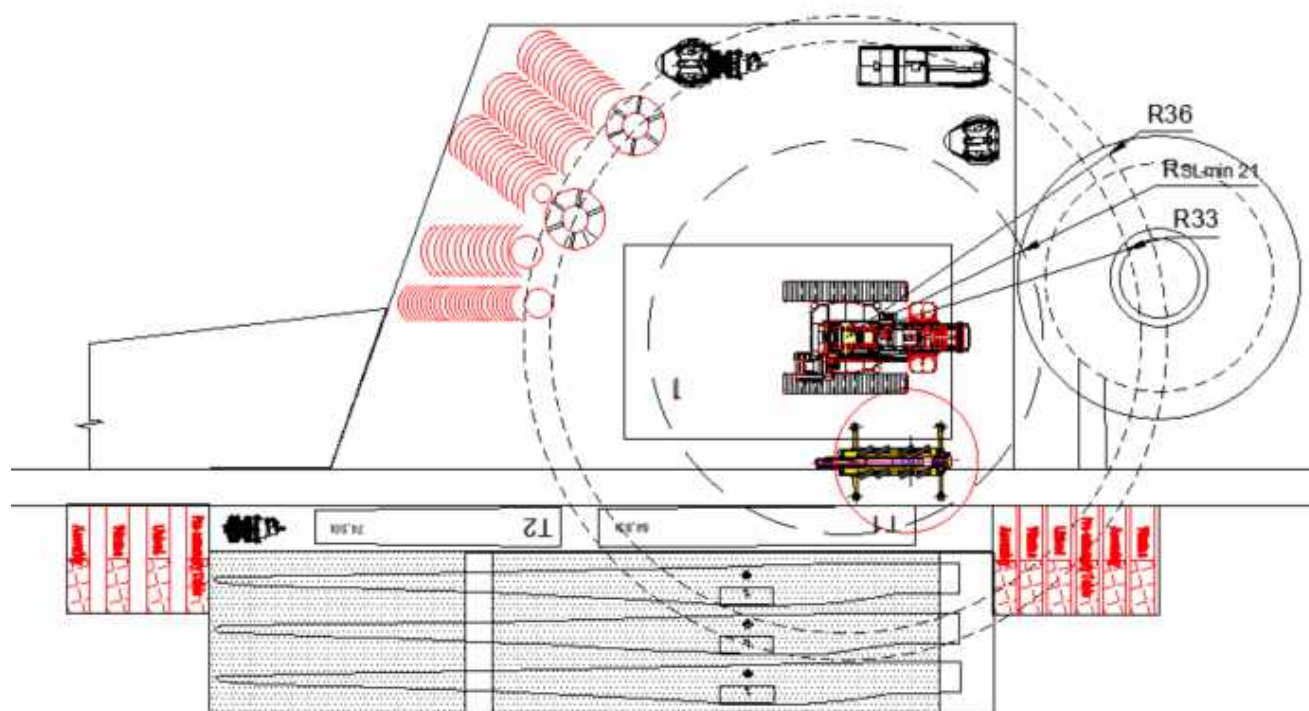
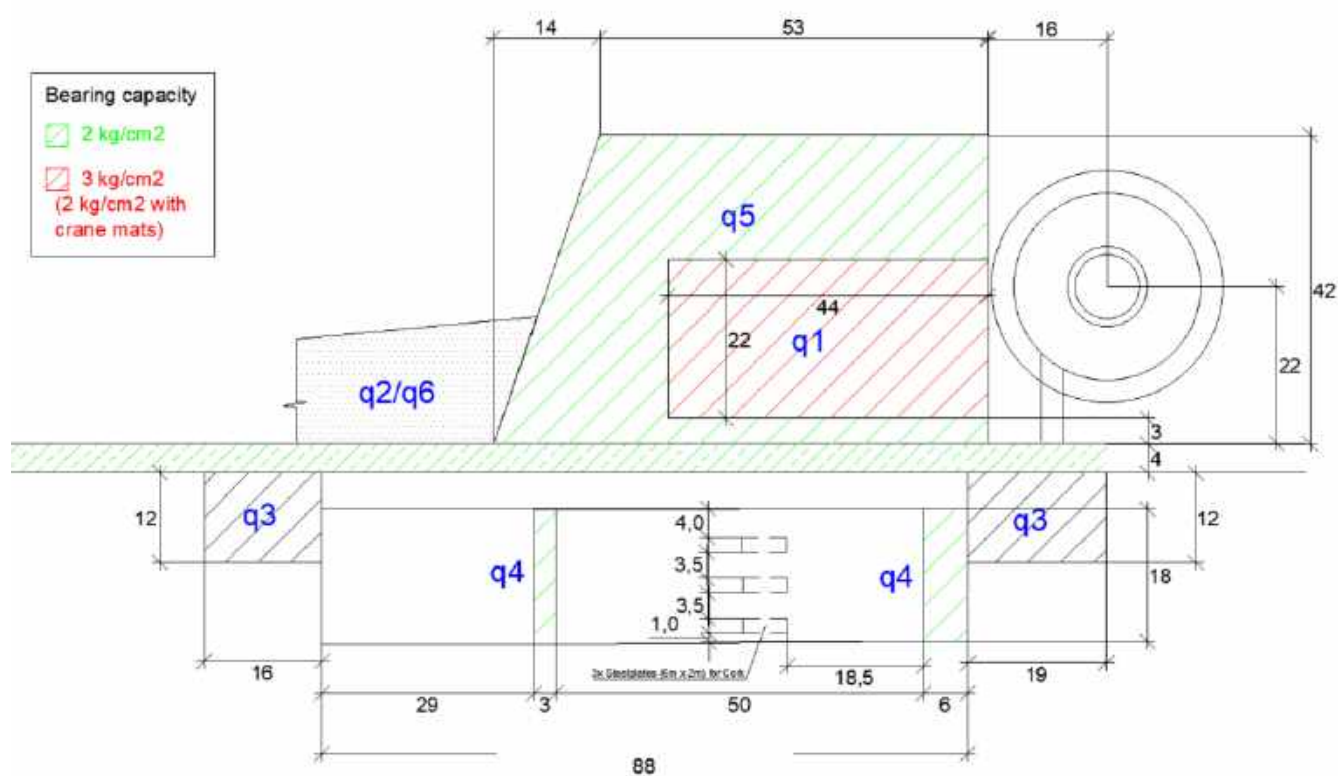


Figure 43. Model T165m MB – Total storage assembling with strategy 3 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)



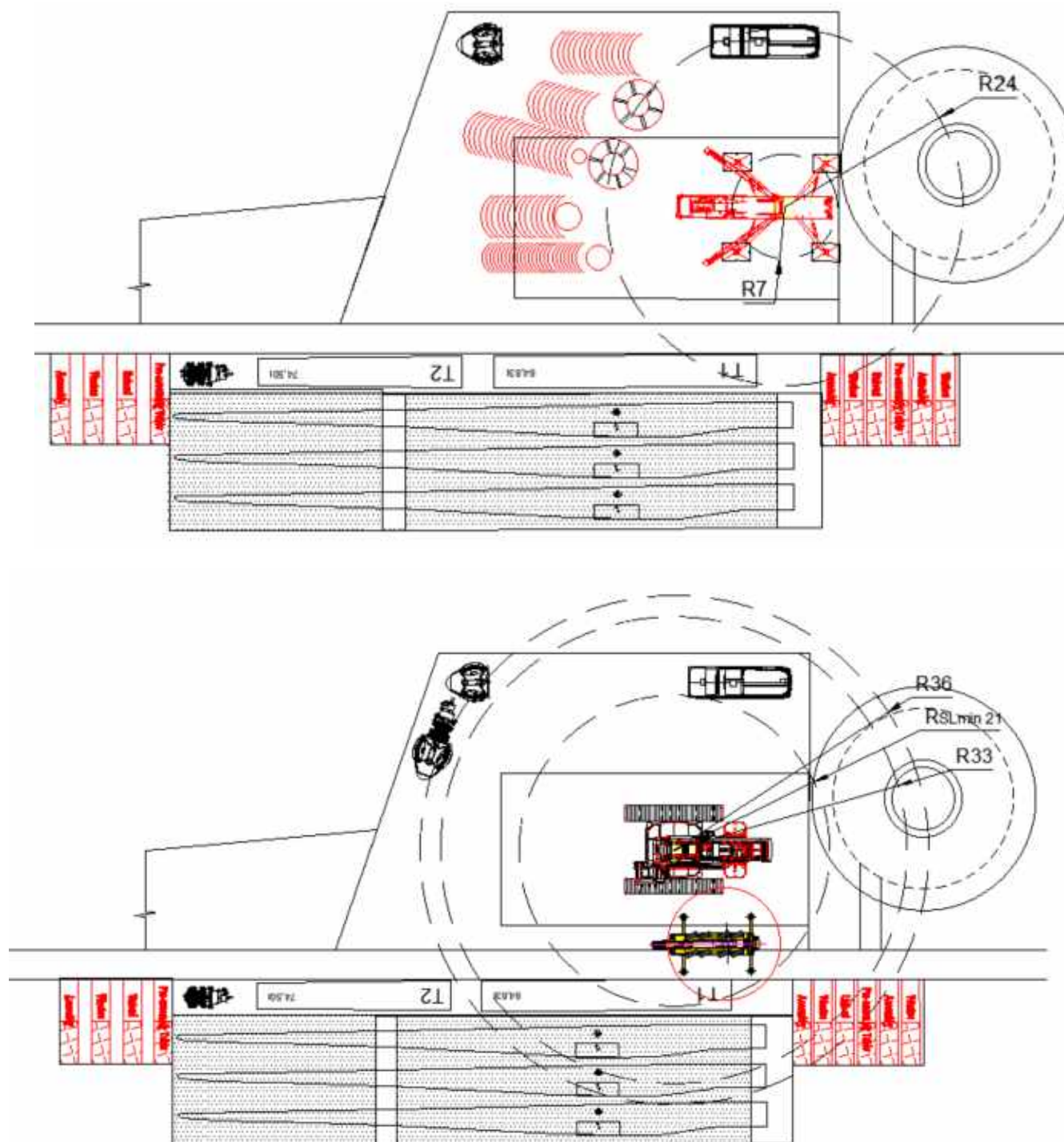


Figure 44. Model T165m MB – WT – Partial storage assembling with strategy 3 in 2 phases



### 5.5.16. T165m & T165m MB – WT tubular steel tower Hardstand with strategy 4

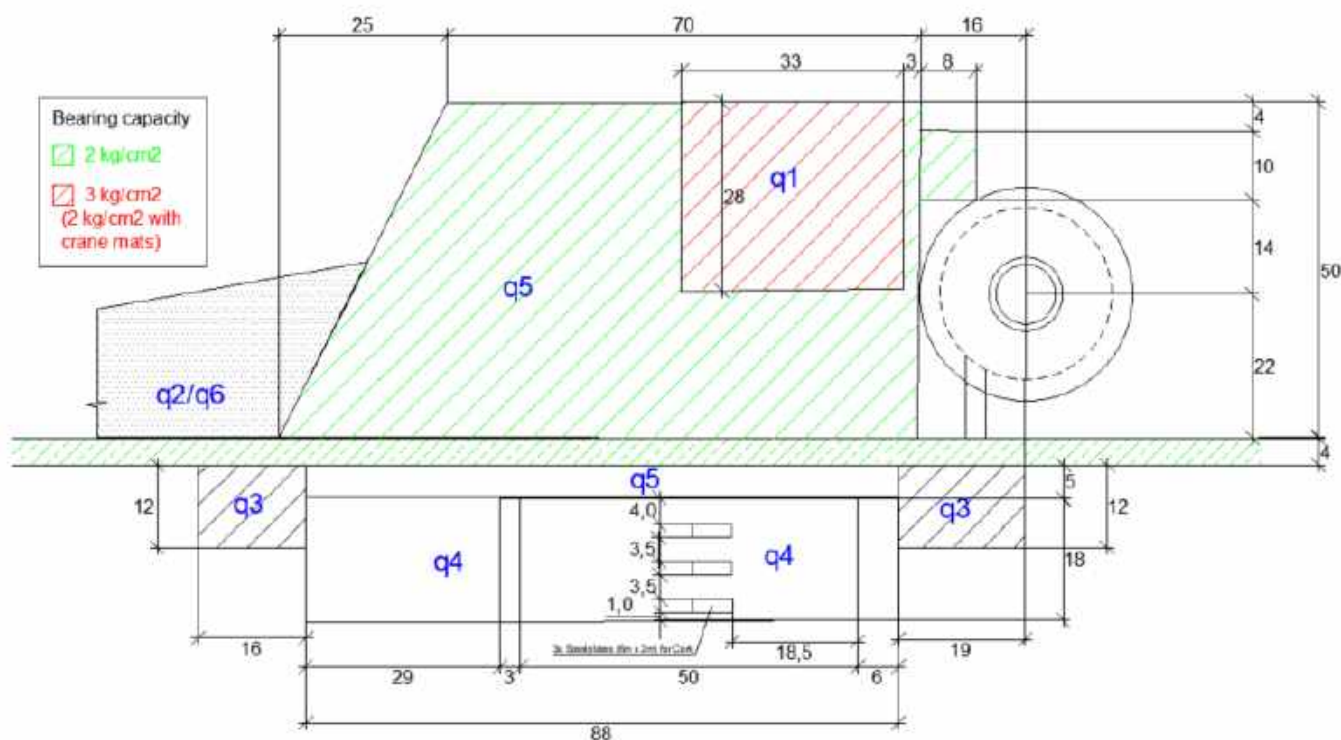
- Tailing crane offloading T165m&T165-MB

| Storage conditions                     | Width x length  |
|--|---|
| <b>Total Storage</b>                   | q1: 33m x 28m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 70m x 50m + (25m x 50m)/2 + 8m x 10m - q1 + 88m x 5m + reinforced road part*<br>q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane  |
| <b>Partial storage (SGRE standard)</b> | q1: 33m x 28m<br>q3: 16m x 12m + 19m x 12m<br>q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)<br>q5: 51m x 50m + (29m x 50m)/2 + 8m x 10m - q1 + 88m x 5m + reinforced road part*<br>q2/q6 : Dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 44.. Dimensions of the areas of model T165m MB – WT with strategy 4 – Tailing crane offloading

\*Referred to 3.1.3 Road width

- Total storage – Assembly in 1phase



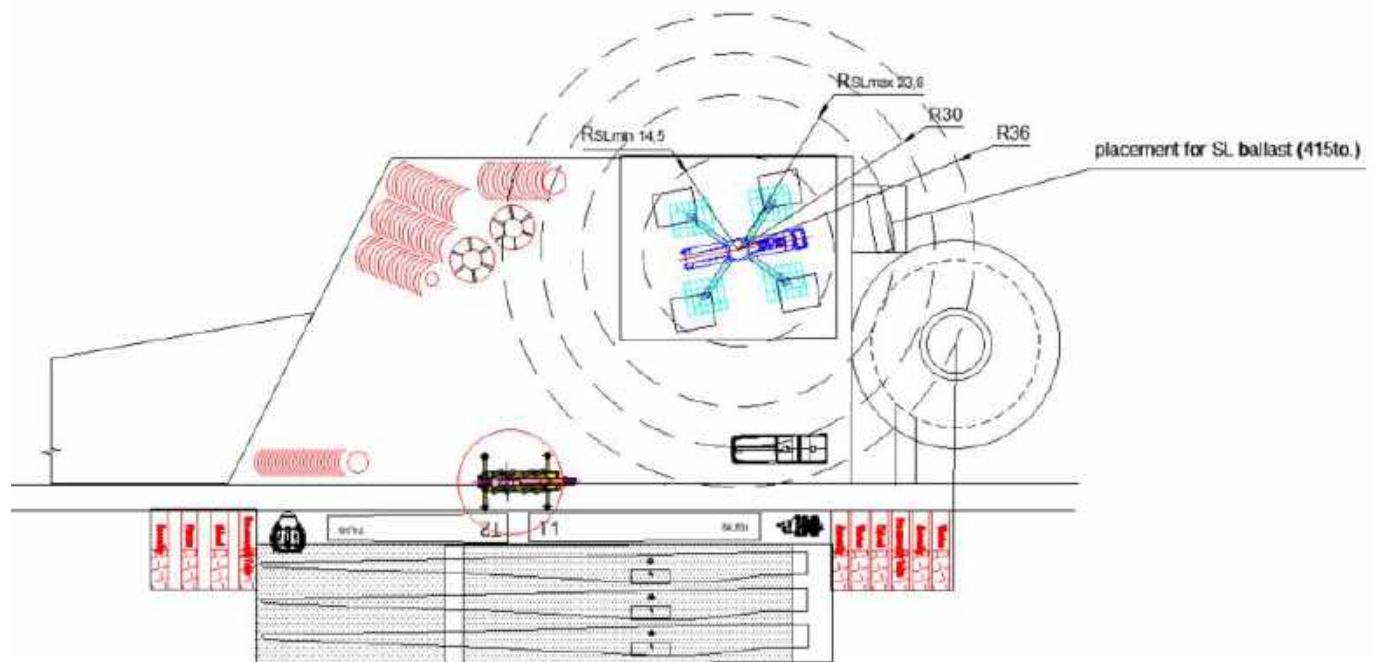
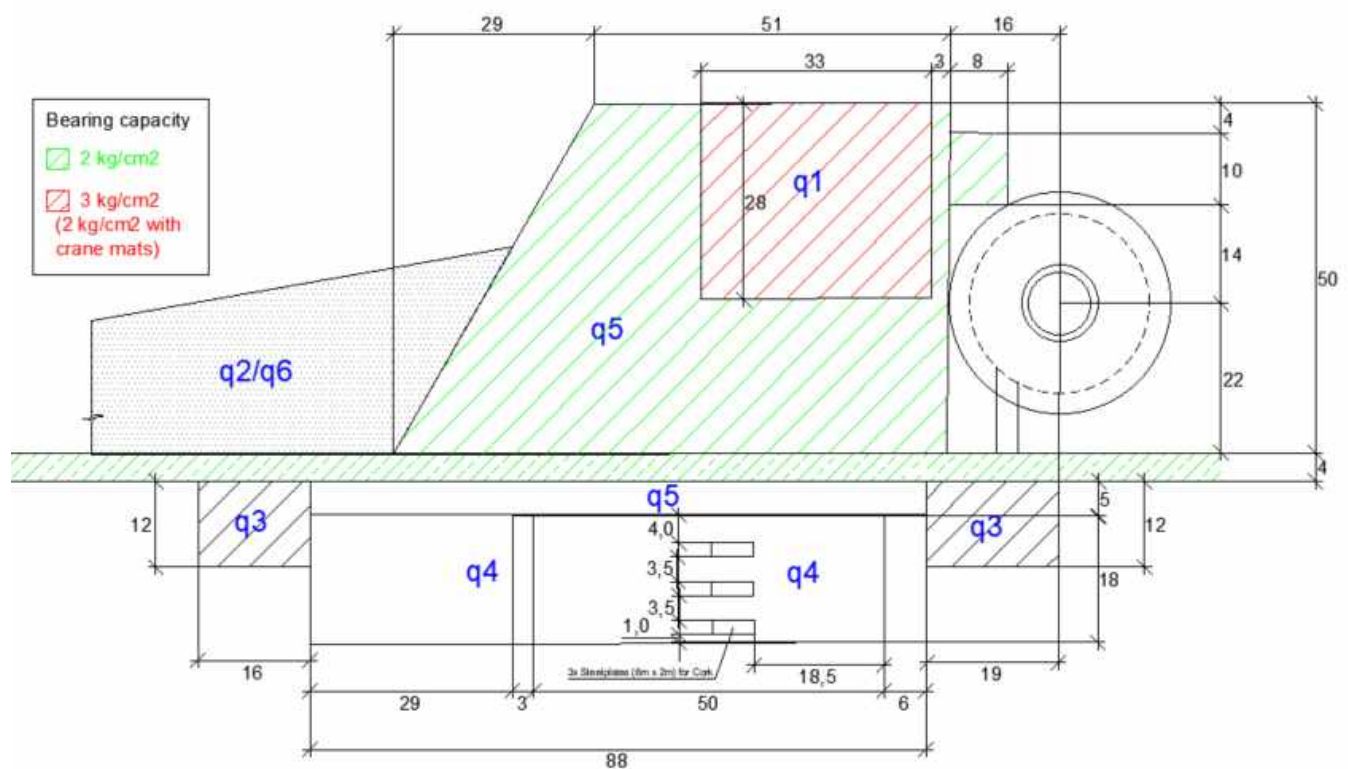


Figure 45. Model T165m MB – WT – Total storage assembling with strategy 4 in 1 phase

- Partial storage – Assembly in 2 phases (SGRE standard)



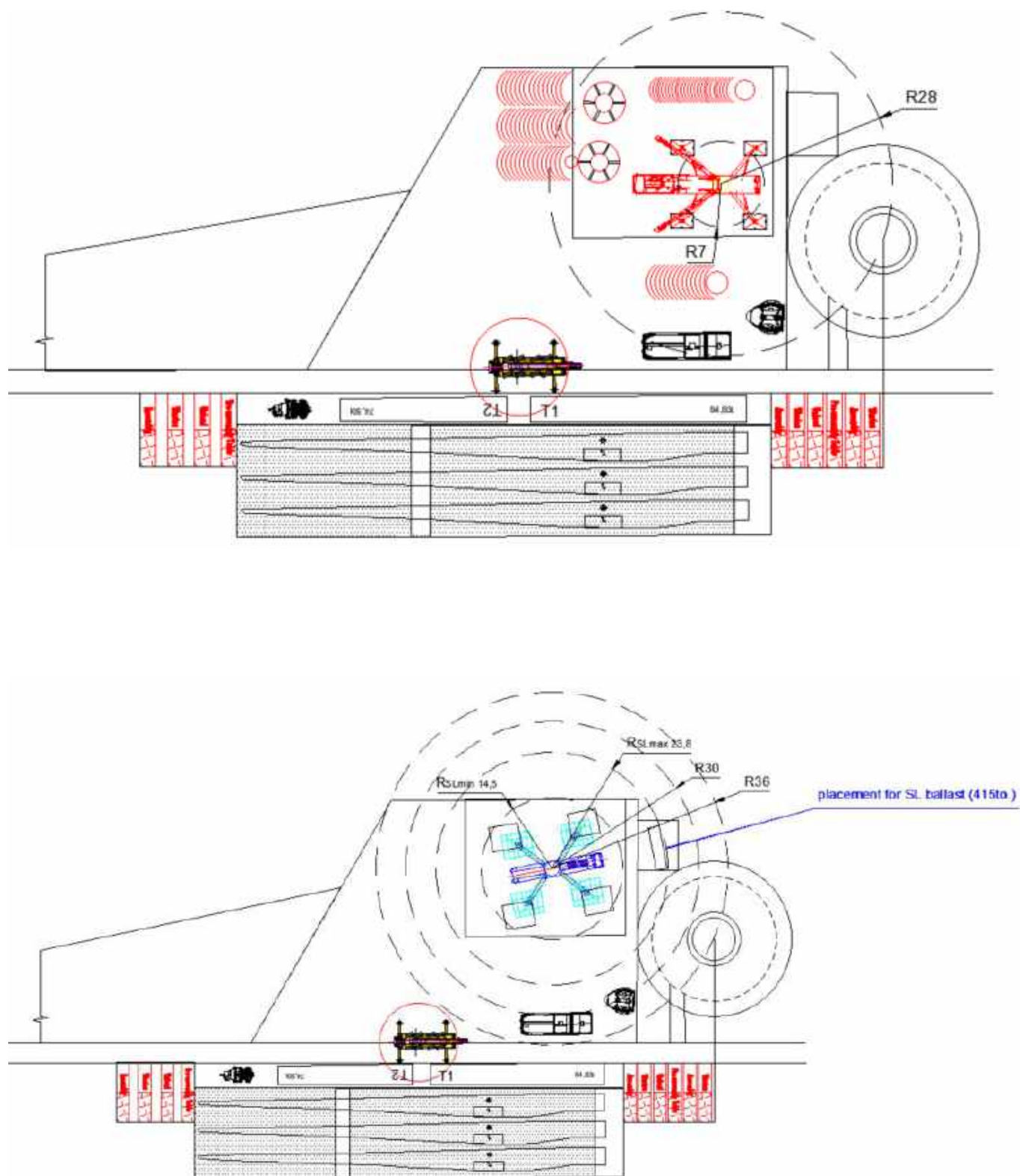


Figure 46. Model T165m MB – WT – Partial storage assembling with strategy 4 in 2 phases



### 5.5.17. JIT storage tubular steel tower Hardstand with strategy 3

The drawings for JIT towers:

- W/o hybrid tower and segmented tower solutions
- With estimated crane type: LG1750
- Estimated for flat foundations

In addition, the legend of the different hardstands and values that appear in the JIT drawings is included below.

#### Legend:

|                             |  |
|-----------------------------|--|
| <b>R<sub>op</sub></b> =     | estimated crane operation radius   |
| <b>R<sub>min</sub></b> =    | min. crane operation radius to hoist components (with specific crane type / crane configuration) |
| <b>R<sub>sl,min</sub></b> = | min. crane superlift radius (min. outer SL rotation diameter)                                    |
| <b>q1</b> =                 | hardstand for main crane   |
| <b>q2</b> =                 | hardstand for assistant crane  |
| <b>q3</b> =                 | storage area for containers and miscellaneous items  |
| <b>q4</b> =                 | blade storage area with blade fingers  |
| <b>q5</b> =                 | storage area for main components   |
| <b>q6</b> =                 | area for crane boom assembly / disassembly   |
| <b>q7</b> =                 | free obstacles area for rotation superlift / suspended ballast of main crane                     |
| <b>X</b> =                  | distance q1 to q5 boundary line  |
| <b>Y</b> =                  | distance q1 to site road   |
| <b>Dim. L x W</b> =         | dimensions length x wide   |
| <b>Area</b> =               | area calculation   |

Figure 47. Legend to define different values of the hardstand drawings

| WTG - Type  | HH<br>[m] | no. of steel<br>towersec. | R <sub>op</sub><br>[m] | X<br>[m] | Y<br>[m] | q1                |                           | q3                |                           | q4                |                           | q5                                  |                           |
|-------------|-----------|---------------------------|------------------------|----------|----------|-------------------|---------------------------|-------------------|---------------------------|-------------------|---------------------------|-------------------------------------|---------------------------|
|             |           |                           |                        |          |          | dim. L x W<br>[m] | area<br>[m <sup>2</sup> ] | dim. L x W<br>[m] | area<br>[m <sup>2</sup> ] | dim. L x W<br>[m] | area<br>[m <sup>2</sup> ] | dim. L x W<br>[m]                   | area<br>[m <sup>2</sup> ] |
| SG5.X - 166 | 90        | 4                         | 24                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 166 | 102.5     | 4                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 166 | 107.5     | 4                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 166 | 113.5     | 5                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 166 | 117.5     | 5                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 166 | 120.5     | 5                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 166 | 122.5     | 5                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 83x18             | 1494                      | (83x5) + (35x44) + ((30*44)/2) - q1 | 2093                      |
| SG5.X - 170 | 100       | 4                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 88x18             | 1584                      | (88x5) + (35x44) + ((30*44)/2) - q1 | 2118                      |
| SG5.X - 170 | 101.5     | 6                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 88x18             | 1584                      | (88x5) + (35x44) + ((30*44)/2) - q1 | 2118                      |
| SG5.X - 170 | 115       | 5                         | 27                     | 7        | 3        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 88x18             | 1584                      | (88x5) + (35x44) + ((30*44)/2) - q1 | 2118                      |
| SG5.X - 170 | 135       | 6                         | 30                     | 7        | 5        | 29x18             | 522                       | (19x12)+(16x12)   | 420                       | 88x18             | 1584                      | (88x5) + (35x44) + ((30*44)/2) - q1 | 2118                      |
| SG5.X - 170 | 145       | 8                         | 32                     | 6        | 5        | 34x23             | 782                       | (19x12)+(16x12)   | 420                       | 88x18             | 1584                      | (88x5) + (35x44) + ((30*44)/2) - q1 | 1858                      |
| SG5.X - 170 | 155       | 8                         | 32                     | 6        | 5        | 34x23             | 782                       | (19x12)+(16x12)   | 420                       | 88x18             | 1584                      | (88x5) + (35x44) + ((30*44)/2) - q1 | 1858                      |

Figure 48. Dimensions of main hardstands

- Tailing crane offloading

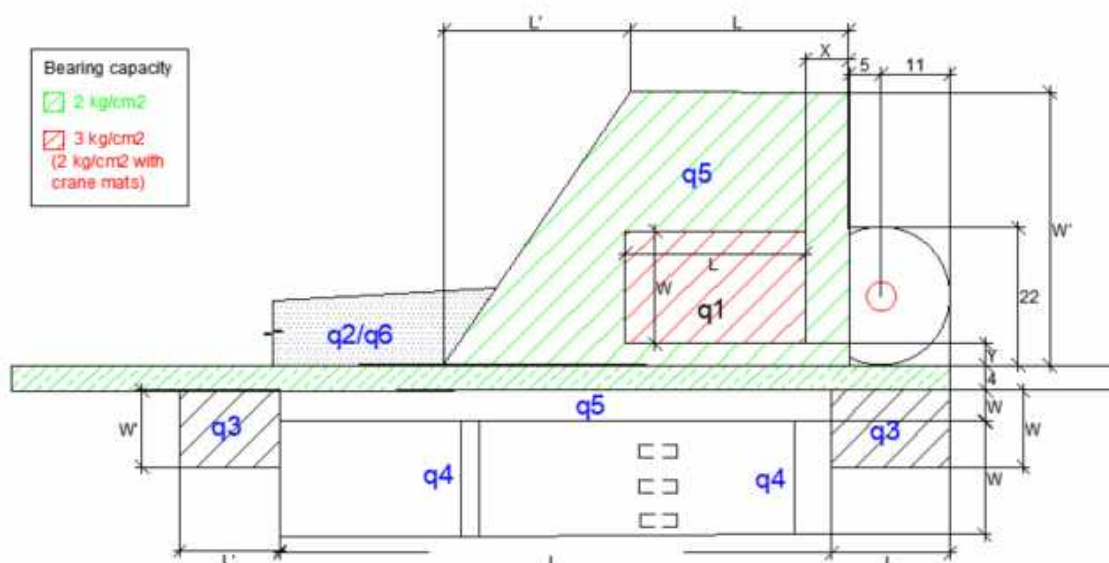
| Storage conditions | HH    | Width x length   |
|--------------------|-------|--|
| <b>JIT</b>         | 100   | q1: 29m x 18m<br>q3: 16m x 12m + 19m x 12m   |
|                    | 110.5 | q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)                   |
|                    | 115   | q5: 35m x 44m + (30m x 44m)/2 – q1 + 88m x 5m + reinforced road part*              |
|                    | 135   | q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |
|                    | **    |  |
| <b>JIT</b>         | 145   | q1: 34m x 23m<br>q3: 16m x 12m + 19m x 12m   |
|                    | 150   | q4: 88m x 18m (with fingers of q5 hardstand 3m x 18m + 6m x 18m)                   |
|                    | 155   | q5: 35m x 44m + (30m x 44m)/2 – q1 + 88m x 5m + reinforced road part*              |
|                    |       | q2/q6: Dimensions according to the 3.2.7. Requirements for assembly the main crane |

Table 13. Dimensions of the areas of JIT storage – Tailing crane offloading

\*Referred to 3.1.3 Road width

\*\* The required dimensions for SE&A JIT hardstands tower height T115m and T135m can be found in document reference INS-62237 Site JIT hardstands in SE&A wind farms.

- Total storage – Assembly in 1 phase



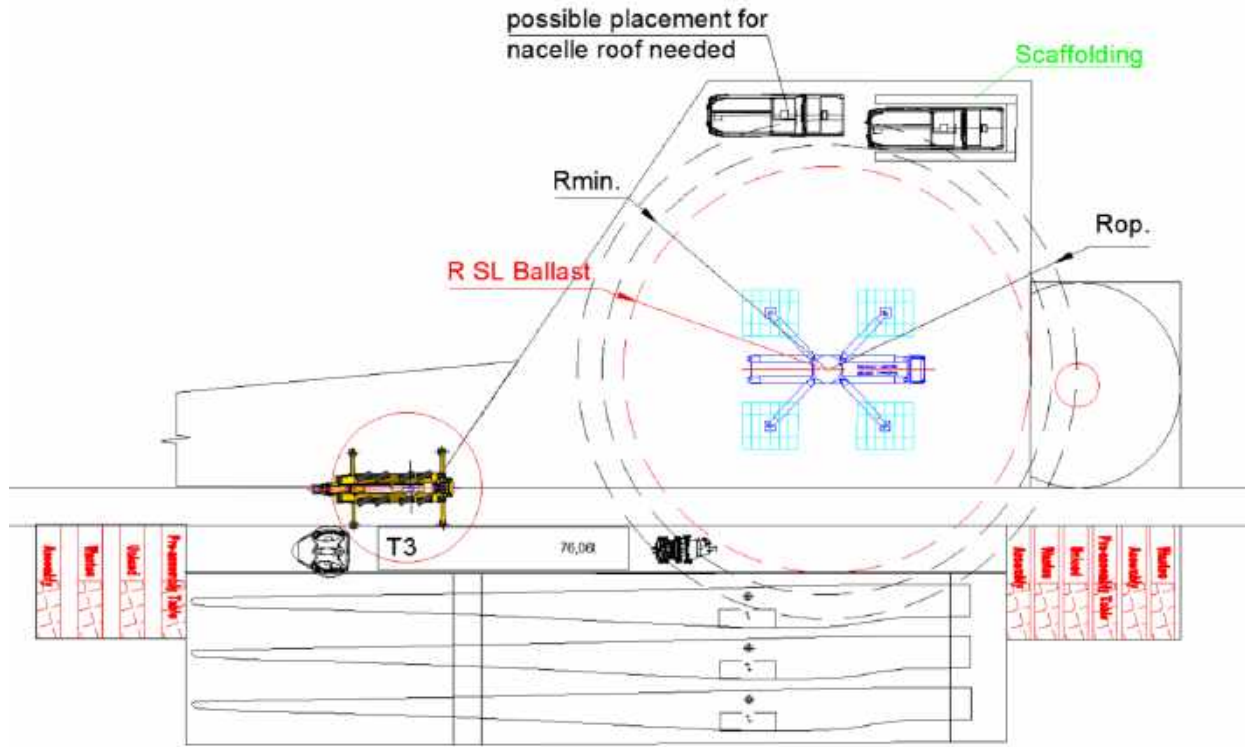


Figure 49. JIT storage reference hardstand

### DISCLAIMER:

The drawings and dimensions shown in the SSR represent standard situations with given assumptions and requirements. The drawings can be project-specifically modified and / or improved, depending on specific conditions or crane used what may have impact in CNS/ LOG cost and planning.

This can / should be done by the individual SGRE regions or by the customer to generate optimized hardstand layouts for each site.

---

### **2.3. CUMPLIMIENTO DE LOS CODIGOS DE RED PARA CONEXIÓN DE PARQUES EÓLICOS**

Documento de cumplimiento de los protocolos de conexión para los aerogeneradores SIEMENS GAMESA

## GCODER\_SPAIN\_SG 5.X

| Document ID and revision   | Status | Status date (yyyy-mm-dd)             | Language            |
|--|--------|--------------------------------------|---------------------|
| GD468732 R3  |        | 2022-02-28                           | en-US               |
| Original or translation of   |        | RDS-PP®                              |                     |
| Original   |        |                                      |                     |
| File name  |        |                                      |                     |
| GD468732 R3.docx   |        |                                      |                     |
| Updates made since the previous revision   |        |                                      |                     |
| Added new grid code documentation (NTS V2.1 and BOE-A-2021-904), New Template, New Grid capability and certifications status. Syntax Update. |        |                                      |                     |
| Confidentiality:   |        | Deliverable Type                     | Doc Classification: |
| 3 / CUSTOMER INFORMATION   |        | S12 - General Characteristics Manual | STD - Support       |

Siemens Gamesa Renewable Energy S.A. Parque Tecnológico de Bizkaia, Edificio 222, 48170, Zamudio, Vizcaya, Spain  
+34 944 03 73 52 – info@siemensgamesa.com – www.siemensgamesa.com

## Table of contents

|  |    |
|--|----|
| 1. Aim .....                                       | 3  |
| 2. Scope .....                                     | 3  |
| 3. Acronyms, Definitions and Legend .....          | 4  |
| 4. Country Regulations Overview .....              | 7  |
| 5. Requirements Analysis .....                     | 8  |
| 5.1. Rated Operation Range .....                   | 8  |
| 5.1.1. Frequency Operation Range .....             | 8  |
| 5.1.2. Voltage Operation Range .....               | 10 |
| 5.1.3. Voltage/Frequency Operation Area .....      | 14 |
| 5.1.4. Reactive Power Operation Range .....        | 17 |
| 5.2. Fault Ride Through Support .....              | 21 |
| 5.2.1. Current Support .....                       | 21 |
| 5.2.2. Active Power Recovery After Clearance ..... | 23 |
| 5.2.3. Consecutive Voltage Dips .....              | 24 |
| 5.3. Active Power / Frequency Regulation .....     | 25 |
| 5.4. Reactive Power / Voltage Regulation .....     | 30 |
| 5.5. Power Quality .....                           | 33 |
| 5.6. Communications .....                          | 34 |



|   |    |
|---|----|
| 5.7. Protections .....  | 36 |
| 5.8. Electrical Simulation Models .....                           | 37 |
| 5.9. WF Simulation/Test/Certification .....                       | 39 |
| 5.10. Special Requirements .....                                  | 41 |
| 5.10.1. Phase Jump .....  | 41 |
| 5.10.2. Inertia Emulation .....                                   | 42 |
| 5.10.3. Power Oscillations Damping (POD) .....                    | 44 |
| 5.10.4. System Strength .....                                     | 45 |
| 5.10.5. Reconnection Blockage / Synchronization to the Grid ..... | 46 |
| 6. Aspects to Clarify .....                                       | 47 |
| 6.1. Active Power/Frequency regulation .....                      | 47 |
| 6.2. Frequency Restoration .....                                  | 48 |
| 7. Summary .....  | 49 |
| 8. References .....   | 51 |

## 1. Aim

This document analyses the capabilities of Wind Turbine Generators (WTGs) developed by Siemens Gamesa Renewable Energy (SGRE) against the Grid Code requirements applicable **Spain** for the connection of Wind Farms (WF) to the **transmission and distribution** power grid. The main objective of this document is to provide a general overview of the compliance level of a WF with SGRE WTGs and SCADA/WF regulators.

## 2. Scope

The document considers **SG 5.X-170** platform together with the SCADA and WF regulator developed by SGRE.

It is important to note that most requirements are applicable at the Point of Common Coupling (PCC) of the WF and not directly at each of the WTGs' terminals. For this reason, the capabilities analysis is carried out with two different approaches depending on the requirement:

- ▶ Requirements for which WF compliance depends fundamentally on the WTG and/or SCADA/WF regulator capabilities (e.g. frequency operation range, fault ride through support, active power/frequency regulation...) → For these, an assessment of the WF compliance level is provided based on WTG and/or SCADA/WF regulator capabilities.
- ▶ Requirements for which the WTG and/or SCADA/WF regulator capabilities are only a factor for the WF compliance (e.g., voltage operation range, reactive power operation range, power quality...) → For these the WTG and/or SCADA/WF regulator capabilities to contribute to the WF compliance are provided.

The most appropriate converter configurations will be considered for the Grid Code analysis so that the requirements are fulfilled at the greatest possible extent but at the lowest cost. Considering the Grid Code analyzed in this document, the converters have been selected according Table 1 and their compliance with the Grid Code analyzed.

| Platform  | Converter |
|-----------|-----------|
| SG5.X-170 | -         |

Table 1 Selected Converters.

### 3. Acronyms, Definitions and Legend

| Acronym | Description   |
|---------|---|
| AM      | Application Mode  |
| BOP     | Balance of Plant  |
| CCU     | Converter Control Unit  |
| DSO     | Distribution System Operator, or the relevant governing body regarding grid connection requirements |
| EMT     | Electromagnetic Transient   |
| FSM     | Frequency Sensitive Mode  |
| GC      | Grid Code   |
| GCA     | Grid Code Analysis  |
| GE      | Global Engineering  |
| GE-GC   | Global Engineering- Grid Connection   |
| HV      | High Voltage  |
| IEC     | International Electrotechnical Commission   |
| IEEE    | Institute of Electrical and Electronic Engineers  |
| PD      | Product Development team  |
| LFSM-O  | Limited Frequency Sensitive Mode - Overfrequency  |
| LFSM-U  | Limited Frequency Sensitive Mode - Underfrequency   |
| LV      | Low Voltage   |
| MV      | Medium Voltage  |
| N/A     | Not Applicable  |
| OLTC    | On Load Tap Changer   |
| OVRT    | Overvoltage Ride Through  |
| PCC     | Point of Common Coupling  |
| PD      | Product Development (PD) team   |
| PGM     | Power Generating Module   |
| PLC     | Programmable Logic Controller   |
| PSS     | Power System Stabilizer   |
| p.u.    | Per Unit  |
| RMS     | Root-Mean-Square  |
| ROCOF   | Rate of Change of Frequency   |

|         |   |
|---------|---|
| SCADA   | Supervisory Control and Data Acquisition  |
| SGRE    | Siemens Gamesa Renewable Energy   |
| SSCI    | Sub-Synchronous Control Interactions  |
| STATCOM | Static Synchronous Compensator, also known as SVG   |
| TSO     | Transmission System Operator, or the relevant governing body regarding grid connection requirements |
| UVRT    | Undervoltage Ride Through   |
| WF      | Wind Farm   |
| WFR     | Wind Farm Regulator   |
| WTG     | Wind Turbine Generator  |

Table 2 Acronyms.

| Definition     | Description               |
|----------------|---------------------------|
| $\cos \varphi$ | Power factor              |
| $f_n$          | Nominal frequency         |
| $I_1$          | Positive Sequence Current |
| $I_2$          | Negative Sequence Current |
| $I_q$          | Reactive Current          |
| $I_r$          | Rated Current             |
| $P$            | Active Power              |
| $P_n$          | Nominal Active Power      |
| $Q$            | Reactive Power            |
| $T_{amb}$      | Rated Ambient Temperature |
| THD            | Total Harmonic Distortion |
| $U_n$          | Nominal Voltage           |

Table 3 Definitions.

| Legend                          | Description   |
|---------------------------------|---|
| ✓ Compliance                    | Compliance is expected  |
| ✂ Development in Progress       | A SCADA or WTG development is planned or underway in order to assure compliance                                 |
| ⚠ Request development upon need | A specific development is required and shall be requested when a project needs to comply with this requirement. |
| ❓ To be Clarified               | The requirement is not clear, or information is missing. Therefore, it shall be clarified with the Operator.    |
| ✗ Non-compliance                | The requirement cannot be fulfilled.  |
| ▶ Wind Farm Study Needed        | Wind Farm Study Needed  |

Table 4 Legend.

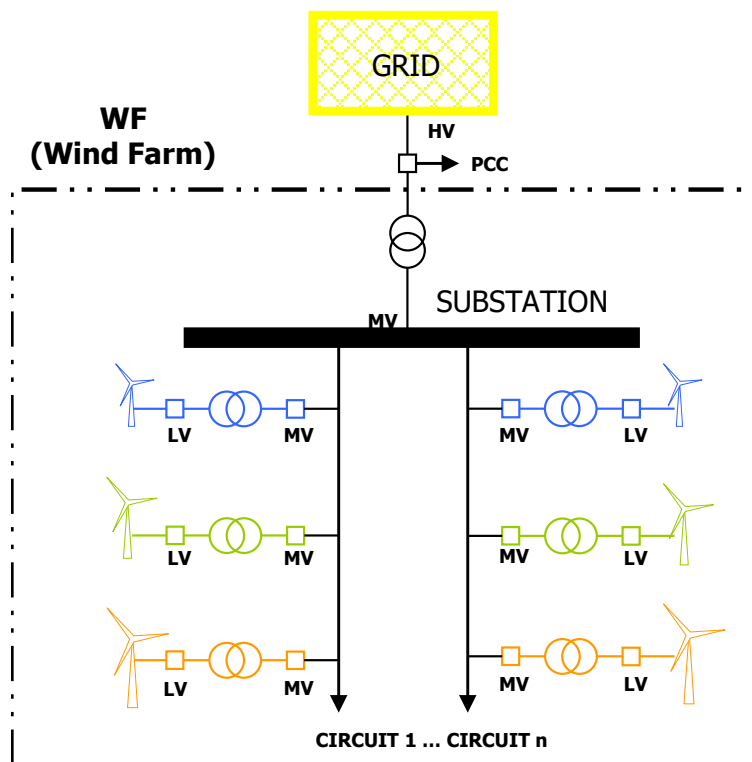


Figure 1 Conceptual scenario.



## SIGN CONVENTION FOR REACTIVE POWER:

The following sign convention regarding reactive power is used for the whole analysis:

- Reactive power absorption: The WTG imports reactive power from the public power grid. This operation is equivalent to a coil/reactor or an underexcited synchronous generator.
- Reactive power supply: The WTG exports reactive power to the public power grid. This operation is equivalent to a capacitor or an overexcited synchronous generator.

The terms “inductive reactive power” and “capacitive reactive power” are intentionally omitted in order to avoid any confusion.

## 4. Country Regulations Overview

The purpose of the analyzed document procedure is to establish minimum requirements for design, equipment, operation, commissioning and safety of the facilities connected to the Spanish mainland electrical system transport network, as well as the production and demand facilities in those aspects that they are applicable because of their influence on the electrical system as a whole, both from the Spanish mainland perspective and from the interconnected European system.

In this sense, the subject of the analyzed procedure is the establishment of the technical requirements and procedures established in the Commission Regulation (EU) 2016/631 of April 14, 2016, which establishes a network code on the connection requirements of generators to the network and complete the development of those requirements required by the Regulation; as well as technical aspects that, a priori, because of their local influence (not "cross-border") are outside the scope of European regulations but that have total relevance in the operation and safety of the electrical system.

The documents to be analyzed are:

- **BOE-A-2020-7439, "Real Decreto 647/2020, de 7 de julio, por el que se regulan aspectos necesarios para la implementación de los códigos de red de conexión de determinadas instalaciones eléctricas", 08/July/2020 [1].**
- **BOE-A-2020-8965, "Orden TED/749/2020, de 16 de julio, por la que se establecen los requisitos técnicos para la conexión a la red necesarios para la implementación de los códigos de red de conexión, 01/August/2020" [2].**
- **"Reglamento (UE) 2016/631. Código de red sobre requisitos de conexión de generadores a la red", April/2016 [3].**
- **Norma técnica de supervisión de la conformidad de los módulos de generación de electricidad según el reglamento UE 2016/631, Revisión 2.1, 09/July/2021 [4].**
- **"P.O. 9 Información intercambiada por el operador del Sistema", 20/December/2019 [5].**
- **"Condiciones de Validacion y Aceptacion de los Modelos", Revision June/2020 [6].**
- **"Requisitos de los modelos de instalaciones eólicas, fotovoltaicas, de almacenamiento y de todas aquellas instalaciones que no utilicen generadores síncronos directamente conectados a la red", Revision June/2020 [7].**
- **"Requisitos de los modelos de instalaciones FACTS", Revision June/2020 [8].**
- **BOE-A-2021-904, "Circular 1/2021, metodología y condiciones del acceso y de la conexión a las redes de transporte y distribución de las instalaciones de producción de energía eléctrica [9].**

Documents [1], [2], [3], [4] and [5] will be simply known as The Grid Code.

The requirements are specified depending on the type of the PGM (power-generating module) capacity and voltage level as specified in Item 1 of "Article 8 – Evaluación de la significatividad de los módulos de generación de electricidad" of the Grid Code [1]

- a) Tipo A: módulos de generación de electricidad cuyo punto de conexión sea inferior a 110 kV y cuya capacidad máxima sea igual o superior a 0,8 kW e igual o inferior a 100 kW.
- b) Tipo B: módulos de generación de electricidad cuyo punto de conexión sea inferior a 110 kV y cuya capacidad máxima sea superior a 100 kW e igual o inferior a 5 MW.
- c) Tipo C: módulos de generación de electricidad cuyo punto de conexión sea inferior a 110 kV y cuya capacidad máxima sea superior a 5 MW e igual o inferior a 50 MW.
- d) Tipo D: módulos de generación de electricidad cuyo punto de conexión sea igual o superior a 110 kV o cuya capacidad máxima sea superior a 50 MW.

For the Power Quality requirements, it is going to be considered the Annex I "Contenido de la base de datos estructural del operador del Sistema" of the document [5].

## 5. Requirements Analysis

### 5.1. Rated Operation Range

#### 5.1.1. Frequency Operation Range

- REQUIREMENTS:

The Grid Code requirements related with the Frequency Operation Range at rated voltage and power – and the allowed power deratings – can be found in section “Rangos de Frecuencia” of document [2].

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item              |                        | Unit | Value      |
|-------------------|------------------------|------|------------|
| Nominal Frequency |                        | Hz   | 50         |
| Underfrequency    |                        |      |            |
| 1                 | Underfrequency Value 1 | p.u. | 0.95       |
|                   | Underfrequency Time 1  | s    | 1800       |
| 2                 | Underfrequency Value 2 | p.u. | 0.97       |
|                   | Underfrequency Time 2  | s    | 1800       |
| 3                 | Underfrequency Value 3 | p.u. | 0.97       |
|                   | Underfrequency Time 3  | s    | continuous |
| 4                 | Underfrequency Value 4 | p.u. | 0.97       |
|                   | Underfrequency Time 4  | s    | continuous |
| 5                 | Underfrequency Value 5 | p.u. | 0.97       |
|                   | Underfrequency Time 5  | s    | continuous |
| Overfrequency     |                        |      |            |
| 1                 | Overfrequency Value 1  | p.u. | 1.03       |
|                   | Overfrequency Time 1   | s    | 1800       |
| 2                 | Overfrequency Value 2  | p.u. | 1.02       |
|                   | Overfrequency Time 2   | s    | 1800       |
| 3                 | Overfrequency Value 3  | p.u. | 1.02       |
|                   | Overfrequency Time 3   | s    | 1800       |
| 4                 | Overfrequency Value 4  | p.u. | 1.02       |

|       |                                 |      |            |
|-------|---------------------------------|------|------------|
|       | Overfrequency Time 4            | s    | continuous |
| 5     | Overfrequency Value 5           | p.u. | 1.02       |
|       | Overfrequency Time 5            | s    | continuous |
| ROCOF |                                 |      |            |
|       | ROCOF limit                     | Hz/s | 2.0        |
|       | Applicable Time Frame for ROCOF | s    | 0.5        |

Table 5 Grid Code requirements for Frequency Operation Range at PCC.

- COMPLIANCE:

SG5.X-170:

According to the correspondent platform documentation, the compliance analysis for a WF with SG5.X-170 WTGs is described in the following table:

| WTGs              | GD Document   | Compliance   |
|-------------------|---------------|--------------|
| <b>SG 5.X-170</b> | D3120497 [10] | ✓ Compliance |

WIND FARM:

The frequency operation requirements can be extrapolated from the PCC and be directly applied to the LV terminals of the WTGs. Therefore, the analysis performed for a SGRE platform can be considered equivalent to the compliance analysis of the WF at its PCC if the rest of the equipment at the WF level also withstands this frequency operation range.



## 5.1.2. Voltage Operation Range

- REQUIREMENTS:

The Grid Code requirements related with the Voltage Operation Range can be found in section “REQUISITOS DE TENSIÓN DE LOS MÓDULOS DE GENERACIÓN DE ELECTRICIDAD” of document [2].

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item         |                      | Unit | Value                                |  |   |   |
|--------------|----------------------|------|--------------------------------------|--|---|---|
| Undervoltage |                      |      | Type B/C < 110kV<br>Distribution (2) | Type B/C/D < 110kV<br>Transmission (3) | Type D ≥ 110kV and < 300 kV<br>Transmission (1) | Type D ≥ 300kV and ≤ 400 kV<br>Transmission |
| 1            | Undervoltage Value 1 | p.u. | 0.85                                 | 0.05                                   | 0.0   | 0.0   |
|              | Undervoltage Time 1  | s    | 0                                    | 0.2                                    | 0.15  | 0.15  |
| 2            | Undervoltage Value 2 | p.u. | 0.85                                 | 0.85                                   | 0.85  | 0.85  |
|              | Undervoltage Time 2  | s    | 1.15                                 | 1.5                                    | 1.5   | 1.5   |
| 3            | Undervoltage Value 3 | p.u. | 0.85                                 | 0.85                                   | 0.85  | 0.85  |
|              | Undervoltage Time 3  | s    | continuous                           | 3600                                   | 3600  | 3600  |
| 4            | Undervoltage Value 4 | p.u. | 0.85                                 | 0.85                                   | 0.9   | 0.9   |
|              | Undervoltage Time 4  | s    | continuous                           | continuous                             | 3600  | 3600  |
| 5            | Undervoltage Value 5 | p.u. | 0.85                                 | 0.85                                   | 0.9   | 0.9   |
|              | Undervoltage Time 5  | s    | continuous                           | continuous                             | continuous                                      | continuous                                  |
| Overvoltage  |                      |      |                                      |  |   |   |
| 1            | Overvoltage Value 1  | p.u. | 1.2                                  | 1.2                                    | 1.2   | 1.2   |
|              | Overvoltage Time 1   | s    | 0                                    | 0                                      | 0   | 0.  |
| 2            | Overvoltage Value 2  | p.u. | 1.15                                 | 1.2                                    | 1.2   | 1.2   |
|              | Overvoltage Time 2   | s    | 0.5                                  | 0.05                                   | 0.05  | 0.05  |
| 3            | Overvoltage Value 3  | p.u. | 1.15                                 | 1.15                                   | 1.15  | 1.1   |
|              | Overvoltage Time 3   | s    | 1                                    | 1                                      | 1   | 1   |
| 4            | Overvoltage Value 4  | p.u. | 1.1                                  | 1.15                                   | 1.15  | 1.1   |
|              | Overvoltage Time 4   | s    | 1                                    | 3600                                   | 3600  | 3600  |

|   |                     |      |            |       |       |        |
|---|---------------------|------|------------|-------|-------|--------|
| 5 | Overtoltage Value 5 | p.u. | 1.1        | 1.118 | 1.118 | 1.0875 |
|   | Overtoltage Time 5  | s    | continuous | 3600  | 3600  | 3600   |

Table 6 Grid Code requirements for Voltage Operation Range at PCC.

## Remarks:

- (1) For voltage operation compliance evaluation is used the worst profile, it is MGE Type D connected to the transmission grid with  **$\geq 110\text{kV}$  and  $< 300\text{ kV}$**
- (2) For WF types B / C connected to the Distribution system, the GC only defines one point for undervoltage condition ( $< 0.85$ ; 1.15 sec), 0.85 is assumed for continuous operation
- (3) For WF types B / C connected to transmission system, the operating range is defined as the envelope of the UVRT curve and the continuous operating voltage table

- COMPLIANCE:

SG5.X-170:

According to the document D3120497 [10], the capability of SG5.X-170 to contribute to the WF compliance of the continuous operation voltage range at rated frequency and rated active power is the following:

| Continuous Operation Voltage Range |        | Maximum Negative Sequence Voltage |
|------------------------------------|--------|-----------------------------------|
| Min                                | Max    |                                   |
| 0.95Un                             | 1.12Un | $\leq 5\%$                        |

Table 7 Continuous operation voltage range of SG5.X-170 at MV terminals.

In addition, they are capable of withstanding symmetrical and asymmetrical faults for any voltage profile within the curves illustrated in Figure 2 without disconnecting.

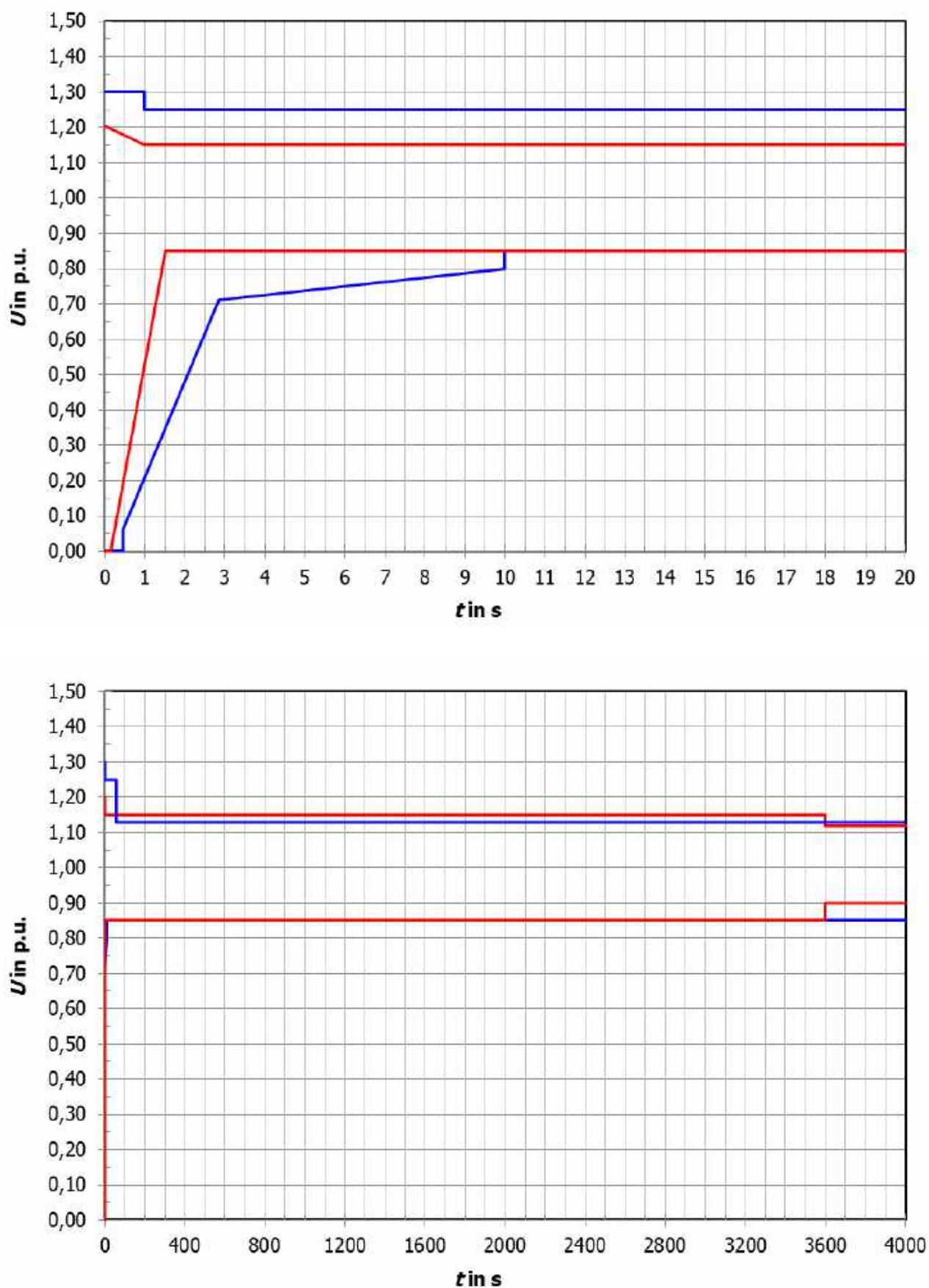


Figure 2. Voltage capability of SG5.X-170 at the **MV terminals** (blue) versus voltage profile required by the Grid Code at the PCC (red).

## WIND FARM:

The requirements regarding voltage operation range are specified at the PCC.

Considering this, to ensure compliance a specific study of the whole WF must be carried out in order to analyze the voltage operation range at the WTGs terminals for different operation scenarios of the WF. If this range can be for a certain time beyond the mentioned WTG limits, the WTGs may disconnect.

The complete WF electrical design must be taken into account for these studies, being the following the higher impact elements:

1. On-Load Tap Changer (OLTC): Substations transformers equipped with OLTC are able to decouple the voltage at the PCC with the voltage at the WF collector system.
2. WF collector system impedances: The voltage drop/rise at WTGs terminals across the WF collector system is dependent on this.
3. Reactive power control operation: The reactive power provided by WTGs and other reactive compensation elements causes voltage drop/rise at WTGs terminals. This control is done:
  - In continuous operation by the WF regulator, dispatching setpoints to the different elements.
  - In transient situations by the individual elements.

## 5.1.3. Voltage/Frequency Operation Area

- REQUIREMENTS:

The Grid Code requirements related with the Voltage/ Frequency Operation Area can be found in section 1.1 “RANGOS DE FRECUENCIA” of document [2].

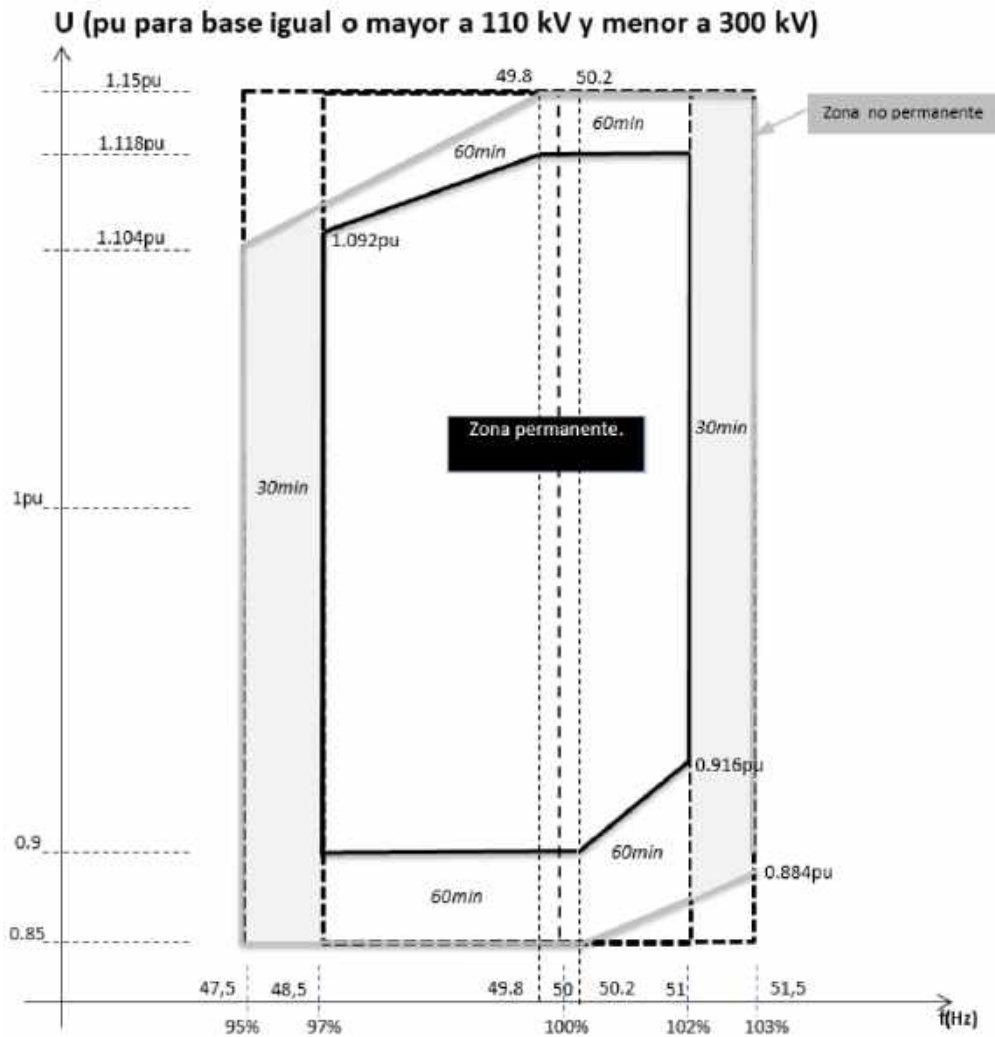


Figure 3. Voltage/Frequency requirements  $\geq 110$  to  $<300$  kV.

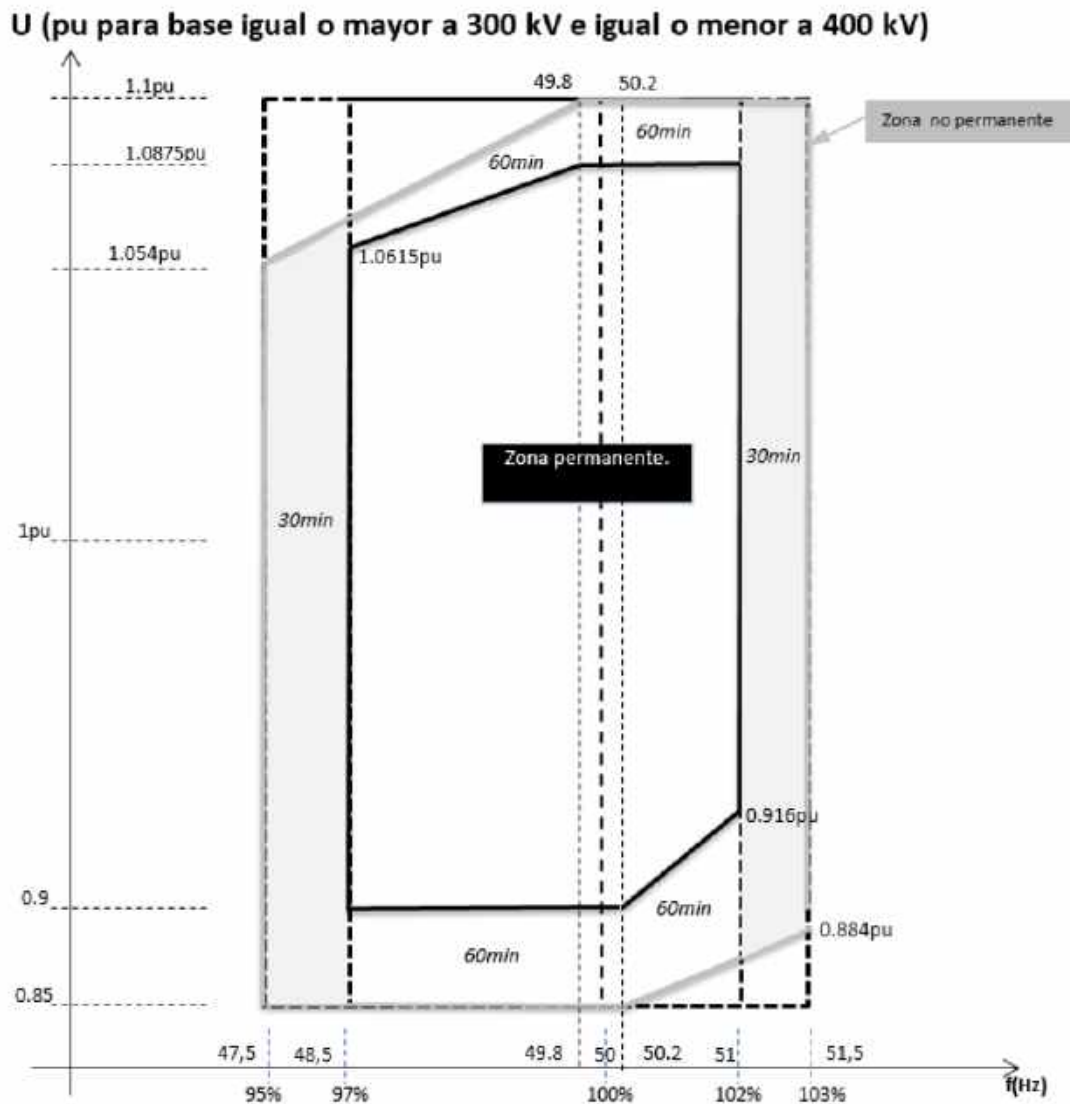


Figure 4. Voltage/Frequency requirements  $\geq 300$  to  $<400$  kV.

- COMPLIANCE:

SG5.X-170:

The capability of SG5.X-170 WTGs to contribute to the WF compliance of this requirement can be found in D3120497 [10].

## WIND FARM:

The requirements regarding voltage/frequency operation range are normally specified at the PCC. Frequency requirements can be extrapolated from the PCC and be directly applied to LV terminals of the WTGs. However, voltage requirements cannot be directly extrapolated to the LV terminals of the WTGs.

Considering this, to ensure compliance a specific study of the whole WF must be carried out in order to analyze the voltage operation range at the WTGs terminals for different operation scenarios of the WF. If this range can be for a certain time beyond the mentioned WTG limits, the WTGs may disconnect.

The complete WF electrical design must be taken into account for these studies, being the following the higher impact elements:

1. On-Load Tap Changer (OLTC): Substations transformers equipped with OLTC are able to decouple the voltage at the PCC with the voltage at the WF collector system.
2. WF collector system impedances: The voltage drop/rise at WTGs terminals across the WF collector system is dependent on this.
3. Reactive power control operation: The reactive power provided by WTGs and other reactive compensation elements causes voltage drop/rise at WTGs terminals. This control is done:
  - In continuous operation by the WF regulator, dispatching setpoints to the different elements.
  - In transient situations by the individual elements.

## 5.1.4. Reactive Power Operation Range

- REQUIREMENTS:

The Grid Code requirements related with the Reactive Power Operation Range can be found in section 2.3.2 “CAPACIDAD DE POTENCIA REACTIVA” of document [2]

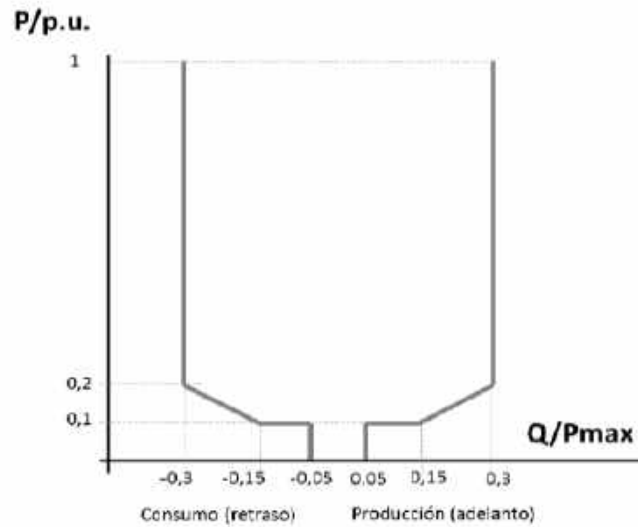


Figure 5. PQ requirements for MGE Type D

- \* 1,10 en el caso de tensiones en el punto de conexión desde 110 hasta 300 kV.
- \*\* 1,0875 en el caso de tensiones en el punto de conexión mayores de 300 y hasta 400 kV.

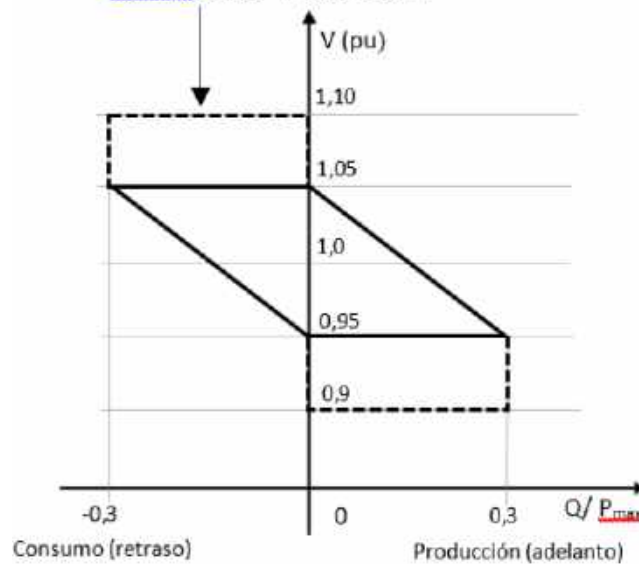


Figure 6. Q-U requirements for MGE Type D.



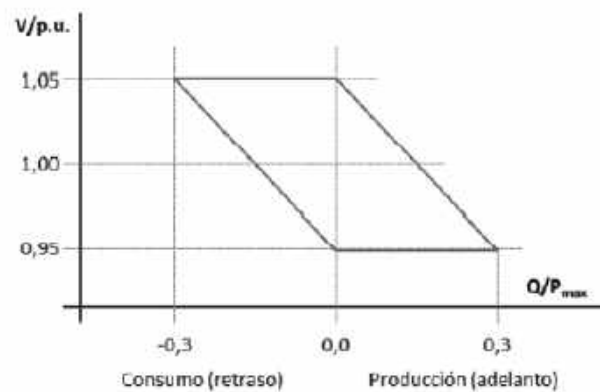


Figure 7. Q-U requirements for MGE Type B or C with  $P_{max} < 15\text{MW}$ .

There are particular Grid Code requirements related with the reactive power operation range when the central busbar of the MPE shares the facilities with other MPEs ( Cases A and B) and it can be found in section 5.7.3.2 “Procedimiento específico en el caso de existencia de instalaciones compartidas” of document [4]

## Case A

In the event that BC of the PGM is located at the HV side of the step-up transformer (LAT) of the PGM, the supplementary simulation shall be carried out considering both the voltage and the reactive power at BC (i.e. LAT in this case) in such a way that it will be necessary to model the collector network from the PGU up to BC, but not the evacuation network up to the NCP

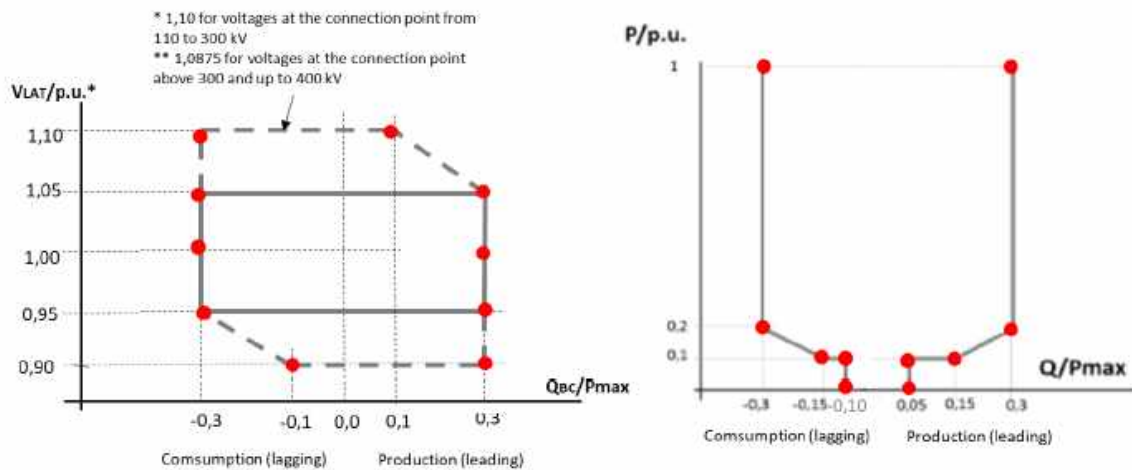


Figure 8. Q-U and PQ requirements for MGE Type D in special Case A

## Case B

If the BC of the PGM is located at the LV side of the PGM step-up transformer, the supplementary simulation shall be performed by measuring the reactive power at BC and considering the voltage at the HV side of the shared step-up transformer, so that it will be necessary to model the collector network from the PGU to BC and the shared transformer, but not the rest of the evacuation network up to the NCP

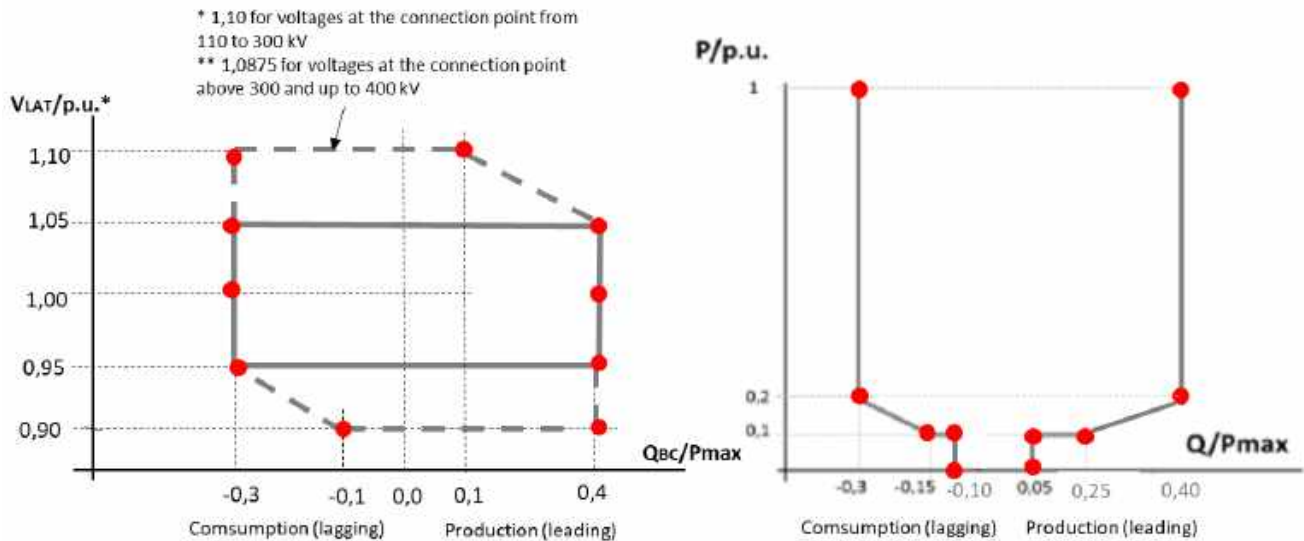


Figure 9. Q-U and PQ requirements for MGE Type D in special Case B

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Type D-C-B |        | Type Case A |        | Type Case B |        |
|------------|--------|-------------|--------|-------------|--------|
| P (pu)     | Q (pu) | P (pu)      | Q (pu) | P (pu)      | Q (pu) |
| 0.00       | -0.05  | 0           | -0.10  | 0.00        | -0.10  |
| 0.10       | -0.05  | 0.10        | -0.10  | 0.10        | -0.10  |
| 0.10       | -0.15  | 0.10        | -0.15  | 0.10        | -0.15  |
| 0.20       | -0.3   | 0.20        | -0.3   | 0.20        | -0.3   |
| 1.00       | -0.3   | 1.00        | -0.3   | 1.00        | -0.3   |
| 1.00       | 0.3    | 1.00        | 0.3    | 1.00        | 0.4    |
| 0.20       | 0.3    | 0.20        | 0.3    | 0.2         | 0.4    |
| 0.10       | 0.15   | 0.10        | 0.15   | 0.10        | 0.25   |
| 0.10       | 0.05   | 0.10        | 0.05   | 0.10        | 0.05   |
| 0.00       | 0.05   | 0.00        | 0.05   | 0.00        | 0.05   |

Table 8 Grid Code requirements for PQ capability at rated voltage.

| Type D<br>≥ 110 to <300 kV. |        | Type D<br>≥ 300 to <400 kV. |        | Type B / C<br>with Pmax<15MW |        | Type Case A |        | Type Case B |        |
|-----------------------------|--------|-----------------------------|--------|------------------------------|--------|-------------|--------|-------------|--------|
| Q (pu)                      | V (pu) | Q (pu)                      | V (pu) | Q (pu)                       | V (pu) | Q (pu)      | V (pu) | Q (pu)      | V (pu) |
| 0.00                        | 0.95   | 0.00                        | 0.95   | 0.00                         | 0.95   | 0.00        | 0.9    | 0           | 0.9    |
| -0.30                       | 1.05   | -0.30                       | 1.05   | -0.30                        | 1.05   | -0.1        | 0.9    | -0.1        | 0.9    |
| -0.30                       | 1.10   | -0.30                       | 1.087  | 0.00                         | 1.05   | -0.3        | 0.95   | -0.3        | 0.95   |
| 0.00                        | 1.10   | 0.00                        | 1.087  | 0.30                         | 0.95   | -0.3        | 1      | -0.3        | 1      |
| 0.00                        | 1.05   | 0.00                        | 1.05   | 0.00                         | 0.95   | -0.3        | 1.05   | -0.3        | 1.05   |
| 0.30                        | 0.95   | 0.30                        | 0.95   |                              |        | -0.3        | 1.10   | -0.3        | 1.1    |
| 0.30                        | 0.90   | 0.30                        | 0.90   |                              |        | 0.1         | 1.10   | 0.1         | 1.1    |
| 0.00                        | 0.90   | 0.00                        | 0.90   |                              |        | 0.3         | 1      | 0.4         | 1.05   |
| 0.00                        | 0.95   | 0.00                        | 0.95   |                              |        | 0.3         | 0.95   | 0.4         | 0.95   |
|                             |        |                             |        |                              |        | 0.3         | 0.9    | 0.4         | 0.9    |

Table 9 Grid Code requirements for QU capability at rated voltage.

- COMPLIANCE:

## SG5.X-170:

The capability of SG5.X-170 WTGs to contribute to the WF compliance of this requirement can be found in the document D2904942 [11]

## WIND FARM:

Considering that the reactive power requirements are specified at the PCC, an electrical study must be carried out by the WF developer in which both the power factor range at the PCC and the voltage deviations at the LV terminals of the WTGs are evaluated. This study would also determine if and to what extent compensation equipment is needed at the WF.

## 5.2. Fault Ride Through Support

### 5.2.1. Current Support

- REQUIREMENTS:

The Grid Code requirements related with Fault Ride Through Current Support can be found in section “2.3 REQUISITOS DE TENSIÓN DE LOS MÓDULOS DE PARQUE ELÉCTRICO” of document [2] .

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item  |                            | Unit  | Value                               |
|---|----------------------------|-------|-------------------------------------|
| Current Support   |                            | -     | Reactive & Active                   |
| Current priority during VRT operation                   |                            | -     | Q priority                          |
| Maximum Required Current Injection/Absorption           |                            | p.u.  | 1.00                                |
| Current Injection/Absorption Calculation Mode           |                            | -     | Relative Value                      |
| Voltage Calculation Mode                                |                            | -     | Relative Value                      |
| k Factor  |                            | -     | $2 \leq K \leq 6$ by default = 3.50 |
| Response Time for Reactive Current Injection/Absorption |                            |       |                                     |
| Tolerance band  |                            | +%/-% | -10% of $I_n$ / +20% of $I_n$       |
| Reaction time   |                            | ms    | $\leq 40$ (1)                       |
| Rise time   |                            | ms    | $\leq 50$                           |
| Reaction time + Rise time                               |                            | ms    | $\leq 50$                           |
| Response time   |                            | ms    | -                                   |
| Settling time   |                            | ms    | $\leq 80$ (1)                       |
| Overshoot   |                            | %     | -                                   |
| Reactive Current Absorption/Injection during UVRT/OVRT  |                            |       |                                     |
| 1   | Voltage Setpoint 1 in p.u. | p.u.  | 1.30                                |
|   | Current Setpoint 1 in p.u. | p.u.  | -1.05                               |
| 2   | Voltage Setpoint 2 in p.u. | p.u.  | 1.10                                |
|   | Current Setpoint 2 in p.u. | p.u.  | -0.35                               |
| 3   | Voltage Setpoint 3 in p.u. | p.u.  | 1                                   |

|   |  |      |                       |
|---|--|------|-----------------------|
|   | Current Setpoint 3 in p.u.                           | p.u. | 0                     |
| 4 | Voltage Setpoint 4 in p.u.                           | p.u. | 0.9                   |
|   | Current Setpoint 4 in p.u.                           | p.u. | 0.35                  |
| 5 | Voltage Setpoint 5 in p.u.                           | p.u. | 0.5                   |
|   | Current Setpoint 5 in p.u.                           | p.u. | 1.75                  |
| 6 | Voltage Setpoint 6 in p.u.                           | p.u. | 0.00                  |
|   | Current Setpoint 6 in p.u.                           | p.u. | 3.50                  |
|   | Controlled Asymmetrical Current Injection/Absorption | -    | DFIG natural response |

Table 10 Grid Code requirements for Current Support.

Remarks:

(1) With regard to the evaluation of these times, if for detecting UVRT condition was used current detection method, up to 20ms are added for the evaluation of these times, in order to determinate the rms value with average values of 20ms.

- COMPLIANCE:

SG5.X-170:

According to the correspondent platform documentation, the compliance analysis for a WF with SG5.X-170 WTGs is described in the following table:

| WTGs              | GD Document   | Compliance   |
|-------------------|---------------|--------------|
| <b>SG 5.X-170</b> | D3120497 [10] | ✓ Compliance |

WIND FARM:

Usually compliance with this requirement is accepted to be evaluated at WTG terminals. Otherwise, if compliance is demanded at PCC, the WF developer must carry out studies in order to analyze the reactive current support achieved by the WF at the PCC and determine what extra equipment for reactive current support is necessary. Nevertheless, SGRE will cooperate with the WF developer in order to find the correct solution.

### 5.2.2. Active Power Recovery After Clearance

- REQUIREMENTS:

The Grid Code requirements related with the Active Power Recovery After Clearance can be found in section 3.3 “REQUISITOS DE ROBUSTEZ DE LOS MÓDULOS DE PARQUE ELÉCTRICO” of document [2] and the section 5.11.2.5 “CRITERIOS DE EVALUACIÓN DEL REQUISITO DE RECUPERACIÓN DE LA POTENCIA ACTIVA TRAS EL HUECO DE TENSIÓN” of document [4]

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item   | Unit | Value   |
|--|------|---|
| Active Power Level for Recovery Acceptance     | %    | 95.0  |
| Maximum Time for Active Power Recovery         | s    | 1 s for $U_{dip} \geq 0.5U_n$<br>2 s for $0.5U_n > U_{dip} \geq 0.2U_n$<br>3 s for $U_{dip} < 0.2U_n$ |
| Active Power Recovery Rate after UVRT Mode     | pu/s | N/A   |
| Active Power tolerance for settling acceptance | %    | 5   |
| Maximum time for active power settling         | s    | 3 s for $U_{dip} \geq 0.5U_n$<br>4 s for $0.5U_n > U_{dip} \geq 0.2U_n$<br>5 s for $U_{dip} < 0.2U_n$ |
| Voltage level for active power recovery        | pu   | 0.85  |

Table 11 Grid Code requirements for Active Power Recovery After Clearance.

- COMPLIANCE:

#### SG5.X-170:

According to the correspondent platform documentation, the compliance analysis for a WF with SG5.X-170 WTGs is described in the following table:

| WTGs              | GD Document   | Compliance   |
|-------------------|---------------|--------------|
| <b>SG 5.X-170</b> | D3120497 [10] | ✓ Compliance |

#### WIND FARM:

Usually compliance with this requirement is accepted to be evaluated at WTG terminals. Otherwise, if compliance is demanded at PCC, the WF developer must carry out studies in order to analyze the active power recovery achieved by the WF at the PCC and determine what extra equipment for active power support is necessary. Nevertheless, SGRE will cooperate with the WF developer in order to find the correct solution.

### 5.2.3. Consecutive Voltage Dips

- REQUIREMENTS:

The Grid Code requirements related with the Consecutive Voltage Dips can be found in section 2.3 “REQUISITOS DE TENSIÓN DE LOS MÓDULOS DE PARQUE ELÉCTRICO” of document [2]

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item   | Unit | Value             |
|--|------|-------------------|
| Time between Consecutive UVRTs                 | s    | 5                 |
| Number of Consecutive UVRTs                    | -    | Not defined by GC |
| Time between series of consecutive UVRTs       | s    | N/A               |
| Voltage level between consecutive voltage dips | %    | Not defined by GC |
| Energy to be dissipated                        | Pn*s | WTG capability    |

Table 12 Grid Code requirements for Consecutive Voltage Dips.

- COMPLIANCE:

#### SG5.X-170:

According to the correspondent platform documentation, the compliance analysis for a WF with SG5.X-170 WTGs is described in the following table:

| WTGs          | GD Document   | Compliance   |
|---------------|---------------|--------------|
| <b>SG 5.X</b> | D3120497 [10] | ✓ Compliance |

#### WIND FARM:

Usually compliance with this requirement is accepted to be evaluated at each individual element of the WF.

### 5.3. Active Power / Frequency Regulation

- REQUIREMENTS:

The Grid Code requirements related with **Active Power Regulation** can be found in section “1.6. Capacidad y rango de control de la potencia activa” of the document [2].

The Grid Code requirements related with **Frequency Regulation** can be found in section “1. REQUISITOS DE FRECUENCIA” of the d document [2].

Figure 1

Active power frequency response capability of power-generating modules in LFSM-O

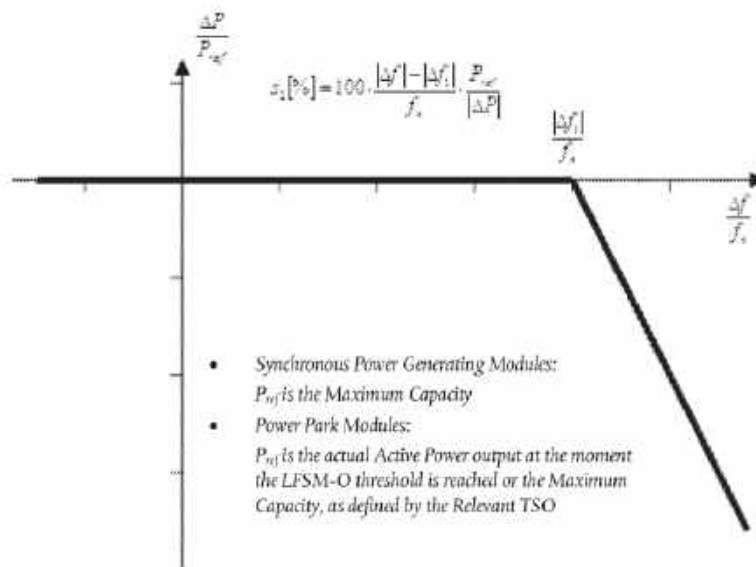


Figure 10 LFSM-O mode [3].

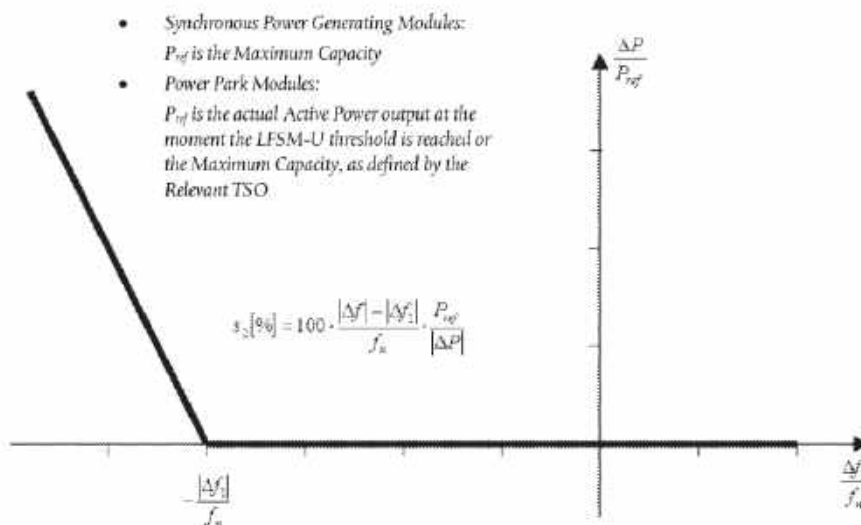


Figure 11 LFSM-U mode [3].



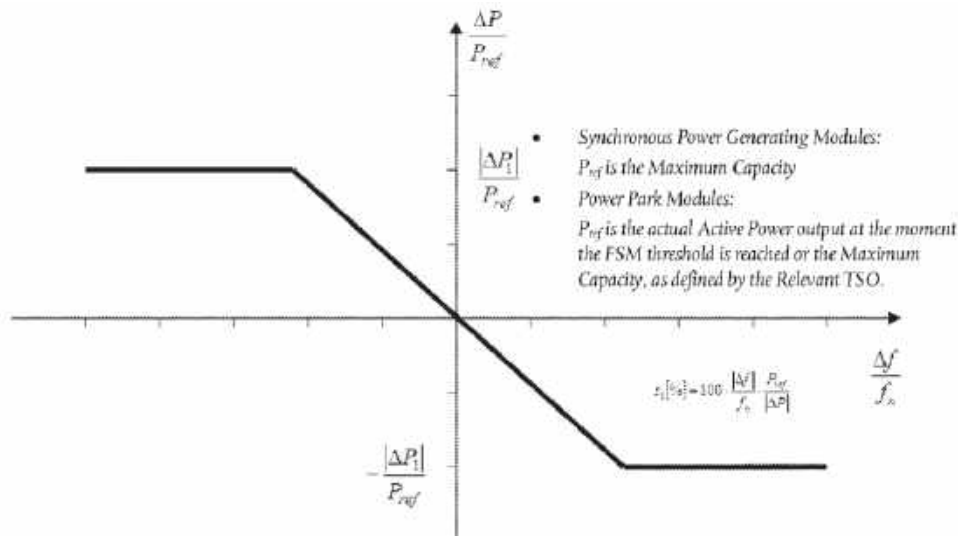


Figure 12 FSM mode [3].

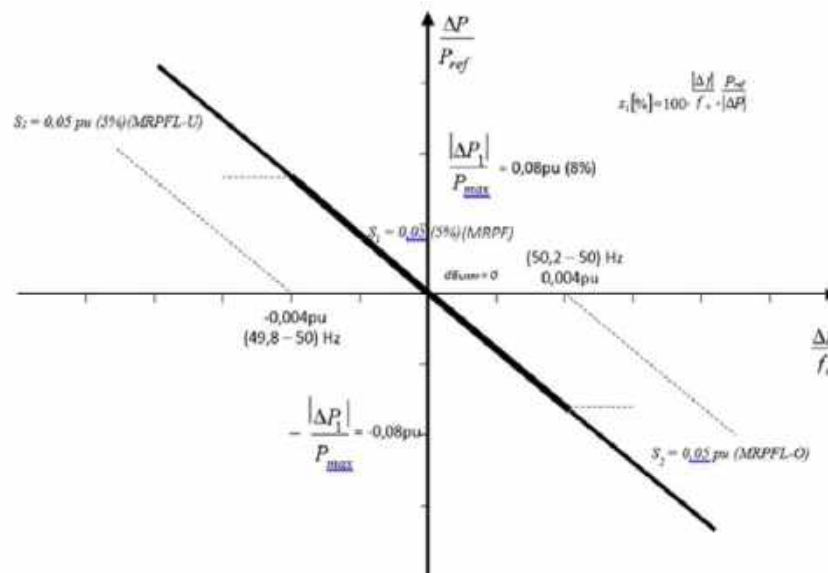


Figure 13 Example of the three modes combined [2].

The Grid Code requirements related with **Active Power Ramp Rates** can be found in section “5.9. Limitación a las rampas de subida y bajada de la potencia” of the document [2].

The Grid Code definition of the **Active Power Regulation Times** can be found in section “1.3” of the document [2]. The SGRE definition of the regulation times is included in the figure below. Note that this SGRE definition matches with the GC.

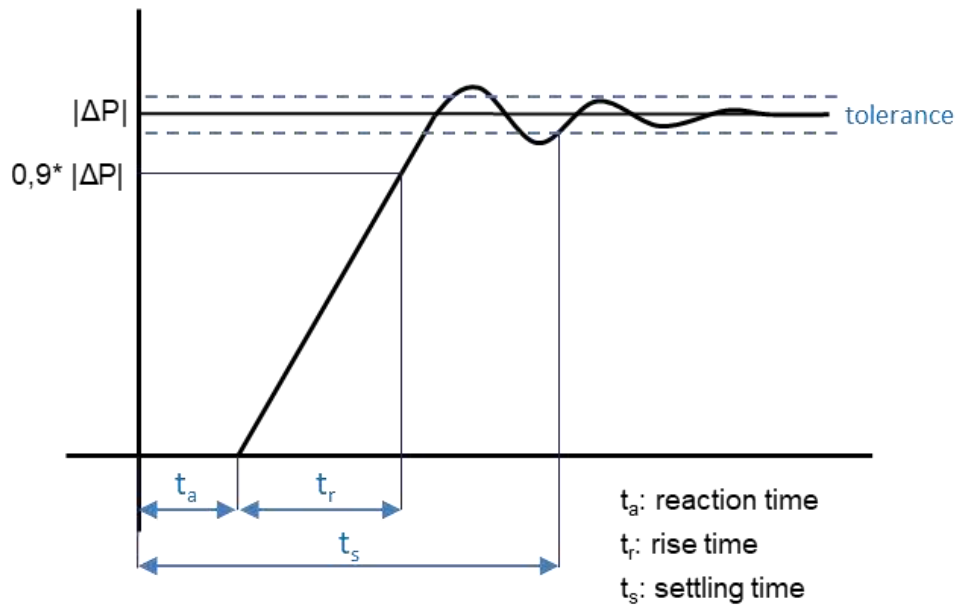


Figure 14 SGRE Definition of the regulation times:  $t_a$ ,  $t_r$  and  $t_s$  (te).

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Requirement Category    | [Doc] Section     | MODE / Requirement                 | Type B   | Type C  | Type D   | Compliance            |
|-------------------------|-------------------|------------------------------------|--|---|--|-----------------------|
| WF Types                |                   | Generator Type thresholds          | $P_n \leq 5 \text{ MW}$<br>and<br>$V_n < 110 \text{ Kv}$ | $P_n \leq 50 \text{ MW}$<br>and<br>$V_n < 110 \text{ Kv}$ | $P_n > 50 \text{ MW}$<br>or<br>$V_n \geq 110 \text{ Kv}$ |                       |
| ACTIVE POWER REGULATION |                   | AVAILABLE POWER MODE               | Not indicated in GC                                      | Not indicated in GC                                       | Not indicated in GC                                      | ✓ Compliance          |
|                         |                   | SPINNING RESERVE / DELTA CONTROL   | Not indicated in GC                                      | Not indicated in GC                                       | Not indicated in GC                                      |                       |
|                         | 1.6 [2]           | CURTAILMENT MODE                   | Required   | Required  | Required   | ✓ Compliance          |
|                         | 5.9 [4]           | Curtailment Ramps                  | -  | To be agreed with SO                                      | To be agreed with SO                                     |                       |
|                         | 1.6 [2]           | Curtailment settling time          | Max 3 min  | Max 2 min   | Max 2 min  |                       |
|                         | 1.6 [2]           | Curtailment Steady state tolerance | $\pm 5\% P_n$  | $\pm 5\% P_n$   | $\pm 5\% P_n$  |                       |
|                         | OTHER:            |                                    |  |   |  |                       |
|                         |                   | CEASE POWER 5s                     | Required   | NA  | NA   | ⚠ To be Clarified (1) |
|                         | 1.3, 1.7, 1.8 [2] | FREQUENCY MODE                     | Required   | Required  | Required   | ✓ Compliance          |

|                      |                   |   |                                   |                               |                               |                       |  |
|----------------------|-------------------|---|-----------------------------------|-------------------------------|-------------------------------|-----------------------|--|
| FREQUENCY REGULATION |                   |   | Frequency Regulation at WTG level | No                            | No                            | No                    |  |
|                      | 1.3, 1.7, 1.8 [2] | ta/tr/ts (ramp down)                    | $\leq 2s/\leq 2s/\leq 20s$        | $\leq 500ms/\leq 2s/\leq 20s$ | $\leq 500ms/\leq 2s/\leq 20s$ | ? To be Clarified (2) |  |
|                      | 1.3, 1.7, 1.8 [2] | ta/tr/ts (ramp up)                      | $\leq 2s/\leq 5s/\leq 30s$        | $\leq 500ms/\leq 5s/\leq 30s$ | $\leq 500ms/\leq 5s/\leq 30s$ | ? To be Clarified (2) |  |
|                      | 1.3, 1.7, 1.8 [2] | Steady state tolerance freq. regulation | $\pm 5\% \Delta P$                | $\pm 5\% \Delta P$            | $\pm 5\% \Delta P$            | (3)                   |  |
|                      | 1.8 [2]           | Secondary Frequency regulation          | ??                                | ??                            | ??                            | ? To be Clarified (4) |  |
|                      | 5.4 [4]           | Frequency Restoration                   | ??                                | ??                            | ??                            | ? To be Clarified (5) |  |
|                      | -                 | Enhanced Frequency Ramps needed         | Yes                               | Yes                           | Yes                           | ? To be Clarified (2) |  |
|                      | OTHER:            |   |                                   |                               |                               |                       |  |
|                      |                   |   |                                   |                               |                               |                       |  |
|                      |                   |   |                                   |                               |                               |                       |  |

Table 13 Grid Code requirements for Active Power / Frequency Regulation.

## Remarks:

- (1) A steady state tolerance expressed as % of  $\Delta P$  could imply a very demanding band for low power increase values. Therefore, ideally the tolerance shall be expressed as % of the rated power.
- (2) Read aspects to clarify section 6.1 in this GCA.
- (3) Read aspects to clarify section 0 in this GCA

According to the SGRE interpretation of the GC, the key frequency regulation parameters are summarized in the following table:

| Mode   | [Doc] Section | Parameter  | Type B      | Type C      | Type D      |
|--------|---------------|--|-------------|-------------|-------------|
| LFSM-O | 1.3 [2]       | LFSM-O frequency threshold                                       | 50,2 Hz     | 50,2 Hz     | 50,2 Hz     |
|        | 1.3 [2]       | LFSM-O Droop setting   | 5%          | 5%          | 5%          |
|        | 5.1 [4]       | LFSM-O definition of Pref  | Pnom        | Pnom        | Pnom        |
|        |               | Behavior of the PGM once the regulating minimum level is reached | Not defined | Not defined | Not defined |

|          |         |   |    |          |          |
|----------|---------|---|----|----------|----------|
| LFSM - U | 1.7 [2] | LFSM-U frequency threshold  | NA | 49.8 Hz  | 49.8 Hz  |
|          | 1.7 [2] | Droop setting   | NA | 5%       | 5%       |
|          | 5.2 [4] | LFSM-U definition of Pref   | NA | Pnom     | Pnom     |
| FSM      | 1.8 [2] | $ \Delta P /P_{ref}$  | NA | 8%       | 8%       |
|          | 1.8 [2] | frequency response insensitivity                                      | NA | = 10 mHz | = 10 mHz |
|          | 1.8 [2] | FSM deadband  | NA | 0 mHz    | 0 mHz    |
|          | 1.8 [2] | FSM droop (up)  | NA | 5%       | 5%       |
|          | 1.8 [2] | FSM droop (down)  | NA | 5%       | 5%       |
|          | 5.3 [4] | FSM definition of Pref  | NA | Pnom     | Pnom     |
|          | 1.8 [2] | t1 maximum admissible initial delay for PGMs without inertia          | NA | 500 ms   | 500 ms   |
|          | 1.8 [2] | t2 maximum admissible full activation time                            | NA | 30 s     | 30 s     |
|          | 1.8 [2] | time period for the provision of full active power frequency response | NA | 15 min   | 15 min   |

Table 14 Grid Code requirements for Regulation Parameters.

- COMPLIANCE:

SG5.X-170:

According to the document D3120497 [10], SG5.X-170 WTGs could comply with the required active power ramp rates.

Time responses required in frequency regulation ( $t_r$ ) makes that fast frequency ramps are required in order to provide fast frequency regulation active power ramps (22.5%Pn/s when decreasing power and 3.6%Pn/s when increasing power). SGRE SG5.X-170 could comply with this requirement but SW logics are pending to implement in serial SW

WIND FARM:

SGRE PPC cannot comply with all the requirements. The requirements related with the MRPF highlighted in section 6.1 of this GCA and the references to Frequency restoration in section 0 must be clarified.

## 5.4. Reactive Power / Voltage Regulation

- REQUIREMENTS:

The Grid Code requirements related with the Reactive Power/Voltage Regulation can be found in section “2.3.3 Modos de control de potencia reactiva” of the document [2].

Additional requirements about reactive power regulation time response times found in the following section “2.3.2.1. Módulos de parque eléctrico tipo D” of document [2].

The SGRE definition of the regulation times is included in the figure below. Note that this SGRE definition does not match with the GC. Therefore, the GC regulation times have been adapted to SGRE definition in this GCA.

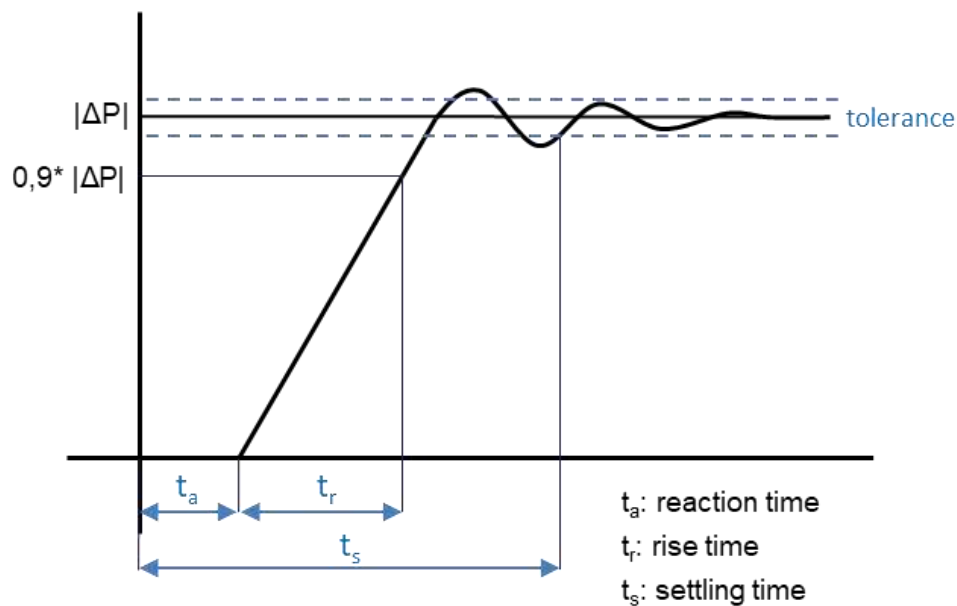


Figure 15 SGRE Definition of the regulation times:  $t_a$ ,  $t_r$  and  $t_s$  (te).

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Requirement Category | [Doc] Section | MODE / Requirement              | Type B   | Type C  | Type D   | Compliance       |
|----------------------|---------------|---------------------------------|--|---|--|------------------|
| WF Types             |               | Generator Type thresholds       | $P_n \leq 5 \text{ MW}$ and $V_n < 110 \text{ Kv}$ | $P_n \leq 50 \text{ MW}$ and $V_n < 110 \text{ Kv}$ | $P_n > 50 \text{ MW}$ or $V_n \geq 110 \text{ Kv}$ |                  |
|                      | 21.3.d.i [3]  | 5.2 COSPHI MODE (POWER FACTOR)  | Required   | Required  | Required   | ✓ Compliance (1) |
|                      | 5.8.2.3 [4]   | (COSPHI) $t_a/t_r/t_s$          | .../.../60s  | .../.../60s   | .../.../60s  |                  |
|                      | 5.8.2.3 [4]   | (COSPHI) Steady state tolerance | $Q = \pm 1.5\% P_{max}$                            | $Q = \pm 1.5\% P_{max}$                             | $Q = \pm 1.5\% P_{max}$                            |                  |

|              |   |                    |                    |                    |                  |
|--------------|---|--------------------|--------------------|--------------------|------------------|
| 21.3.d.i [3] | 5.3 REACTIVE POWER MODE (Q)                 | Required           | Required           | Required           | ✓ Compliance (1) |
| 5.8.2.3 [4]  | (MODE Q) ta/tr/ts                           | .../.../60s        | .../.../60s        | .../.../60s        |                  |
| 5.8.2.3 [4]  | (MODE Q) Steady state tolerance             | Q= ±1.5%Pmax       | Q= ±1.5%Pmax       | Q= ±1.5%Pmax       |                  |
|              | 5.4 DIRECT VOLTAGE MODE (V)                 | NA                 | NA                 | NA                 |                  |
| 2.3.3 [2]    | 5.5 REACTIVE POWER / VOLTAGE MODE (Q/V)     | Required           | Required           | Required           | ✓ Compliance (1) |
| 2.3.3 [2]    | (Q/V) curve defined by slope                | Required           | Required           | Required           |                  |
| 2.3.3 [2]    | (Q/V) ta/tr/ts                              | ta+tr=1s<br>ts= 5s | ta+tr=1s<br>ts= 5s | ta+tr=1s<br>ts= 5s | (2)              |
|              | AVAILABLE REACTIVE POWER AT PCC CALCULATION | NA                 | NA                 | NA                 |                  |
| OTHER:       |   |                    |                    |                    |                  |
|              |   |                    |                    |                    |                  |
|              |   |                    |                    |                    |                  |
|              |   |                    |                    |                    |                  |

Table 15 Grid Code Requirements for Reactive Power / Voltage Regulation.

Remarks:

(1) It must be agreed with client/SO the mode of operation of the reactive power/voltage control and its final parameter settings.

According to the SGRE interpretation of the GC, the key voltage regulation parameters are summarized in the following table:

| Mode                       | [Doc] Section | Parameter           | Type B      | Type C      | Type D      |
|----------------------------|---------------|---------------------|-------------|-------------|-------------|
|                            |               |                     |             |             |             |
| Q/V curve defined by slope |               | Slope (droop)       | 2%          | 2%          | 2%          |
|                            |               | Slope resolution    | Not defined | Not defined | Not defined |
|                            |               | Deadband            | 0 p.u.      | 0 p.u.      | 0 p.u.      |
|                            |               | Deadband resolution | Not defined | Not defined | Not defined |

|                                   |  |                                    |             |             |             |
|-----------------------------------|--|------------------------------------|-------------|-------------|-------------|
|                                   |  | Vmin/Vn                            | Not defined | Not defined | Not defined |
|                                   |  | Vmax/Vn                            | Not defined | Not defined | Not defined |
|                                   |  | Qmin                               | Not defined | Not defined | Not defined |
|                                   |  | Qmax                               | Not defined | Not defined | Not defined |
| Q/V curve<br>defined by<br>points |  | [Q <sub>1</sub> ; P <sub>1</sub> ] | NA          | NA          | NA          |
|                                   |  | [Q <sub>2</sub> ; P <sub>2</sub> ] | NA          | NA          | NA          |
|                                   |  | [Q <sub>3</sub> ; P <sub>3</sub> ] | NA          | NA          | NA          |
|                                   |  | [Q <sub>4</sub> ; P <sub>4</sub> ] | NA          | NA          | NA          |
|                                   |  | [Q <sub>5</sub> ; P <sub>5</sub> ] | NA          | NA          | NA          |

Table 16 Grid Code requirements for Regulation Parameters.

- COMPLIANCE:

SG5.X-170:

According to the document D3120497 [10], SG5.X-170 WTGs can comply with the required reactive power ramp rates.

WIND FARM:

SGRE PPC can comply with all the requirements.

## 5.5. Power Quality

- REQUIREMENTS:

No specific requirements for power quality have been found in the main document of the Grid Code [2]. It is important to highlight that even there is not a requirement in the Grid Code, SGRE will expect that the TSO will ask for some power quality measurements, such as asked in the Annex I “Contenido de la base de datos estructural del operador del Sistema” of the document “P.O. 9 Información intercambiada por el operador del Sistema” [5]

Remarks:

The GC requires voltage harmonic measures. These measures are outside of IEC 61000-21 scope. Therefore, it needs to consider voltage harmonic measures and current harmonic measures and should be to consider into account in the offer

- COMPLIANCE:

The WF developer may perform a power quality study to gain some certainty on the WF fulfilment of these requirements, and SGRE can provide WTG power quality reports or harmonic models for this purpose, but the recommendation is to only evaluate this once real WF measurements are available so effective solutions can be properly designed.



## 5.6. Communications

- REQUIREMENTS:

The Grid Code requirements related with the Communications can be found in section “5.1 Intercambio de información” of the document [2]

*“5.1 Intercambio de información.*

*Para los módulos de generación de electricidad de tipo A, B, C o D será de aplicación lo recogido en el procedimiento de operación que regule la información intercambiada por el operador del sistema y, en todo caso, en la normativa que al respecto sea aprobada para el intercambio de información con los gestores de la red.”*

More signal requirements regarding MRPF mode can be found on section “1.8. Modo de regulación potencia-frecuencia (MRPF)” of the document [2].

*“Adicionalmente a lo especificado en cuanto a la monitorización en tiempo real del MRPF en el Reglamento (UE) 2016/631, de 14 de abril de 2016, el módulo de generación de electricidad estará capacitado para recibir en tiempo real del operador del sistema e implementar consignas de potencia en reserva a subir y a bajar mínimas garantizadas, que podrían ser diferentes. En el caso de módulos de parque eléctrico, las consignas de banda a subir y bajar se respetarán en la cuantía que permita la diferencia entre el recurso primario disponible y el nivel mínimo de regulación.”*

In addition, the RfG 2016/631 [3] establishes for the MRPF mode the below requirements, as it's indicated in the paragraph above:

*“Section 15.2 g) [Applies to MPE. Type C and Type D]*

*En cuanto a la monitorización en tiempo real del MRPF:*

*i) para monitorizar el funcionamiento de la respuesta frecuencia-potencia, la interfaz de comunicación deberá estar equipada para transferir en tiempo real y de forma segura desde la instalación de generación de electricidad hasta el centro de control de la red del gestor de red pertinente o del GRT pertinente, a instancias del gestor de red pertinente o del GRT pertinente, al menos las señales siguientes:*

*señal de estado del MRPF (activado/desactivado);  
salida de potencia activa programada;  
valor efectivo de la salida de potencia activa;  
ajuste efectivo de los parámetros de respuesta de la potencia activa con la variación de frecuencia;  
estatismo y banda muerta;*

*ii) el gestor de red pertinente y el GRT pertinente deberán especificar las señales adicionales que deberá proporcionar la instalación de generación de electricidad por los dispositivos de monitorización y registro con el fin de verificar el funcionamiento del suministro de reservas de regulación frecuencia-potencia por parte de los módulos de generación de electricidad participantes.”*

| Requirement Category | [Doc] Section | MODE / Requirement | Type B | Type C | Type D | Compliance |
|----------------------|---------------|--------------------|--------|--------|--------|------------|
|----------------------|---------------|--------------------|--------|--------|--------|------------|

| WF Types       |  | Generator Type thresholds   | Pn ≤ 5 MW and Vn < 110 Kv | Pn ≤ 50 MW and Vn < 110 Kv | Pn >50 MW or Vn ≥ 110 Kv |                                  |
|----------------|--|---|---------------------------|----------------------------|--------------------------|----------------------------------|
| COMMUNICATIONS |  | Hardwired signals required  | Not defined               | Not defined                | Not defined              | ? To be Clarified <sup>(1)</sup> |
|                |  | Signal list defined in the GC                                     | Not defined               | Not defined                | Not defined              | ? To be Clarified <sup>(1)</sup> |
|                |  | External communication protocols defined in the GC for SGRE SCADA | Not defined               | Not defined                | Not defined              | ? To be Clarified <sup>(1)</sup> |
|                |  |   |                           |                            |                          |                                  |
|                |  |   |                           |                            |                          |                                  |

Remarks:

- (1) The signal types and the communication protocols are not defined, so the project's specific signal list and communications architecture must be negotiated with the TSO and WF developer during the connection conditions agreement.

- COMPLIANCE:

#### WIND FARM:

SGRE CSSS/PPC has different communications protocols, installed and tested, to access third party data, such as the substation or the weather mast, and/or to permit third parties to access wind farm data without requiring additional development. These protocols are mainly OPC-UA, and IEC 60870-5-104.

The following topics must be considered:

- Communication with the System Operator will have to be performed by the Wind Farm Developer through a Substation RTU. The SGRE SCADA system can communicate with the RTU installed in the substation by using one of the protocols mentioned above (preferably IEC 60870-5-104 protocol).
- Signals of the substation devices, such as transformer taps, switchgears, connection breakers, etc. can be integrated in the SGRE SCADA system provided. These are included in the substation integration through the RTU by using IEC 60870-5-104 protocol.
- Signals referred to the WTGs can be provided by the SGRE SCADA system to the Substation RTU by using IEC 60870-5-104 protocol.
- The installation of a met mast should be considered by the WF developer. The signals of the met mast can be integrated in the SGRE SCADA system. The communication protocol for this has not been defined at the time of preparation of this document.

Anyway, the final signal types and the communication protocols are not defined, so the project's specific signal list and communications architecture must be negotiated with the TSO/DSO and WF developer during the connection conditions agreement.

## 5.7. Protections

- REQUIREMENTS:

The Grid Code requirements related with the Protections can be found in Annex I “Contenido de la base de datos estructural del operador del Sistema” of the document “P.O. 9 Información intercambiada por el operador del Sistema” of the document [5]

**“1.2.5.2 Protecciones asociadas a cada unidad generadora (aerogenerador, inversor, etc.).**

- *Relé de mínima tensión: indicar fases en que mide y ajustes.*
- *Relé de sobretensión: ajustes.*
- *Protección de mínima frecuencia: ajustes y cumplimiento del procedimiento por el que se establecen los Planes de Seguridad.*
- *Protección de sobrefrecuencia. Ajustes.*
- *Dispositivos automáticos de reposición por frecuencia: Confirmar que no existen o que están deshabilitados.*
- *Disparo por sobrevelocidad, en su caso. Valor de disparo.”*

Therefore, the Grid Code as defining the information regarding the WTG protections: **undervoltage, overvoltage, underfrequency, overfrequency and overspeed.**

- COMPLIANCE:

SG 5.X-170:

According to document D3120497 and D2314253 SG 5 X can comply with this requirement.

## 5.8. Electrical Simulation Models

- REQUIREMENTS:

The Grid Code requirements related with the electrical simulation models can be found in section 5.2 “MODELOS DE SIMULACIÓN” of the document [2].

Furthermore, the following documents define requirements about the electrical models:

- Section “6. Validación del modelo de Simulación” of the document [4]
- Annex I “Contenido de la base de datos estructural del operador del Sistema”, section 1.4 “Datos necesarios para la realización de estudios dinámicos” of the document [5]
- “Condiciones de validación y aceptación de los modelos” [6]
- “Requisitos de los modelos de instalaciones eólicas, fotovoltaicas, de almacenamiento y de todas aquellas instalaciones que no utilicen generadores síncronos directamente conectados a la red” [7]

According to the SGRE interpretation of the GC, the models required are summarized in the following table:

| Item                          | Value   |
|-------------------------------|---|
| RMS Model                     |   |
| WTG RMS model                 | YES   |
| WFC RMS model                 | YES   |
| RMS model software            | PSS/E and DigSilent (1)                                 |
| WTG RMS Model validation      | YES   |
| WFC RMS Model validation      | YES   |
| RMS Model validation standard | Yes Based on section 6 of document [4] and document [6] |
| Library Model                 |   |
| WTG Library Model             | YES   |
| WFC Library Model             | YES   |
| Library models standards      | N/A   |
| EMT Model                     |   |

|                               |   |
|-------------------------------|---|
| WTG EMT model                 | YES, Based on section 6 of document [4] |
| WFC EMT model                 | YES, Based on section 6 of document [4] |
| EMT model software            | N/A                                     |
| WTG EMT Model validation      | N/A                                     |
| WFC EMT Model validation      | N/A                                     |
| EMT Model validation standard | N/A                                     |
| Harmonic Model                |   |
| WTG Harmonic model            | NO                                      |

Table 17 Grid Code required models.

- COMPLIANCE:

The availability of an electrical simulation model for a specific WTG configuration and WFC, in the requested simulation SW (PSS/E, DigSilent, library model parameters) and for a specific purpose (RMS and EMT) can be requested to SGRE. However, the following tables shows validation status:

| Item       | Value WTG                                  |                               |
|------------|--|-------------------------------|
| Platform   | Validation Status according to REE (P.O.9) | Certificated according to NTS |
| SG 5.X-170 | Pending                                    | Pending                       |

| Item     | Value WFR                                  |                               |
|----------|--|-------------------------------|
| Platform | Validation Status according to REE (P.O.9) | Certificated according to NTS |
| PMUA     | Pending                                    | OK                            |

## Remarks:

- (1) Grid operator (REE) request PSSe model based on reference [6] and [7] but for running simulations requested in NTS v2.1 [4] any model RMS/EMT validated is accepted

## 5.9. WF Simulation/Test/Certification

- REQUIREMENTS:

The Grid Code requirements related with the simulation/test/certification can be found in section 4.1. “ASPECTOS GENERALES” of the document [4]

According to the SGRE interpretation of the GC, the requirements are summarized in the following table:

| Item                             | WF Simulation Required | WF Test Required    | WTG Certification Required | WFC Certification Required | WF Certification Required | Models included in Certification (2) |
|----------------------------------|------------------------|---------------------|----------------------------|----------------------------|---------------------------|--------------------------------------|
| Frequency range                  | No                     | No                  | No                         | No                         | No                        | No                                   |
| Voltage range                    | No                     | No                  | No                         | No                         | No                        | No                                   |
| Fault Ride Through - UVRT        | Yes                    | No                  | Yes                        | No                         | No                        | Yes                                  |
| Fault Ride Through - OVRT        | No                     | No                  | No                         | No                         | No                        | No                                   |
| Reactive power capability        | Yes                    | No                  | Yes                        | No                         | No                        | Yes                                  |
| Fault current support            | Yes                    | No                  | Yes                        | No                         | No                        | Yes                                  |
| Post fault active power recovery | Yes                    | No                  | Yes                        | No                         | No                        | Yes                                  |
| Active power control             | No                     | Yes*                | No                         | Yes                        | No                        | No                                   |
| Frequency control                | No                     | Yes*                | No                         | Yes                        | No                        | No                                   |
| Frequency restoration            | No                     | To be clarified (1) | No                         | No                         | No                        | No                                   |
| Power factor control             | Yes                    | Yes*                | No                         | Yes                        | No                        | No                                   |
| Reactive power control           | Yes                    | Yes*                | No                         | Yes                        | No                        | No                                   |
| Voltage control                  | Yes                    | Yes*                | No                         | Yes                        | No                        | No                                   |
| Power Quality                    | No                     | No                  | No                         | No                         | No                        | No                                   |
| Inertia Emulation (optional)     | Yes                    | No                  | No                         | No                         | No                        | No                                   |
| Power Oscillations Damping       | Yes                    | No                  | Yes                        | Yes                        | No                        | No                                   |

Table 18 Grid Code required Simulation / Test / Certification.

\*On site tests may not be required if certification is available.

- COMPLIANCE:

SG5.X-170:

Information under request on SG5.X-170 WTGs capabilities can be provided to support WF simulations or test.

The required WTG certificate is not yet available for SG5.X-170.

WIND FARM:

Information under request on PPC capabilities can be provided to support WF simulations or test.

The required WFC (PMUA) certificate is already available for PPC.

## 5.10. Special Requirements

### 5.10.1. Phase Jump

- REQUIREMENTS:

The Grid Code requirements related with the capability of withstanding a phase jump, can be found in section 3.3.2 “CAPACIDAD PARA SOPORTAR SALTOS ANGULARES” of the document [2].

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item               | Unit | Value |
|--------------------|------|-------|
| Maximum Phase Jump | °    | 20    |

Table 19 Grid Code requirements for Phase Jump.

- COMPLIANCE:

#### SG5.X-170:

According to the correspondent platform documentation, the compliance analysis for a WF with SG5.X-170 WTGs is described in the following table:

| WTGs              | GD Document   | Compliance   |
|-------------------|---------------|--------------|
| <b>SG 5.X-170</b> | D3120497 [10] | ✓ Compliance |



## 5.10.2. Inertia Emulation

- REQUIREMENTS:

The Grid Code requirements related with the provision of Inertia Emulation, can be found in section 1.9 “EMULACIÓN DE INERCIA” of the document [2].

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item  | Unit       | Value        |
|---|------------|--------------|
| Applicability of Inertia Emulation requirement                                  | -          | Optional (2) |
| Minimum Required Duration for Additional Active Power - $t_{\Delta P}$          | s          | 8            |
| Minimum Additional Active Power – $\Delta P$                                    | %          | 10%          |
| Reference for Additional Active Power   | -          | Prated       |
| Additional active power proportional to frequency deviation                     | % / Hz     | N/A          |
| Additional active power proportional to ROCOF                                   | % / (Hz/s) | N/A          |
| Activation by frequency / ROCOF   | -          | ROCOF        |
| Frequency activation threshold  | Hz         | N/A          |
| ROCOF activation threshold  | Hz/s       | $\pm 0.5$    |
| Maximum reaction time   | s          | N/A          |
| Maximum response time - $t_{\text{response}}$                                   | s          | 0.15         |
| Maximum overshoot   | %          | N/A          |
| Deactivation by frequency / ROCOF   | -          | Frequency    |
| Frequency deactivation threshold  | Hz         | $\pm 0.5$    |
| ROCOF deactivation threshold  | Hz/s       | N/A          |
| Maximum downwards active power ramp rate  | % / s      | N/A          |
| Max. Subsequent Power Drop below Pre-disturbance - $\Delta P_{\text{drop}}$     | %          | N/A          |
| Max recovery time between consecutive inertia responses - $t_{\text{recovery}}$ | s          | N/A          |
| Minimum Active Power for Inertia Response Availability - $P_{\text{min}}$       | pu         | N/A          |

Table 20 Grid Code requirements for Inertia Emulation.

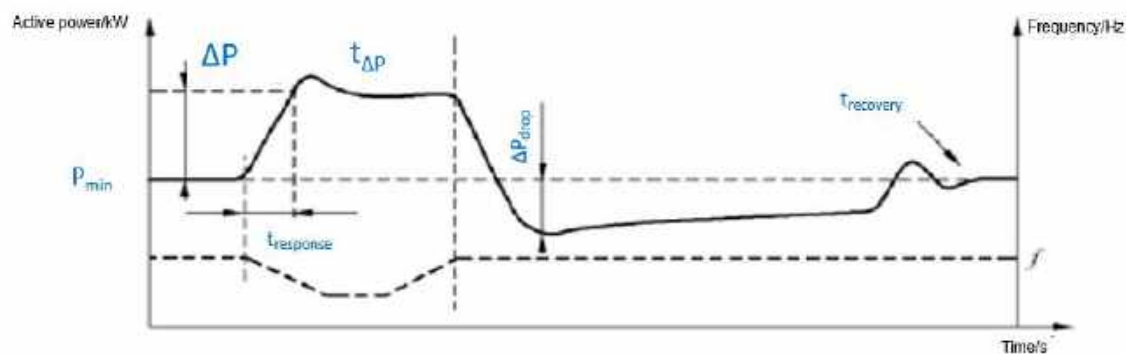


Figure 16 Example of the inertia emulation behavior.

- COMPLIANCE:

SG5.X-170:

According to the correspondent platform documentation, the compliance analysis for a WF with SG5.X-170 WTGs is described in the following table:

| WTGs              | GD Document   | Compliance                             |
|-------------------|---------------|--|
| <b>SG 5.X-170</b> | D2097474 [12] | <b>✗</b> Non-compliance <sup>(1)</sup> |

WIND FARM:

SGRE PPC is used to operate the Inertial response and enables SGRE Wind Turbines to provide an overproduction of active power. SGRE PPC cannot comply with all the requirements.

### 5.10.3. Power Oscillations Damping (POD)

- REQUIREMENTS:

The Grid Code requirements related with the provision of a Power Oscillations Damping (POD) system can be found in section 2.3.5 “AMORTIGUAMIENTO DE LAS OSCILACIONES DE POTENCIA” of the document [2] and section 5.10 “AMORTIGUAMIENTO DE LAS OSCILACIONES DE POTENCIA EN MPE” of document [4]

#### **5.10.3.1. Acceptance criteria for analysis based on eigenvalues**

*The criterion for the assessment of the study described in the subsection shall consider that the PPM does not adversely contribute to the damping of oscillation modes between 0.1 Hz and 1.5 Hz if the following conditions are met:*

- *The introduction of a PPM in node 1 does not introduce new oscillation modes with a damping of less than 5%.*
- *Under no circumstances will existing modes reduce their damping below 5%.*

- COMPLIANCE:

SG 5.X-170:

SGRE can prepare the models and reports required by TSO according to NTSV2.1 to show compliance with the requirement

## 5.10.4. System Strength

- REQUIREMENTS:

The Grid Code doesn't define a minimum System Strength value (short circuit value-SCR), however, in section "Disposición adicional segunda. Valor de los parámetros, porcentajes y ratios contenido en los anexos." of the document [9] defines a SCR value

*"Para los nudos con módulos de parque eléctrico existentes o con permisos de acceso concedidos, que no cumplen con el Reglamento (UE) 2016/631 de la Comisión, de 14 de abril de 2016, se fija en 10 el valor mínimo del parámetro WSCR al que se refiere el apartado 4 del anexo I. Para el resto de nudos, dicho valor se fija en 6."*

## In English:

*"For electrical nodes with power park modules under operation or with access permits guaranteed, that do not comply with Regulation (EU) 2016/631 of the Commission, of April 14, 2016, the minimum value of Weighted Short Circuit Ratio (WSCR) will be 10 based on section 4 of annex I. For the rest of electrical nodes, **this value will be 6.**"*

- COMPLIANCE:

SG5.X-170:

According to document D3120497 [10], the capability of SG5.X-170 to contribute to the WF compliance of this requirement is the following:

| Parameter   | Value                           |
|---|---------------------------------|
| Min. SCR at WTG MV Terminals<br><b>V-Direct operation</b>                             | 2<br><b>2 &gt; SCR &gt; 1.5</b> |
| Min. SCR at WTG MV Terminals<br><b>Q-Direct operation</b>                             | 3<br><b>3 &gt; SCR &gt; 1.5</b> |
| Min X/R at WTG MV Terminals<br><b>V-Direct operation</b><br><b>Q-Direct operation</b> | <b>3</b>                        |

Table 21 Standard minimum interconnection electrical characteristics for SG5.X-170.

WIND FARM:

The requirements regarding short circuit ratio (SCR) are specified at the PCC.

Considering this, to ensure compliance a specific study of the whole WF must be carried out in order to analyze the SCR at the WTGs terminals for different operation scenarios of the WF.

### 5.10.5. Reconnection Blockage / Synchronization to the Grid

- REQUIREMENTS:

The Grid Code requirements related with the Reconnection Blockage can be found in section “CAPACIDAD TÉCNICA DE RECONEXIÓN TRAS PERTURBACIÓN” of the document [2]

According to the SGRE interpretation of the GC, the key requirements are summarized in the following table:

| Item  | Unit | Value                            |
|---|------|----------------------------------|
| Minimum reconnection voltage                    | p.u  | 0.9                              |
| Maximum reconnection voltage                    | p.u. | >220 kV - 1.118<br>< 220 kV -1.1 |
| Minimum reconnection frequency                  | Hz   | 47.5                             |
| Maximum reconnection frequency                  | Hz   | 51.5                             |
| Reconnection observation time for the voltage   | Sec  | Not defined                      |
| Reconnection observation time for the frequency | Sec  | Not defined                      |
| Other reconnection measurement variable         | -    | N/A                              |
| Reconnection based on WF/WTG measurement        | -    | WF/WTG                           |

Table 22 Grid Code requirements for Reconnection Blockage.

- COMPLIANCE:

The blockage of the automatic reconnection as a function of the grid voltage or frequency is implemented by SGRE at WTG level. If the Grid Operator requests this function at PCC level, it shall be clarified if the SGRE function at WTG level is accepted by the Operator.

## 6. Aspects to Clarify

### 6.1. Active Power/Frequency regulation

The following requirement in the MRPF section 1.8 of document [2] requires clarification:

*“1.8. Modo de regulación potencia-frecuencia (MRPF)*

*(...)*

*Adicionalmente a lo especificado en cuanto a la monitorización en tiempo real del MRPF en el Reglamento (UE) 2016/631, el módulo de generación de electricidad estará capacitado para recibir en tiempo real del operador del sistema e implementar consignas de potencia en reserva a subir y a bajar mínimas garantizadas, que podrían ser diferentes. En el caso de módulos de parque eléctrico, las consignas de banda a subir y bajar se respetarán en la cuantía que permita la diferencia entre el recurso primario disponible y el nivel mínimo de regulación.”*

The wording of this requirement is not clear. Since it is in the MRPF section, SGRE understands that the “reserves” mentioned are in fact the “ $|\Delta P_1|/P_{max}$ ” parameters of the MRPF mode (read screenshot from [2] below) which are available in the SGRE regulation tool. However, note that these parameters are not power reserves but power ranges of operation of the MRPF mode. Moreover, the requirement indicates that these reserves shall be “guaranteed”, however, note that a WF depends on a variable energy source so the SO shall define how they expect a WF to response.

1.8 Modo de regulación potencia-frecuencia (MRPF). En relación con el modo de regulación potencia-frecuencia (MRPF), los módulos de generación de electricidad de tipo C o D deberán ser capaces de activar el suministro de reservas de regulación potencia-frecuencia, de acuerdo con lo especificado a este respecto en el Reglamento (UE) 2016/631, de 14 de abril de 2016. A este respecto, las características estáticas de las respuestas de los modos MRPFL-O y MRPFL-U se acumulan, en su caso, a la característica estática de la respuesta de este modo MRPF.

Salvo indicación en contra del operador del sistema, los parámetros ajustables del MRPF serán los siguientes:

- a) Intervalo de potencia activa en relación con la capacidad máxima  $|\Delta P_1|/P_{max}$  igual al 8 %.
- b) Insensibilidad de respuesta con la variación de frecuencia  $|\Delta f_1|$  igual al 10 mHz.
- c) Banda muerta de respuesta con la variación de frecuencia igual al 0 mHz.
- d) Estatismo  $s_1$  igual al 5 %.

A confirmation of SGRE interpretation of the requirement is necessary. It is important to remark that in case that the SO states SGRE interpretation is not accurate, the requirements shall be analyzed in order to assure compliance.

## 6.2. Frequency Restoration

The following test referenced in the NTS [4] appears to be related with the frequency restoration, however, it is not clearly defined. **It shall be clarified if this test applies to WFs and if it does, the test procedure and the technical requirements shall be defined by the SO.**

| REQUISITO      |  |          |                                 | FORMA DE EVALUACIÓN |               |
|----------------|--|----------|---------------------------------|---------------------|---------------|
| Artículo [1]   | Definición del Requisito   | Tipo MGE | Subapartado de la Norma Técnica | MPE                 | MGES          |
| 13.2           | Modo regulación potencia-frecuencia limitado-sobrefrecuencia (MRPFL-O)     | ≥A       | 5.1                             | (S y P) o C**       | (S y P) o C** |
| 15.2.(a) y (b) | Capacidad de control y el rango de control de la potencia activa en remoto | ≥C       | 5.5                             | P o C               | N/A           |
| 15.2.e         | Control de potencia-frecuencia   | ≥C       | 5.4                             | P                   | P             |

### “5.4. Capacidad de control de potencia-frecuencia

*El objetivo es verificar que el MGE es capaz de ofrecer funciones que cumplan las especificaciones del GRT, con el objetivo de restablecer la frecuencia a su valor nominal o de mantener los flujos de intercambio de potencia entre las zonas de control en sus valores programados, según lo indicado en:*

*- Artículo 15.2.e del Reglamento.*

*En virtud del artículo 45 del Reglamento, la conformidad del MGE con este requisito se podrá realizar a través de prueba, tanto a nivel UGE como MGE, o de certificado de equipo. No obstante, la evaluación de este requisito la realizará el GRT conforme a los protocolos de pruebas establecidos en la regulación vigente en el momento de la puesta en servicio del MGE, que indicará el GRT al propietario del MGE.”*

The referenced article 15.2.e [3] states the following:

*“with regard to **frequency restoration control**, the power-generating module shall provide functionalities complying with specifications specified by the relevant TSO, aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values;”*

## 7. Summary

The following table reflects the evaluation in terms of Grid Code compliance for a WF comprised of a certain type of WTGs. This summary table is based in **the AM0 of the SGRE WTGs**.

|         |   | Section | SG 5.X-170 (9)                 |
|---------|---|---------|--------------------------------|
|         |   |         | PPC                            |
|         | Frequency Operation Range                           | 5.1.1   | ✓ Compliance                   |
|         | Voltage Operation Range                             | 5.1.2   | ▢ Wind Farm Study Needed       |
|         | Voltage/Frequency Operation Area                    | 5.1.3   | ▢ Wind Farm Study Needed       |
|         | Reactive Power Operation Range                      | 5.1.4   | ▢ Wind Farm Study Needed       |
| Fault   | Current Support                                     | 5.2.1   | ✓ Compliance                   |
| Ride    | Active Power Recovery after Clearance               | 5.2.2   | ✓ Compliance                   |
| Through | Consecutive Voltage Dips                            | 5.2.3   | ✓ Compliance                   |
|         | Active Power/Frequency Regulation                   | 5.3     | ? To be Clarified<br>(1)(2)(3) |
|         | Reactive Power/Voltage Regulation                   | 0       | ✓ Compliance<br>(4)            |
|         | Power Quality                                       | 5.5     | ▢ Wind Farm Study Needed       |
|         | Communications                                      | 5.6     | ? To be Clarified (5)          |
|         | Protections   | 5.7     | ✓ Compliance                   |
|         | Electrical Simulation Models                        | 5.8     | ✂ Development in Progress      |
|         | WF Simulation / Test / Certification                | 5.9     | ✓ Compliance                   |
|         | Phase Jump  | 5.10.1  | ✓ Compliance                   |
|         | Inertia Emulation                                   | 5.10.2  | ✗ Non-compliance (8)           |
|         | Power Oscillations Damping (POD)                    | 5.10.3  | ✂ Development in Progress      |
|         | System Strength                                     | 5.10.4  | ▢ Wind Farm Study Needed       |
|         | Reconnection Blockage / Synchronization to the Grid | 5.10.5  | ✓ Compliance                   |

Table 23 Summary.



| Legend                          | Description   |
|---------------------------------|---|
| ✓ Compliance                    | Compliance is expected  |
| ✂ Development in Progress       | A SCADA or WTG development is planned or underway in order to assure compliance                                 |
| ⚠ Request development upon need | A specific development is required and shall be requested when a project needs to comply with this requirement. |
| ❓ To be Clarified               | The requirement is not clear, or information is missing. Therefore, it shall be clarified with the Operator.    |
| ✗ Non-compliance                | The requirement cannot be fulfilled.  |
| ▢ Wind Farm Study Needed        | Wind Farm Study Needed  |

Table 24 Legend.

## Remarks:

- (1) The requirements related with the MRPF and frequency restoration highlighted in sections 6.1 and 0 **must be clarified.**
- (2) It must be agreed with SO, the mode of operation of the reactive power/voltage control and its final parameter settings in the corresponding connection agreement.
- (3) The final WF signals list should be established in the connection agreement.
- (4) **According to Certification Report Fault Ride Through [13], [14], [15], [16], we could comply**
- (5) **The Grid Code has only been analyzed against the SG5.X-170. Reference document [10] is only valid for 170 rotor diameter variants. The grid capability document for SG5.X-155 variant (155 rotor diameter) is under development.**

## 8. References

- [1] BOE-A-2020-7439, "Real Decreto 647/2020, de 7 de julio, por el que se regulan aspectos necesarios para la implementación de los códigos de red de conexión de determinadas instalaciones eléctricas", 08/July/2020.
- [2] BOE-A-2020-8965, "Orden TED/749/2020, de 16 de julio, por la que se establecen los requisitos técnicos para la conexión a la red necesarios para la implementación de los códigos de red de conexión, 01/Agust/2020".
- [3] Reglamento (UE) 2016/631 de la comision de 14 de abril de 2016 que establece un codigo de red sobre requisitos de conexion de generadores a la red, 2016.
- [4] Norma técnica de supervisión de la conformidad de los módulos de generación de electricidad según el reglamento UE 2016/631, Revisión 2.1, 09/July/2021.
- [5] P.O. 9 Información intercambiada por el operador del Sistema, 20/December/2019.
- [6] Condiciones de Validacion y Aceptacion de los Modelos, Revision June/2020.
- [7] "Requisitos de los modelos de instalaciones eólicas, fotovoltaicas, de almacenamiento y de todas aquellas instalaciones que no utilicen generadores síncronos directamente conectados a la red", Revision June/2020..
- [8] "Requisitos de los modelos de instalaciones FACTS", Revision June/2020.
- [9] BOE-A-2021-904, "Circular 1/2021, metodología y condiciones del acceso y de la conexión a las redes de transporte y distribución de las instalaciones de producción de energía eléctrica.
- [10] SG 5.X-170: D3120497, "SGRE ON SG6.2, SG6.6-170 Capabilities"..
- [11] SG 5.X PLATFORM: D2904942, "Reactive Power Capaility - 50 & 60Hz.
- [12] SG5.X PLATFORM: D2097474, "SGRE ON SG5X Inertial Response".
- [13] CR-GCC-NTS631-08094-A066-0 - Fault-ride-through\_\_final.
- [14] CR-GCC-NTS631-07893-A066-0 - Fault-ride-through.
- [15] CR-GCC-NTS631-07610-A066-0 - Fault-ride-through\_final.
- [16] CR-GCC-NTS631-08008-A066-0 - Fault-ride-through\_final.



The latest released version of these documents must always be reviewed.