

ANNEXES

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**ANNEXE A. INVENTAIRES ET BASES DE DONNÉES OISEAUX ET
CHAUVES-SOURIS**

Nivelles-Genappe

Bases de données externes (2026)

1 Site d'intérêt biologique

Tableau 1 : Liste des sites d'intérêt biologique présents au sein du périmètre de 10 km autour du projet (février 2026).

Code	Nom du site	Type	Distance minimale au projet (km)
3668	Prairies humides entre Thines et Baulers (Nivelles)	SGIB	2,0
1798	Décanteurs de l'ancienne sucrerie de Genappe (Genappe)	SGIB	2,2
6095	Décanteurs de la sucrerie de Genappe	RND	2,2
BE31010	Sources de la Dyle	Natura2000	2,2
3667	Etangs et prairies humides du Merly (Nivelles)	SGIB	2,4
1354	Ancien circuit automobile de Nivelles (Nivelles)	SGIB	2,6
3671	Vallon du Ri de Hondeuse (Genappe)	SGIB	3,8
270	Vallée de la Lasne aux environs de Maransart (Genappe, Lasne)	SGIB	4,5
3666	Bois de Sépulcre (Nivelles)	SGIB	4,8
2692	Zone humide du Paradis (Braine-l'Alleud)	SGIB	5,2
3669	Marais de Grambais (Nivelles)	SGIB	5,4
2796	Bois du Hautmont (Braine-le-Château)	SGIB	5,7
BE31001	Affluents brabançons de la Senne	Natura2000	5,7
1864	Vallée de la Cala (Genappe)	SGIB	5,8
3543	Basse-Nivelles (Braine-l'Alleud, Braine-le-Château)	SGIB	6,0
BE31011	Vallée de la Thyte	Natura2000	6,0
3659	Baudémont (Ittre)	SGIB	6,1
3450	Etang Maternel et Ri de Gemioncourt (Genappe, Les Bons Villers, Villers-la-Ville)	SGIB	6,4
645	Sablère du Bois du Foriest (Braine-l'Alleud)	SGIB	6,8
254	Bois de l'Hôpital - Bois du Planti - Vallée du Pont-à-Mousson (Nivelles, Seneffe)	SGIB	7,0
647	Sablère du Champ de la Boule (Lasne)	SGIB	7,0
BE32008	Bois d'Arpes et de l'Hôpital	Natura2000	7,0
3665	Sources du Ri Mathieu Simon à Bornival (Nivelles)	SGIB	7,1
292	Bois d'Arpes (Nivelles, Seneffe)	SGIB	7,2
2888	Roselière de Petit Maransart (Lasne)	SGIB	7,3
269	Vallée du Smohain (Lasne)	SGIB	7,5
222	Ru Milhoux (Lasne)	SGIB	7,8
2764	Ri de Hé (Genappe)	SGIB	7,8
3542	Etang de Boularmont (Braine-le-Château)	SGIB	7,8
6408	Milhoux (Ru)	ZHIB	7,8
BE31002	Vallées de l'Argentine et de la Lasne	Natura2000	7,8
2883	Bois de Couture-Saint-Germain (Lasne)	SGIB	7,9
195	Bois du Chapitre et Ruisseau de l'Ermitage (Braine-le-Château)	SGIB	8,3
643	Sablère d'Alconval (Braine-l'Alleud)	SGIB	8,3
1143	Landes de Bousval (Genappe)	SGIB	8,3
3664	Prairie maigre de Bornival (Braine-le-Comte, Nivelles)	SGIB	8,5
3670	Vallon du Ri de Bornival (Braine-le-Comte)	SGIB	9,0
76	Ronquières (Braine-le-Comte, Nivelles, Seneffe)	SGIB	9,1
6014	Ronquières	RND	9,1
644	Sablère 'Tout lui Faut' (Braine-l'Alleud)	SGIB	9,3
2887	Les Sources Vives (Lasne)	SGIB	9,3
6552	Bois d'Apecheau	SGIB	9,3
6552	Bois d'Apecheau	RND	9,3
2886	Suintements du Petit Champ (Lasne)	SGIB	9,4

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Busard des roseaux (<i>Circus aeruginosus</i>)	4	2023	204
Busard indéterminé (<i>Circus sp.</i>)	1	2022	2111
Busard pâle (<i>Circus macrourus</i>)	1	2020	3645
Busard Saint-Martin (<i>Circus cyaneus</i>)	3	2024	67
Buse variable (<i>Buteo buteo</i>)	8	2024	256
Butor étoilé (<i>Botaurus stellaris</i>)	1	2019	2942
Caille des blés (<i>Coturnix coturnix</i>)	3	2022	1681
Canard chipeau (<i>Mareca strepera</i>)	36	2024	2750
Canard colvert (<i>Anas platyrhynchos</i>)	400	2024	1307
Canard mandarin (<i>Aix galericulata</i>)	5	2023	9448
Canard siffleur (<i>Mareca penelope</i>)	4	2024	2836
Canard souchet (<i>Spatula clypeata</i>)	25	2024	2750
Chardonneret élégant (<i>Carduelis carduelis</i>)	4	2023	1515
Chevalier aboyeur (<i>Tringa nebularia</i>)	2	2020	6537
Chevalier culblanc (<i>Tringa ochropus</i>)	2	2023	2514
Chevalier guignette (<i>Actitis hypoleucos</i>)	2	2019	8203
Chevalier sylvain (<i>Tringa glareola</i>)	18	2022	2424
Choucas des tours (<i>Corvus monedula</i>)	40	2024	176
Chouette hulotte (<i>Strix aluco</i>)	1	2021	7296
Cigogne blanche (<i>Ciconia ciconia</i>)	200	2023	319
Cigogne noire (<i>Ciconia nigra</i>)	2	2023	1936
Combattant varié (<i>Calidris pugnax</i>)	11	2023	1202
Corbeau freux (<i>Corvus frugilegus</i>)	15	2024	256
Cornelle noire (<i>Corvus corone</i>)	60	2024	176
Corvidés indéterminé	60	2024	6371
Coucou gris (<i>Cuculus canorus</i>)	1	2024	6517
Cygne chanteur (<i>Cygnus cygnus</i>)	7	2019	2443
Cygne tuberculé (<i>Cygnus olor</i>)	4	2024	5266
Echasse blanche (<i>Himantopus himantopus</i>)	3	2021	2622
Epervier d'Europe (<i>Accipiter nisus</i>)	1	2022	5986
Étourneau sansonnet (<i>Sturnus vulgaris</i>)	109	2024	1515
Faisan de Colchide (<i>Phasianus colchicus</i>)	6	2024	176
Faucon crécerelle (<i>Falco tinnunculus</i>)	5	2024	1189
Faucon émerillon (<i>Falco columbarius</i>)	2	2024	324
Faucon hobereau (<i>Falco subbuteo</i>)	2	2022	3238
Faucon kobez (<i>Falco vespertinus</i>)	1	2020	5251
Faucon pèlerin (<i>Falco peregrinus</i>)	5	2024	580
Fauvette à tête noire (<i>Sylvia atricapilla</i>)	6	2024	1307
Fauvette babillarde (<i>Sylvia curruca</i>)	1	2021	7065
Fauvette des jardins (<i>Sylvia borin</i>)	2	2023	2764
Fauvette grisette (<i>Sylvia communis</i>)	6	2024	1032
Foulque macroule (<i>Fulica atra</i>)	100	2024	2482
Fuligule hybride	1	2023	2870
Fuligule milouin (<i>Aythya ferina</i>)	29	2024	2750
Fuligule morillon (<i>Aythya fuligula</i>)	19	2024	2750
Fuligule nyroca (<i>Aythya nyroca</i>)	1	2023	3389
Gallinule poule d'eau (<i>Gallinula chloropus</i>)	13	2024	2505
Geai des chênes (<i>Garrulus glandarius</i>)	23	2024	2915
Gobemouche gris (<i>Muscicapa striata</i>)	1	2017	6048
Goéland argenté (<i>Larus argentatus</i>)	30	2023	2844
Goéland brun (<i>Larus fuscus</i>)	130	2023	2844
Goéland cendré (<i>Larus canus</i>)	3	2022	4510

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2318	Lande du chemin des Ornois (Lasne)	SGIB	9,5
2882	Landes du Bois de Noirhat (Court-Saint-Etienne)	SGIB	9,5
BE2400009	Hallerbos en nabije boscomplexen met brongebieden en heiden	ZSC_FL	9,6
38187	Hallerbos	Natuurbeheerplan Type 4	9,6
263	Bief 29 de l'ancien canal de Charleroi (Ittre)	SGIB	9,7
386	Vallée de la Sennette à Ittre (Ittre)	SGIB	9,7
6552	Bois d'Apecheau	SGIB	9,8

Légende : RN : réserve naturelle, SGIB : site de grand intérêt biologique ; ZHIB : zone humide d'intérêt biologique ; CSIS : cavité souterraine d'intérêt scientifique.
Source : SPW-DGO3-DEMNA, 2026

2 Avifaune

Oiseaux signalés dans la base de données du DEMNA (source : DEMNA, DGO3-SPW, 2026)

Pour chaque espèce signalée par le Demna dans un périmètre de 10 km autour du projet, une analyse croisée est effectuée de manière à connaître de manière indépendante l'effectif maximal observé dans le périmètre des 10 km, ensuite l'année la plus récente où l'espèce a été détectée dans le périmètre des 10 km et la distance la plus faible entre une espèce et le projet éolien. Ainsi, les colonnes fournissent des informations qui ne sont pas corrélées entre elles.

Exemple : pour l'espèce Accenteur mouchet, le groupe le plus conséquent observé sur le périmètre des 10 km autour du projet est de 6 individus. Les observations les plus récentes inscrites dans la base du DEMNA datent de 2024 pour cette espèce. La plus faible distance à laquelle est renseignée l'Accenteur mouchet est de 482 mètres d'une des éoliennes du projet. Ainsi, la lecture des colonnes NE DOIT PAS se comprendre comme suit : 6 Accenteurs mouchet observés en 2024 à 482 mètres du projet.

Espèce	Effectif maximal	Observation la plus récente	Distance minimale au projet (m)
Accenteur mouchet (<i>Prunella modularis</i>)	6	2024	482
Aigrette garzette (<i>Egretta garzetta</i>)	2	2023	2384
Alouette des champs (<i>Alauda arvensis</i>)	17	2024	176
Alouette lulu (<i>Lullula arborea</i>)	19	2024	323
Autour des palombes (<i>Accipiter gentilis</i>)	1	2023	5840
Avocette élégante (<i>Recurvirostra avosetta</i>)	1	2021	2942
Balbuzard pêcheur (<i>Pandion haliaetus</i>)	2	2023	327
Bécasse des bois (<i>Scolopax rusticola</i>)	1	2021	2757
Bécassine des marais (<i>Gallinago gallinago</i>)	1000	2024	1797
Bécassine sourde (<i>Lymnocyrtus minimus</i>)	8	2023	1821
Bergeronnette des ruisseaux (<i>Motacilla cinerea</i>)	2	2023	1896
Bergeronnette grise (<i>Motacilla alba</i>)	5	2024	176
Bergeronnette printanière (<i>Motacilla flava</i>)	15	2024	176
Bemache du Canada (<i>Branta canadensis</i>)	75	2024	1896
Bemache nonnette (<i>Branta leucopsis</i>)	22	2021	7883
Bihoreau gris (<i>Nycticorax nycticorax</i>)	2	2023	2942
Blongios nain (<i>Ixobrychus minutus</i>)	1	2014	2942
Bondrée pivote (<i>Pernis ptilorhynchus</i>)	8	2023	438
Bouvreuil pivone (<i>Pyrrhula pyrrhula</i>)	2	2021	5239
Bruant des roseaux (<i>Emberiza schoeniclus</i>)	2	2021	1307
Bruant jaune (<i>Emberiza citrinella</i>)	6	2024	676
Bruant ortolan (<i>Emberiza hortulana</i>)	1	2020	3186
Busard cendré (<i>Circus pygargus</i>)	2	2022	1056

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Goéland indéterminé (<i>Larus sp.</i>)	2	2022	4584
Gorge bleue à miroir (<i>Luscinia svecica</i>)	2	2023	2468
Gorgebleue à miroir blanc (<i>Luscinia svecica cyaneola</i>)	1	2018	2574
Grand corbeau (<i>Corvus corax</i>)	1	2023	8007
Grand Cormoran (<i>Phalacrocorax carbo</i>)	13	2024	2570
Grand-duc d'Europe (<i>Bubo bubo</i>)	4	2024	2729
Grande Aigrette (<i>Ardea alba</i>)	15	2024	649
Grèbe castagneux (<i>Tachybaptus ruficollis</i>)	7	2024	2570
Grèbe huppé (<i>Podiceps cristatus</i>)	5	2024	2850
Grimpereau des jardins (<i>Certhia brachyactyla</i>)	2	2023	3165
Grive draine (<i>Turdus viscivorus</i>)	2	2024	979
Grive litorne (<i>Turdus pilaris</i>)	55	2023	5239
Grive mauvis (<i>Turdus iliacus</i>)	150	2021	7065
Grive muscinienne (<i>Turdus philomelos</i>)	6	2024	2764
Grosbec casse-noyaux (<i>Coccothraustes coccothraustes</i>)	3	2023	4584
Grue cendrée (<i>Grus grus</i>)	500	2023	181
Guifette moustac (<i>Chlidonia hybrida</i>)	1	2021	2456
Guifette noire (<i>Chlidonia niger</i>)	3	2023	2382
Héron cendré (<i>Ardea cinerea</i>)	12	2024	482
Héron pourpré (<i>Ardea purpurea</i>)	1	2023	1566
Hibou des marais (<i>Asio flammeus</i>)	1	2023	290
Hibou moyen-duc (<i>Asio otus</i>)	1	2016	2915
Hippolaïs indéterminé	1	2014	8478
Hirondelle de fenêtre (<i>Delichon urbicum</i>)	10	2023	1283
Hirondelle de rivage (<i>Riparia riparia</i>)	20	2023	2488
Hirondelle rustique (<i>Hirundo rustica</i>)	48	2024	676
Huitrier pie (<i>Haematopus ostralegus</i>)	2	2022	4629
Hypolaïs icterine (<i>Hippolaïs icterina</i>)	1	2021	1789
Hypolaïs indéterminé (<i>Hypolaïs sp.</i>)	3	2014	8478
Laridé sp	3	2019	7841
Linotte mélodieuse (<i>Linaria cannabina</i>)	42	2024	482
Locustelle lusciniote (<i>Locustella luscinioides</i>)	1	2019	9649
Loriot d'Europe (<i>Oriolus oriolus</i>)	1	2021	9416
Marouette ponctuée (<i>Porzana porzana</i>)	1	2022	2330
Marinnet noir (<i>Apus apus</i>)	25	2022	1896
Martin-pêcheur d'Europe (<i>Alcedo atthis</i>)	5	2024	1990
Merle à plastron (<i>Turdus torquatus</i>)	1	2020	9395
Merle noir (<i>Turdus merula</i>)	14	2024	482
Mésange bleue (<i>Parus caeruleus</i>)	9	2025	979
Mésange à longue queue (<i>Aegithalos caedatus</i>)	5	2023	7714
Mésange boréale (<i>Parus montanus</i>)	1	2021	9297
Mésange charbonnière (<i>Parus major</i>)	13	2025	979
Mésange huppée (<i>Parus cristatus</i>)	2	2024	9027
Mésange noire (<i>Parus ater</i>)	1	2020	9139
Mésange nonnette (<i>Parus palustris</i>)	1	2023	7237
Milan noir (<i>Milvus migrans</i>)	3	2023	145
Milan royal (<i>Milvus milvus</i>)	3	2024	330
Moineau domestique (<i>Passer domesticus</i>)	30	2024	676
Moineau friquet (<i>Passer montanus</i>)	2	2020	5546
Mouette mélanocéphale (<i>Ichthyophaga melanocephalus</i>)	2	2023	2533

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Mouette rieuse (<i>Chroicocephalus ridibundus</i>)	65	2024	1767
Nette rousse (<i>Netta rufina</i>)	1	2021	4805
Oie à tête barrée (<i>Anser indicus</i>)	1	2021	5292
Oie cendrée (<i>Anser anser</i>)	14	2025	4825
Ouette d'Égypte (<i>Alopochen aegyptiaca</i>)	123	2025	748
Perdrix grise (<i>Perdix perdix</i>)	8	2021	1752
Perruche à collier (<i>Psittacula krameri</i>)	4	2022	2915
Petit Gravelot (<i>Charadrius dubius</i>)	2	2018	10026
Phragmite des joncs (<i>Acrocephalus schoenobaenus</i>)	2	2023	2441
Pic épiche (<i>Dendrocopos major</i>)	3	2023	2915
Pic épicéte (<i>Dryobates minor</i>)	1	2014	9027
Pic mar (<i>Dendrocygna media</i>)	4	2023	2758
Pic noir (<i>Dryocopus martius</i>)	4	2024	584
Pic vert (<i>Picus viridis</i>)	2	2023	1515
Pie bavarde (<i>Pica pica</i>)	11	2024	676
Pie-grièche écorcheur (<i>Lanius collurio</i>)	1	2021	1478
Pie-grièche grise (<i>Lanius excubitor</i>)	1	2015	2575
Pigeon biset (<i>Columba livia</i>)	25	2023	676
Pigeon colombin (<i>Columba oenas</i>)	25	2025	4825
Pigeon ramier (<i>Columba palumbus</i>)	125	2025	256
Pinson des arbres (<i>Fringilla coelebs</i>)	36	2025	482
Pinson du Nord (<i>Fringilla montifringilla</i>)	5	2014	8478
Pipit farlouse (<i>Anthus pratensis</i>)	2	2023	1603
Pipit indéterminé (<i>Anthus sp.</i>)	3	2015	7065
Pipit rousseline (<i>Anthus campestris</i>)	1	2023	743
Pluvier doré (<i>Pluvialis apricaria</i>)	150	2023	337
Pouillot fitis (<i>Phylloscopus trochilus</i>)	3	2021	4947
Pouillot véloce (<i>Phylloscopus collybita</i>)	3	2024	676
Râle d'eau (<i>Rallus aquaticus</i>)	2	2024	2505
Râle des genets (<i>Crex crex</i>)	1	2018	2882
Roitelet à triple bandeau (<i>Regulus ignicapillus</i>)	1	2021	8278
Roitelet huppé (<i>Regulus regulus</i>)	1	2022	7065
Rossignol philomèle (<i>Luscinia megarhynchos</i>)	1	2024	7536
Rougegorge familier (<i>Eriothacus rubecula</i>)	4	2025	979
Rougequeue à front blanc (<i>Phoenicurus phoenicurus</i>)	1	2021	6308
Rougequeue noir (<i>Phoenicurus ochruros</i>)	3	2023	1283
Rousserolle effarvatte (<i>Acrocephalus scirpaceus</i>)	2	2021	7356
Rousserolle indéterminée (<i>Acrocephalus sp.</i>)	2	2014	8478
Rousserolle turdoïde (<i>Acrocephalus arundinaceus</i>)	1	2017	2699
Rousserolle verderolle (<i>Acrocephalus palustris</i>)	2	2024	3326
Sarcelle d'été (<i>Spatula querquedula</i>)	11	2023	1566
Sarcelle d'hiver (<i>Anas crecca</i>)	180	2024	1569
Sittelle torchepot (<i>Sitta europaea</i>)	5	2023	3602
Spatule blanche (<i>Platalea leucorodia</i>)	1	2021	2815
Sterne pierregarin (<i>Sterna hirundo</i>)	1	2022	5653
Tadome de Belon (<i>Tadorna tadorna</i>)	2	2023	9272
Tarier des prés (<i>Saxicola rubetra</i>)	12	2023	356
Tarier pâtre (<i>Saxicola rubicola</i>)	1	2021	3879
Torcol fourmilier (<i>Jynx torquilla</i>)	1	2022	2662

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Tourterelle turque (<i>Streptopelia decaocto</i>)	4	2025	1283
Traquet motteux (<i>Oenanthe oenanthe</i>)	17	2024	147
Troglodyte mignon (<i>Troglodytes troglodytes</i>)	7	2024	979
Vanneau huppé (<i>Vanellus vanellus</i>)	100	2023	1767
Verdier d'Europe (<i>Carduelis chloris</i>)	12	2023	979

Oiseaux signalés dans la base de données d'AVES (Natagora) (source : AVES, Natagora, 2026)

Pour chaque espèce signalée par la base de données AVES dans un périmètre de 10 km autour du projet, une analyse croisée est effectuée de manière à connaître de manière indépendante l'effectif maximal observé dans le périmètre des 10 km, ensuite l'année la plus récente où l'espèce a été détectée dans le périmètre des 10 km et la distance la plus faible entre une espèce et le projet éolien. Ainsi, les colonnes fournissent des informations qui ne sont pas corrélées entre elles.

Exemple : pour l'espèce Accenteur mouchet ci-dessous, le groupe le plus conséquent observé sur le périmètre des 10 km autour du projet est de 13 individus. Les observations les plus récentes inscrites dans la base d'AVES datent de 2026 pour cette espèce. La plus faible distance à laquelle est renseignée l'Accenteur mouchet est de 256 mètres d'une des éoliennes du projet. Ainsi, la lecture des colonnes NE DOIT PAS se comprendre comme suit : 13 Accenteurs mouchet observés en 2026 à 256 mètres du projet.

Espèce	Effectif maximal	Observation la plus récente	Distance minimale au projet (m)
Accenteur mouchet (<i>Prunella modularis</i>)	13	2026	256
Aigle botté (<i>Hieraetus pennatus</i>)	1	2020	5725
Aigrette garzette (<i>Egretta garzetta</i>)	4	2025	2337
Alouette des champs (<i>Alauda arvensis</i>)	770	2026	85
Alouette lulu (<i>Lullula arborea</i>)	47	2025	323
Anatidae indet.	2	2022	2621
Astrild ondulé (<i>Estrilda astrild</i>)	4	2020	9513
Autour des palombes (<i>Accipiter gentilis</i>)	2	2025	1646
Avocette élégante (<i>Recurvirostra avosetta</i>)	1	2021	2942
Balbusard pêcheur (<i>Pandion haliaetus</i>)	2	2025	327
Barge à queue noire (<i>Limosa limosa</i>)	49	2023	1550
Barge rousse (<i>Limosa lapponica</i>)	20	2016	5513
Bécasse des bois (<i>Scolopax rusticola</i>)	3	2026	2132
Bécasseau cocorli (<i>Calidris ferruginea</i>)	1	2024	4477
Bécasseau de Temminck (<i>Calidris temminckii</i>)	4	2024	2924
Bécasseau indéterminé	1	2024	9958
Bécasseau maubèche (<i>Calidris canutus</i>)	3	2016	5503
Bécasseau variable (<i>Calidris alpina</i>)	4	2024	2942
Bécassine des marais (<i>Gallinago gallinago</i>)	26	2026	1797
Bécassine sourde (<i>Lymnocyprpes minimus</i>)	3	2025	1821
Bécasseau sanderting (<i>Calidris alba</i>)	1	2021	4495
Bec-croisé des sapins (<i>Loxia curvirostra</i>)	20	2025	653
Bergeronnette de Yarell (<i>Motacilla alba yarellii</i>)	2	2025	554
Bergeronnette des ruisseaux (<i>Motacilla cinerea</i>)	6	2025	584
Bergeronnette flavéole (<i>Motacilla flava flavissima</i>)	1	2025	3971
Bergeronnette grise (<i>Motacilla alba</i>)	150	2025	176
Bergeronnette grise spp alba (<i>Motacilla alba alba</i>)	1	2022	7928
Bergeronnette printanière (<i>Motacilla flava</i>)	67	2025	176
Bergeronnette printanière nordique (<i>Motacilla flava thunbergi</i>)	2	2025	3964

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Bergeronnette printanière spp flava (<i>Motacilla flava flava</i>)	1	2020	6919
Bergeronnette sp.	6	2024	289
Bemache de Hutchins (<i>Branta hutchinsii</i>)	1	2025	4404
Bemache du Canada (<i>Branta canadensis</i>)	400	2025	1585
Bemache néné (<i>Branta sandvicensis</i>)	5	2025	4432
Bemache nonnette (<i>Branta leucopsis</i>)	50	2025	1585
Bemache sp. (<i>Branta sp.</i>)	32	2025	2385
Bihoreau gris (<i>Nycticorax nycticorax</i>)	2	2025	2942
Bondrée apivore (<i>Pernis apivorus</i>)	6	2025	438
Bouscarle de Cetti (<i>Cettia cetti</i>)	7	2025	2349
Bouvreuil pivone (<i>Pyrrhula pyrrhula</i>)	6	2025	2159
Bruant des roseaux (<i>Emberiza schoeniclus</i>)	60	2025	2082
Bruant jaune (<i>Emberiza citrinella</i>)	130	2025	165
Bruant ortolan (<i>Emberiza hortulana</i>)	1	2020	3186
Bruant proyer (<i>Emberiza calandra</i>)	11	2024	2942
Busard cendré (<i>Circus pygargus</i>)	1	2025	1056
Busard des roseaux (<i>Circus aeruginosus</i>)	4	2025	204
Busard indéterminé (<i>Circus sp.</i>)	1	2024	2111
Busard pâle (<i>Circus macrourus</i>)	1	2023	3333
Busard Saint-Martin (<i>Circus cyaneus</i>)	3	2025	67
Buse pattue (<i>Buteo lagopus</i>)	1	2024	4060
Buse variable (<i>Buteo buteo</i>)	40	2026	176
Butor étoilé (<i>Botaurus stellaris</i>)	1	2024	2942
Caille des blés (<i>Coturnix coturnix</i>)	6	2025	255
Calopittie élégante (<i>Nymphicus hollandicus</i>)	1	2025	8608
Canard à collier noir (<i>Callonetta leucophrys</i>)	1	2020	2698
Canard à crinière (<i>Chenonetta jubata</i>)	1	2024	5445
Canard bahamensis (<i>Anas bahamensis</i>)	1	2021	2634
Canard carolin (<i>Aix sponsa</i>)	3	2020	8529
Canard chipeau (<i>Mareca strepera</i>)	144	2026	2299
Canard colvert (<i>Anas platyrhynchos</i>)	66666	2026	313
Canard de Chiloe (<i>Mareca sibilatrix</i>)	1	2023	2942
Canard hybride	3	2025	2561
Canard mandarin (<i>Aix galericulata</i>)	23	2025	2803
Canard masqué (<i>Cairina moschata</i>)	1	2025	2942
Canard pilot (<i>Anas acuta</i>)	16	2026	2366
Canard siffleur (<i>Mareca penelope</i>)	12	2025	1585
Canard souchet (<i>Spatula clypeata</i>)	51	2026	2351
Canard sp.	2	2017	9884
Chardonneret élégant (<i>Carduelis carduelis</i>)	70	2026	553
Chevalier aboyeur (<i>Tringa nebularia</i>)	10	2025	2366
Chevalier arlequin (<i>Tringa erythropus</i>)	2	2025	2427
Chevalier culblanc (<i>Tringa ochropus</i>)	16	2025	948
Chevalier gambette (<i>Tringa totanus</i>)	11	2025	2385
Chevalier quignette (<i>Actitis hypoleucos</i>)	9	2025	1638
Chevalier sylvain (<i>Tringa glareola</i>)	18	2025	2373
Chevêche d'Athènes (<i>Athene noctua</i>)	4	2025	978
Choucas des tours (<i>Coloeus monedula</i>)	600	2026	176
Chouette hulotte (<i>Strix aluco</i>)	5	2025	1566
Cigogne blanche (<i>Ciconia ciconia</i>)	250	2025	319
Cigogne noire (<i>Ciconia nigra</i>)	6	2025	1936
Cincla plongeur (<i>Cinclus cinclus</i>)	2	2024	5324

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Circaète Jean-le-Blanc (<i>Circaetus gallicus</i>)	1	2023	5732
Combattant varié (<i>Calidris pugnax</i>)	15	2025	2376
Corbeau freux (<i>Corvus frugilegus</i>)	200	2025	92
Cormoran huppé (<i>Gulosus aristotelis</i>)	1	2025	4417
Cornelle noire (<i>Corvus corone</i>)	300	2026	176
Corvidés indéterminé	1	2023	4850
Coucou gris (<i>Cuculus canorus</i>)	2	2025	438
Courlis cendré (<i>Numenius arquata</i>)	1	2025	815
Courlis corlieu (<i>Numenius phaeopus</i>)	4	2025	2660
Cygne chanteur (<i>Cygnus cygnus</i>)	7	2019	2443
Cygne noir (<i>Cygnus atratus</i>)	1	2025	7460
Cygne tuberculé (<i>Cygnus olor</i>)	8	2026	2346
Cygnus spec.	7	2024	9486
Echasse blanche (<i>Himantopus himantopus</i>)	3	2021	2622
Efraine des clochers (<i>Tyto alba</i>)	3	2025	2189
Elanion blanc (<i>Elanus caeruleus</i>)	1	2025	3090
Epervier d'Europe (<i>Accipiter nisus</i>)	6	2025	729
Étourneau roselin (<i>Pastor roseus</i>)	1	2021	5835
Étourneau sansonnet (<i>Sturnus vulgaris</i>)	2000	2025	256
Faisan de Colchide (<i>Phasianus colchicus</i>)	109	2026	176
Faisan doré (<i>Chrysolophus pictus</i>)	2	2021	9622
Faisan vénéré (<i>Symycterus reevesii</i>)	10	2024	6216
Faisan versicolore (<i>Phasianus versicolor</i>)	1	2025	8026
Faucon crécérille (<i>Falco tinnunculus</i>)	8	2025	223
Faucon émerillon (<i>Falco columbarius</i>)	2	2025	324
Faucon gerfaut (<i>Falco rusticolus</i>)	1	2022	3045
Faucon hobereau (<i>Falco subbuteo</i>)	5	2025	649
Faucon kobez (<i>Falco vespertinus</i>)	1	2023	3221
Faucon pèlerin (<i>Falco peregrinus</i>)	5	2026	580
Fauvette à tête noire (<i>Sylvia atricapilla</i>)	24	2025	322
Fauvette babillarde (<i>Curruca curruca</i>)	4	2025	857
Fauvette des jardins (<i>Sylvia borin</i>)	14	2025	402
Fauvette grisette (<i>Curruca communis</i>)	34	2025	126
Fou de Bassan (<i>Morus bassanus</i>)	1	2022	5450
Foulque macroule (<i>Fulca atra</i>)	150	2026	1628
Fringille hybride	1	2019	6701
Fringille spec.	300	2022	5581
Fuligule hybride	4	2025	1999
Fuligule milouin (<i>Aythya ferina</i>)	118	2025	2351
Fuligule milouinan (<i>Aythya marila</i>)	4	2022	2439
Fuligule morillon (<i>Aythya fuligula</i>)	110	2026	1202
Fuligule nyroca (<i>Aythya nyroca</i>)	2	2023	1999
Gallinule poule d'eau (<i>Gallinula chloropus</i>)	50	2026	1823
Garrot à œil d'or (<i>Bucephala clangula</i>)	1	2019	9660
Geai des chênes (<i>Garrulus glandarius</i>)	52	2026	946
Géopélie diamant (<i>Geopelia cuneata</i>)	1	2023	9389
Gobemouche gris (<i>Muscicapa striata</i>)	5	2025	1488
Gobemouche noir (<i>Ficedula hypoleuca</i>)	2	2025	2562
Goéland argenté (<i>Larus argentatus</i>)	200	2026	1114
Goéland brun (<i>Larus fuscus</i>)	350	2025	256
Goéland brun occidental (<i>Larus fuscus graellsii</i>)	1	2021	5771
Goéland brun scandinave (<i>Larus fuscus intermedius</i>)	1	2018	2942

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Goéland cendré (<i>Larus canus</i>)	40	2025	2101
Goéland leucopée (<i>Larus michahellis</i>)	6	2025	2451
Goéland marin (<i>Larus marinus</i>)	10	2025	2482
Goéland pontique (<i>Larus cachinnans</i>)	2	2025	5209
Goéland spéc. (<i>Larus spec.</i>)	500	2025	2722
Gorge bleue à miroir (<i>Luscinia svecica</i>)	1	2025	1169
Gorgebleue à miroir blanc (<i>Luscinia svecica cyaneocula</i>)	1	2018	2574
Grand corbeau (<i>Corvus corax</i>)	3	2025	2428
Grand Cormoran (<i>Phalacrocorax carbo</i>)	180	2026	164
Grand cormoran atlantique (<i>Phalacrocorax carbo carbo</i>)	5	2024	5545
Grand Gravelot (<i>Charadrius hiaticula</i>)	10	2025	2382
Grand-duc d'Europe (<i>Bubo bubo</i>)	4	2025	2729
Grande Aigrette (<i>Ardea alba</i>)	17	2026	649
Grèbe à cou noir (<i>Podiceps nigricollis</i>)	26	2025	1999
Grèbe castagneux (<i>Tachybaptus ruficollis</i>)	44	2026	1080
Grèbe huppé (<i>Podiceps cristatus</i>)	15	2025	2327
Grimpereau des bois (<i>Certhia familiaris</i>)	1	2025	2384
Grimpereau des jardins (<i>Certhia brachydactyla</i>)	7	2025	891
Grimpereau sp. (<i>Certhia spec.</i>)	1	2025	8496
Grive draine (<i>Turdus viscivorus</i>)	25	2025	979
Grive litorne (<i>Turdus pilaris</i>)	400	2026	868
Grive mauvis (<i>Turdus iliacus</i>)	400	2025	345
Grive musicienne (<i>Turdus philomelos</i>)	300	2025	256
Grosbec casse-noyaux (<i>Coccothraustes coccothraustes</i>)	11	2025	584
Grue cendrée (<i>Grus grus</i>)	706	2025	181
Guépier d'Europe (<i>Merops apiaster</i>)	5	2024	2838
Guifette moustac (<i>Chlidonia hybrida</i>)	1	2021	2456
Guifette noire (<i>Chlidonia niger</i>)	1	2025	2382
Harle bièvre (<i>Mergus merganser</i>)	8	2025	2425
Harle huppé (<i>Mergus serrator</i>)	1	2023	2370
Héron cendré (<i>Ardea cinerea</i>)	23	2026	329
Héron garde-boue (<i>Bubulcus ibis</i>)	3	2025	2387
Héron pourpre (<i>Ardea purpurea</i>)	1	2024	2305
Hibou des marais (<i>Asio flammeus</i>)	1	2024	290
Hibou moyen-duc (<i>Asio otus</i>)	15	2025	560
Hibou sp. (<i>Asio sp.</i>)	1	2024	5050
Hirondelle de fenêtre (<i>Delichon urbicum</i>)	200	2025	779
Hirondelle de rivage (<i>Riparia riparia</i>)	20	2025	2437
Hirondelle rustique (<i>Hirundo rustica</i>)	300	2025	364
Hirondelle sp.	90	2023	9308
Huitrier pie (<i>Haematopus ostralegus</i>)	4	2025	2390
Huppe fasciée (<i>Upupa epops</i>)	1	2025	4483
Hypolaïs icterine (<i>Hippolais icterina</i>)	2	2025	1413
Hypolaïs indéterminé (<i>Hypolaïs sp.</i>)	1	2022	3127
Hypolaïs polyglotte (<i>Hippolais polyglotta</i>)	2	2024	2523
Ibis falcinelle (<i>Plegadis falcinellus</i>)	1	2016	2942
Ibis rouge (<i>Eudocimus ruber</i>)	1	2020	9098
Indetermine	30	2025	4712
Jaseur boréal (<i>Bombus garrulus</i>)	3	2019	5378
Linotte mélodieuse (<i>Linaria cannabina</i>)	125	2025	91

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Locustelle luscinoïde (<i>Locustella luscinioides</i>)	1	2019	9649
Locustelle tachetée (<i>Locustella naevia</i>)	1	2023	2813
Loriot d'Europe (<i>Oriolus oriolus</i>)	1	2025	2729
Marouette ponctuée (<i>Porzana porzana</i>)	1	2022	2329
Martin huppé (<i>Acridotheres cristatellus</i>)	1	2024	9621
Martinot à ventre blanc (<i>Tachymarpis melba</i>)	1	2020	5595
Martinot noir (<i>Apus apus</i>)	250	2025	643
Martin-pêcheur d'Europe (<i>Alcedo atthis</i>)	5	2025	1990
Merle à plastron (<i>Turdus torquatus</i>)	8	2025	1999
Merle noir (<i>Turdus merula</i>)	37	2026	256
Mésange à longue queue (<i>Aegithalos caudatus</i>)	50	2026	323
Mésange bleue (<i>Cyanistes caeruleus</i>)	157	2026	323
Mésange boréale (<i>Parus montanus</i>)	6	2025	2399
Mésange charbonnière (<i>Parus major</i>)	26	2026	330
Mésange huppée (<i>Parus cristatus</i>)	5	2025	1696
Mésange indéterminée	2	2025	2676
Mésange noire (<i>Periparus ater</i>)	10	2025	2427
Mésange nonnette (<i>Poecile palustris</i>)	5	2025	779
Milan noir (<i>Milvus migrans</i>)	3	2025	145
Milan royal (<i>Milvus milvus</i>)	3	2025	330
Moineau domestique (<i>Passer domesticus</i>)	70	2025	607
Moineau friquet (<i>Passer montanus</i>)	25	2025	574
Mouette mélanocéphale (<i>Ichthyaetus melanocephalus</i>)	2	2025	2533
Mouette pygmée (<i>Hydrocoleus minutus</i>)	3	2025	2464
Mouette rieuse (<i>Chroicocephalus ridibundus</i>)	700	2026	553
Nette rousse (<i>Netta rufina</i>)	1	2025	2559
Oedicnème criard (<i>Burhinus oedicnemus</i>)	1	2020	9090
Oie à tête barrée (<i>Anser indicus</i>)	4	2024	2676
Oie cendrée (<i>Anser anser</i>)	170	2025	646
Oie cianôide (<i>Anser cygnoides</i>)	2	2025	5514
Oie cygnôide (<i>Anser cygnoides</i>)	2	2025	5500
Oie de la toundra (<i>Anser serrirostris</i>)	2	2024	762
Oie de Magellan (<i>Chloephaga picta</i>)	2	2016	6951
Oie domestique (<i>Anser anser domestica</i>)	14	2025	2528
Oie hybride	40	2024	1968
Oie rieuse (<i>Anser albifrons</i>)	30	2025	331
Ouette d'Égypte (<i>Alopochen aegyptiaca</i>)	250	2025	285
Panure à moustaches (<i>Panurus biarmicus</i>)	3	2024	2942
Perdrix grise (<i>Perdix perdix</i>)	56	2025	259
Perruche à collier (<i>Psittacula krameri</i>)	300	2025	1458
Perruche à croupion rouge (<i>Psephotus haematorotus</i>)	20	2025	3250
Perruche à oreilles jaunes (<i>Platycercus icterotis</i>)	1	2021	9451
Perruche onnicolore (<i>Platycercus eximius</i>)	1	2018	9207
Petit Gravelot (<i>Charadrius dubius</i>)	10	2025	2342
Phœnicopteridae indéterminé	1	2023	5409
Phragmite des joncs (<i>Acrocephalus schoenobaenus</i>)	2	2025	2441
Pic épicé (<i>Dendrocopos major</i>)	7	2026	779
Pic épichette (<i>Dryobates minor</i>)	4	2025	2325
Pic mar (<i>Dendrocoptes medius</i>)	4	2025	2573
Pic noir (<i>Dryocopus martius</i>)	4	2025	584

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Pic vert (<i>Picus viridis</i>)	4	2025	323
Pie bavarde (<i>Pica pica</i>)	200	2026	293
Pie-grièche écorcheur (<i>Lanius collurio</i>)	1	2024	1478
Pigeon biset (<i>Columba livia</i>)	100	2025	607
Pigeon colombine (<i>Columba oenas</i>)	120	2026	1675
Pigeon ramier (<i>Columba palumbus</i>)	6000	2026	256
Pinson des arbres (<i>Fringilla coelebs</i>)	2000	2026	112
Pinson du Nord (<i>Fringilla montifringilla</i>)	141	2026	1500
Pipit à gorge rousse (<i>Anthus cervinus</i>)	1	2024	3091
Pipit de Richard (<i>Anthus richardi</i>)	1	2016	5089
Pipit des arbres (<i>Anthus trivialis</i>)	37	2025	2333
Pipit farlouse (<i>Anthus pratensis</i>)	750	2025	112
Pipit rousseline (<i>Anthus campestris</i>)	3	2024	743
Pipit sp. (<i>Anthus sp.</i>)	51	2024	2662
Pipit spioncelle (<i>Anthus spinoletta</i>)	38	2025	1674
Pluvier argenté (<i>Pluvialis squatarola</i>)	4	2024	659
Pluvier doré (<i>Pluvialis apricaria</i>)	37	2025	337
Pluvier guignard (<i>Charadrius morinellus</i>)	9	2025	3263
Pouillot à grand sourcil (<i>Phylloscopus inornatus</i>)	1	2025	9013
Pouillot brun (<i>Phylloscopus fuscatus</i>)	1	2018	2942
Pouillot de Sibérie (<i>Phylloscopus collybita tristis</i>)	1	2021	4480
Pouillot fitis (<i>Phylloscopus trochilus</i>)	4	2025	1708
Pouillot siffleur (<i>Phylloscopus sibilatrix</i>)	1	2022	7700
Pouillot véloce (<i>Phylloscopus collybita</i>)	20	2025	323
Pouillot véloce scandinave (<i>Phylloscopus collybita abietinus</i>)	1	2017	3184
Poule domestique (<i>Gallus gallus</i>)	1	2025	8164
Râle d'eau (<i>Rallus aquaticus</i>)	7	2025	2330
Râle des genets (<i>Crex crex</i>)	1	2018	2882
Rémiz penduline (<i>Remiz pendulinus</i>)	3	2018	2627
Roitelet huppé (<i>Regulus regulus</i>)	13	2026	575
Roitelet triple-bandeau (<i>Regulus ignicapilla</i>)	6	2026	1032
Rosignol philomèle (<i>Luscinia megarhynchos</i>)	2	2025	2541
Rougegorge familier (<i>Erithacus rubecula</i>)	19	2026	282
Rougequeue à front blanc (<i>Phoenicurus phoenicurus</i>)	3	2025	1697
Rougequeue noir (<i>Phoenicurus ochruros</i>)	11	2026	612
Rousserolle effarvée (<i>Acrocephalus scirpaceus</i>)	17	2025	1800
Rousserolle turdoïde (<i>Acrocephalus arundinaceus</i>)	1	2017	2699
Rousserolle verderolle (<i>Acrocephalus palustris</i>)	35	2025	2130
Sarcelle d'été (<i>Spatula querquedula</i>)	11	2025	1566
Sarcelle d'hiver (<i>Anas crecca</i>)	180	2026	1999
Serin à pointine citron (<i>Citragora citrinipectus</i>)	1	2021	3912
Serin cini (<i>Serinus serinus</i>)	6	2024	2551
Sittelle torchepot (<i>Sitta europaea</i>)	9	2026	1032
Sizerin flammé (<i>Acanthis flammea</i>)	50	2025	2113
Spatule blanche (<i>Platalea leucorodia</i>)	1	2021	2815
Sterne pierregarin (<i>Sterna hirundo</i>)	1	2024	9217
Tadome à tête grise (<i>Tadorna cana</i>)	1	2016	9642
Tadome casarca (<i>Tadorna ferruginea</i>)	24	2025	1561
Tadome de Belon (<i>Tadorna tadorna</i>)	15	2026	2378

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Tarier des prés (<i>Saxicola rubetra</i>)	12	2025	356
Tarier pâle (<i>Saxicola rubicola</i>)	4	2025	1974
Tarin des aulnes (<i>Spinus spinus</i>)	150	2025	2020
Trocol fourmilier (<i>Jynx torquilla</i>)	1	2025	2942
Tourterelle des bois (<i>Streptopelia turtur</i>)	2	2025	2649
Tourterelle turque (<i>Streptopelia decaocto</i>)	50	2026	675
Traquet moiteux (<i>Oenanthe oenanthe</i>)	17	2025	147
Troglodyte mignon (<i>Troglodytes troglodytes</i>)	25	2025	183
Turdidae indet.	100	2025	1391
Vanneau huppé (<i>Vanellus vanellus</i>)	1000	2025	111
Vautour fauve (<i>Gyps fulvus</i>)	25	2023	3170
Verdier d'Europe (<i>Chloris chloris</i>)	156	2026	979

3 Chiroptérofaune

Chauves-souris inventoriées dans le périmètre de 10 km autour du projet (source : SPW-DG03, DEMNA, 2026)

Espèce	Effectif maximal	Observation la plus récente	Distance minimale au projet (m)
Chiroptère sp.	1250	2023	1654
Murin de Bechstein (<i>Myotis bechsteinii</i>)	1	2025	9687
Murin de Daubenton (<i>Myotis daubentonii</i>)	9	2025	1654
Murin de Natterer (<i>Myotis nattereri</i>)	13	2025	6585
Murin sp. (<i>Myotis sp.</i>)	938	2023	1654
Murin à moustaches (<i>Myotis mystacinus</i>)	151	2024	2260
Murin à moustaches de Brandt / d'Alcathoe	151	2025	2205
Murin à oreilles échanquées (<i>Myotis emarginatus</i>)	10	2019	7665
Noctule commune (<i>Nyctalus noctula</i>)	2	2024	2566
Noctule de Leisler (<i>Nyctalus leisleri</i>)	1	2024	8171
Noctule sp. (<i>Nyctalus sp.</i>)	1	2020	9657
Oreillard gris (<i>Plecotus austriacus</i>)	1	2023	6604
Oreillard roux (<i>Plecotus auritus</i>)	45	2025	4020
Oreillard sp. (<i>Plecotus sp.</i>)	5	2022	7503
Pipistrelle commune (<i>Pipistrellus pipistrellus</i>)	5974	2025	1654
Pipistrelle commune / de Nathusius (<i>Pipistrellus pipistrellus / nathusii</i>)	20	2022	2733
Pipistrelle commune / pygmée (<i>Pipistrellus pipistrellus / pygmaeus</i>)	157	2023	1654
Pipistrelle de Nathusius (<i>Pipistrellus nathusii</i>)	33	2025	2670
Pipistrelle indéterminée (<i>Pipistrellus sp.</i>)	110	2022	2039
Pipistrelle pygmée (<i>Pipistrellus pygmaeus</i>)	4	2024	7367
Sérotine commune (<i>Eptesicus serotinus</i>)	45	2025	1654
Sérotine indéterminée (<i>Eptesicus sp.</i>)	3	2022	5105
Sérotule indéterminée	516	2023	1654

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ANNEXE B. ETUDE DE VENT



Etude du potentiel éolien - Projet éolien de Renner Energies à Nivelles

Rapport final

Client : Renner Energies

Versions

NUMERO	DATE	AUTEUR	VERIFICATION	MODIFICATIONS
1.0	12/12/2023	Alix Njamkepo	Pierre Antoine Mail	
2.0	18/07/2024	Alix Njamkepo		Mise à jour de la MCP Suppression d'un modèle
3.0	24/02/2026	Alix Njamkepo		Etude de nouveaux modèles

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LISTE DES ABBRÉVIATIONS

P50 brut : Niveau de production annuelle brute (sans pertes) la plus probable.

P50 net : Niveau de production annuelle nette (avec pertes & systèmes de bridages) la plus probable.

WAsP : Wind Atlas Analysis and Application Program.

MERRA2 : Modern-Era Retrospective analysis for Research and Applications, Version 2, réanalyse atmosphérique mondiale produite par la NASA Données issues d'un modèle de prévision météorologique.

ERA5 : Cinquième génération du jeu de données ECMWF (European Centre for Medium-Range Weather Forecasts), réanalyse atmosphérique du climat mondial couvrant la période de janvier 1940 à aujourd'hui.

MNT : Modèle Numérique de Terrain (Données d'altitude du sol d'une résolution d'un mètre, issues d'acquisitions Lidar effectuées entre 2012 et 2014 en Wallonie).

Corine Land Cover 2018 : Base de données vectorielle sur l'occupation des sols, créée par l'Agence Européenne de l'Environnement, principalement à partir d'images satellite.

RIX : Ruggedness Index, déterminant la complexité d'un terrain.

CNR : Carrier to Noise Ratio. Rapport entre l'intensité du niveau du signal reçu et l'intensité du bruit ambiant. Il dépend de la concentration de particules atmosphériques qui rétrodiffusent le laser et donc des conditions météorologiques. Un coefficient de rétrodiffusion atmosphérique élevé entraîne un CNR élevé, et garantissent une bonne qualité des données.

SYNTHÈSE DES RÉSULTATS

Tableau 1 : Perspectives de production du projet éolien de Renner Energies à Nivelles

Modèle d'éoliennes	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
Nombre d'éoliennes	6	6	6
Diamètre du rotor (m)	114	112	110
Hauteur d'axe (m)	93	94	95
Hauteur totale (m)	150	150	150
Puissance éolienne (MW)	2,6	3,3	2,2
Puissance installée du parc (MW)	15,6	19,8	13,2
Production électrique P50 brute (MWh/an)	52,777	54,340	47,881
Pertes systématiques cumulées (%)	9,6%	9,6%	9,4%
Production électrique P50 nette (MWh/an), Sans bridage	47,723	49,108	43,380
Facteur de charge (%)	34,9%	28,3%	37,5%
Heures équivalent pleine charge (h)	3,059	2,480	3,286
Avec bridage acoustique (conditions sectorielles 2021) :			
Production électrique P50 nette (MWh/an)	47,568	48,907	41,559
Pertes bridage (%)	0,3%	0,4%	4,2%
Avec module d'arrêt chauve-souris :			
Production électrique P50 nette (MWh/an)	46,567	48,075	42,277
Pertes bridage (%)	2,4%	2,1%	2,5%
Avec module d'arrêt ombre :			
Production électrique P50 nette (MWh/an)	47,718	49,102	43,375
Pertes bridage (%)	0,0%	0,0%	0,0%
Avec bridage cumulé (acoustique conditions sectorielles 2021 + chauve-souris + ombre) :			
Production électrique P50 nette (MWh/an)	46,410	47,873	40,498
Pertes bridage (%)	2,8%	2,5%	6,6%

1. INTRODUCTION

Renner Energies développe un projet de six éoliennes sur les territoires communaux de Genappe et de Nivelles, en zone agricole.

GreenPlug a procédé à une étude indépendante du potentiel éolien du site dont les résultats sont consignés dans ce rapport. L'objectif de l'étude est d'évaluer la ressource en vent du site et de calculer la production électrique annuelle générée par le projet pour différents modèles d'éolienne.

L'évaluation du potentiel éolien s'appuie sur le modèle d'écoulement du vent WASP et sur les données de vent mesurées par un LiDAR WindCube 2.1 installé sur site pendant une durée de 18 mois entre octobre 2022 et avril 2024.

Ce rapport constitue une actualisation du rapport « Etude du potentiel éolien - Projet éolien de Renner Energies à Nivelles, version v2.0, 18/17/2024 », portant sur l'étude de nouveaux modèles.

2. MÉTHODOLOGIE

L'évaluation du potentiel éolien repose sur la prévision du climat local de vent à hauteur de nacelle de chaque éolienne du parc. Les distributions des vitesses calculées sont ensuite combinées à la courbe de puissance de l'éolienne pour en calculer la production électrique brute. Les pertes de production systématiques, incluant les pertes par effet de sillage, sont ensuite évaluées et déduites pour déterminer la production électrique nette de l'éolienne.

Dans le cadre de cette étude, la prévision du vent local s'appuie sur le modèle d'écoulement du vent WASP et sur les données de vent mesurées sur le site.

Les principales étapes de la procédure d'évaluation sont schématisées à la figure suivante.



Des données de vent ont été mesurées sur site à l'aide d'un LiDAR WindCube 2.1, pendant 18 mois, d'octobre 2022 à avril 2024. Pour tenir compte de la variabilité du vent, les données mesurées sont extrapolées sur une longue période de temps (minimum 10 ans) en appliquant des techniques de corrélation avec des données de référence. Cette étape permet de normaliser les données mesurées sur une période de temps représentative du climat. Les données sont finalement extrapolées à hauteur de mât de chaque éolienne à l'aide du modèle WASP pour tenir compte de l'influence du relief, de la couverture de terrain et de la stabilité de l'atmosphère sur l'écoulement du vent.

3. DONNÉES UTILISÉES

3.1. LE PROJET

Le projet prévoit la construction de six éoliennes en zone agricole, à proximité de la route nationale N25 sur les territoires communaux de Nivelles et de Genappe.

Plusieurs parcs en fonction (Nivelles Rossel), autorisés (Genappe-Glabais et Braine-l'Alleud) et en projet (Ittre et Nivelles-R24) sont localisés à ~5 km du projet et pris en compte dans l'étude.

La localisation et les coordonnées des éoliennes du projet, ainsi que celles du LiDAR sont indiquées sur la carte de la figure 1 et au tableau 2.

Figure 1 : Localisation des éoliennes en projet (symbole rouge), et du Lidar (symbole orange), du parc en construction de Genappe-Glabais (symbole jaune), du parc autorisé de Braine-l'Alleud (symbole vert), de l'éolienne en fonction de Nivelles-Rossel (symbole bleu turquoise), du parc à l'instruction de Nivelles R24 (symbole orange) et du parc à l'instruction d'Ittre (symbole bleu)

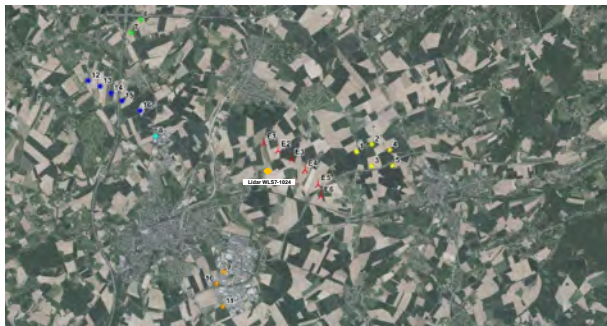


Tableau 2 : Coordonnées des éoliennes en projet et du LiDAR (Système de coordonnées : Lambert 72)

EOLIENNE N°	COORDONNÉE X	COORDONNÉE Y
E1	150,204	145,962
E2	150,651	145,722
E3	151,076	145,466
E4	151,493	145,114
E5	151,902	145,675
E6	151,996	145,311
LiDAR	150,251	145,155

3.2. LES MODÈLES D'ÉOLIENNE

Le modèle d'éolienne sélectionné par le client pour son projet est indiqué au tableau 3 avec les spécifications techniques principales.

Tableau 3 : Modèles et spécifications techniques des éoliennes étudiées

MODÈLE D'ÉOLIENNE	SIEMENS GAMESA SG114 2.6 MW	VESTAS V112 3.3 MW	VESTAS V1102.2 MW
Diamètre du rotor (m)	117	112	110
Hauteur de mât (m)	91	94	95
Hauteur totale (m)	150	150	150
Puissance éolienne (kW)	2,600	3,300	2,200
Vitesse de démarrage (m/s)	3	3	3
Vitesse coupure (m/s)	25	25	20
Puissance acoustique (dB)	104.6	106.1	104.4
Courbe de puissance	Calculée par le constructeur	Calculée par le constructeur	Calculée par le constructeur

Les courbes de puissance des éoliennes fournies par les constructeurs, pour une densité de l'air de 1.225 kg/m³, sont reprises à l'annexe 6. Les courbes de puissances ont été ajustées dans les calculs de production pour tenir compte de la densité de l'air calculée sur le site.

3.3. LES PARCS VOISINS

Les parcs éoliens voisins autorisés, exploités ou en projet situés à proximité (~5 km) du projet ont été considérés pour calculer les effets de parc. Au-delà de cette distance, les effets de sillages sont négligeables. La liste des éoliennes communiquée par l'auteur d'étude d'incidences est reprise en annexe 1 avec les modèles considérés pour notre étude.

3.4. LES DONNÉES DE VENT

Les données de vent utilisées pour cette étude proviennent d'une campagne de mesure de vent réalisée sur site à l'aide d'un LiDAR WindCube 2.1. Ces données de vent primaires ont été contrôlées avec des données de vent secondaires (issues des stations synoptiques opérées par l'IRM ou Météo Wing en Belgique) ou de campagnes de mesures réalisées par des mâts de mesures et lidars en Région Wallonne).

La campagne de mesure de vent s'est déroulée du 01 octobre 2022 au 02 avril 2024, permettant de collecter des données sur site à des hauteurs allant de 60 m à 240 m.

Pour normaliser le climat de vent et réaliser l'extrapolation long terme des données mesurées, les données météorologiques de référence disponibles dans la région ont été inventoriées.

La sélection des données météorologiques de référence a été réalisée en appliquant les critères suivants :

- La cohérence et la stabilité des données sur une période de 10 ans minimum ; analyse de l'historique des stations, analyse du taux de couverture/ disponibilité des données, test de cohérence et de stabilité des données au cours du temps.

- L'environnement du mât de mesures ; seules les stations de classe 1, la plus exigeante en termes de dégagement par rapport aux obstacles environnants, ont été sélectionnées pour les stations IRM-Meteo Wing. La classification des stations a été réalisée par l'IRM.
- La représentativité des données: seules les stations répondant aux critères précédents et situées à moins de 100 km du site ont été retenues.

En appliquant les critères de sélection précédents, 2 sources de données météorologiques de référence ont finalement été retenues pour la suite de l'étude.

Tableau 4 : Inventaire des données météorologiques disponibles pour l'étude

STATION	HAUTEUR MESURES (M)	DISTANCE SITE (KM)	PERIODE (MOIS/ANNEE)	VITESSE MOYENNE (M/S)	DONNEES DISPONIBLES	RESOLUTION DONNEES	Taux RECOUVREMENT DONNEES (%)
LIDAR	60,80,100,120,140,160,180,200,220,240	0	10/2022 – 04/2024	6.3, 6.8, 7.2, 7.7, 8.1, 8.5, 8.9, 9.3, 9.6, 9.9	Vitesse et direction (moyenne, max, min, écart type)	10 minutes	90.8
MERRA 2 (N50.50, E4.750)	50	13	01/1993 – 06/2024	6.75	Vitesse et direction (moyenne)	Horaire	100
EMD ERA 5 (N50.50_E00 3.75)	100	16	01/1993 – 06/2024	6.68	Vitesse et direction (moyenne)	Horaire	100

3.5. LE MODÈLE D'ÉCOULEMENT DU VENT

Le modèle d'écoulement WasP a été utilisé pour extrapoler les données de vent du LiDAR vers les éoliennes en tenant compte de l'influence du relief, de la couverture de terrain et de la stabilité de l'atmosphère.

WasP est le logiciel de référence internationalement utilisé dans l'industrie éolienne pour la prévision du vent et la production des parcs éoliens; il a été développé par l'institut de recherche DTU au Danemark.

WasP est un modèle d'écoulement linéaire, adapté aux terrains non complexes. La complexité du site a été évaluée à partir de l'indicateur RIX (Ruggedness Index) qui détermine la complexité du site à partir d'une analyse des pentes du terrain. La valeur de RIX doit être proche de 0% pour respecter l'enveloppe de performance du modèle ce qui est bien le cas pour le site du projet.

A l'intérieur et à proximité d'une zone forestière ou boisée, il est recommandé d'appliquer dans WasP [6] une correction sur la hauteur des anémomètres et sur la hauteur du mât des éoliennes pour tenir compte de l'influence de la forêt sur le profil des vitesses du vent. La hauteur de déplacement a été calculée à partir de la hauteur moyenne des obstacles environnants et de leur distance par rapport aux instruments de mesures et aux éoliennes.

4. ANALYSE, EVALUATION ET EXTRAPOLATION DES MESURES DE VENT

4.1. DESCRIPTION DE LA CAMPAGNE DE MESURES DE VENT

Un LiDAR de la marque Vaisala (modèle WindCube 2.1, n° de série WLS7-1024) a été installé sur site afin de mesurer la vitesse du vent à des altitudes importantes, allant de 60 m à 240 m. La campagne de mesure couvre 18 mois de données, d'Octobre 2022 à Avril 2024.

Figure 2 : Equipements installés sur site



Lidar WindCube 2.1



Power Pack



3.6. LE MODÈLE DE TERRAIN

Le modèle de terrain intègre une modélisation du relief sur un rayon de 10 km autour du site à partir des données MNT (issues d'acquisitions LiDAR effectuées entre 2012 et 2014) et une modélisation de la rugosité sur un rayon de 20 km à partir des données numériques Corine Land Cover 2018. Cette construction du modèle répond aux recommandations du modèle WasP et permet de tenir compte des effets de terrain sur le vent en amont du site.

Le modèle de terrain a été affiné par l'analyse de données exogènes (Orthophotoplans 2022 et cartes topographiques).

L'équipement LiDAR WindCube 2.1 de la marque Vaisala est certifié par l'entreprise Deutsche WindGuard Consulting GmbH selon la norme IEC 61400-12-1, Ed2.

L'équipement a été déployé de manière conforme pour assurer son bon fonctionnement. Le rapport d'installation indique un bon fonctionnement de l'appareil dès le début de la campagne.

Deux événements ont conduit à l'arrêt des mesures durant la campagne :

- Un défaut du système d'alimentation externe (220 V), remplacé par un système d'alimentation autonome en Juin 2023 (Power Pack : batteries 2 x 12 V alimentées par une pile à méthanol et un panneau photovoltaïque 400 Wc). L'appareil a été mis hors tension le 19 Février, du 16 Avril au 26 Avril 2023, et le 12 juin.
- Le dysfonctionnement du câble d'alimentation interne du LiDAR (mauvais câblage de mise à la terre) remplacé lors d'une opération de maintenance en Juin 2023. L'appareil a été mis hors tension du 20 au 22 juin.

On dénombre au total une interruption des mesures pendant 17 jours. Aucun autre problème n'a été rencontré.

Les données ont été enregistrées toutes les 10 minutes, avec un taux d'échantillonnage d'1 Hz. Sont relevés :

- Les paramètres externes : température interne et externe (°C), la pression (hPa) et le taux d'humidité (%)
- Pour chaque hauteur, la vitesse horizontale (m/s), la direction du vent (°), la vitesse verticale z (m/s), la disponibilité (%) et le Carrier to Noise Ratio - CNR (dB).

4.2. ANALYSE DES DONNÉES

Les données de vent ont été analysées afin d'évaluer la cohérence et filtrer les valeurs erronées ou anormales :

- Identification des données manquantes
- Contrôle visuel des données (vitesse et rose des vents)
- Suppression des données erronées et/ou non plausibles (filtres sur la disponibilité > 80% et le CNR < - 23 dB)
- Application d'un offset (5° Est)

L'analyse des données a permis de mettre en évidence un taux de recouvrement élevé des données (~91%). A noter qu'on observe que le taux de disponibilité diminue avec l'altitude, du fait de la présence moins importante de particules atmosphériques à mesurer.

Les données enregistrées au cours de la campagne sont résumées au tableau suivant pour chaque hauteur. Un rapport plus détaillé des mesures de vent est repris en annexe 2.

Tableau 5 : Statistiques des données de vent mesurées par le LiDAR (01/10/2022 – 02/04/2024)

HAUTEUR (M)	VITESSE MOYENNE (M/S)	WEIBULL A	WEIBULL K	Taux RECOUVREMENT DONNEES VITESSE (%)
60	6.26	7.06	2.389	95.4%
80	6.77	7.63	2.454	95.4%
100	7.23	8.15	2.513	95.2%

HAUTEUR (M)	VITESSE MOYENNE (M/S)	WEIBULL A	WEIBULL K	Taux RECOURVEMENT DONNEES VITESSE (%)
120	7.68	8.65	2.571	94.4%
140	8.11	9.12	2.618	93.8%
160	8.51	9.58	2.649	92.7%
180	8.90	10.01	2.671	90.8%
200	9.26	10.42	2.677	88.3%
220	9.61	10.81	2.679	84.9%
240	9.90	11.13	2.650	77.0%

4.3. EXTRAPOLATION LONG TERME DES DONNEES

Les données mesurées sur site à 80 m et 120 m (hauteurs représentatives de la hauteur de mât du modèle d'éolienne étudié) ont été extrapolées sur le long terme à l'aide de la méthode MCP afin d'ajuster le climat et obtenir une année normale de vent.

La méthode MCP (Mesurer-Corréler-Prédire) consiste à établir une relation entre les données concurrentes mesurées et des données de référence long terme puis appliquer cette relation aux données de références pour normaliser les données de vent mesurées.

4.3.1. Sélection des données de référence

Pour pouvoir appliquer la méthode MCP, la corrélation entre les données doit être suffisamment élevée ; on considère généralement que le coefficient de corrélation doit être supérieur à 75%.

Au niveau des directions du vent, le degré de corrélation entre données est élevé quel que soit la station de référence retenue. Au niveau des vitesses, les coefficients de corrélation entre les données mesurées et les données de référence long terme ont été calculés sur la période concomitante pour les deux stations de référence les plus proches.

Tableau 6 : Coefficients de corrélation entre données mesurées (LIDAR à 80 m) et données de référence

DONNEES DE REFERENCE	DISTANCE SITE (KM)	COEFFICIENT CORRELATION (VITESSE)
MERRA 2	13	89.9%
EMD ERA 5	16	91.6%

Tableau 7 : Coefficients de corrélation entre données mesurées (LIDAR à 120 m) et données de référence

DONNEES DE REFERENCE	DISTANCE SITE (KM)	COEFFICIENT CORRELATION (VITESSE)
MERRA 2	13	89.9%
EMD ERA 5	16	92.4%

Les données de référence ERA5 présentent le meilleur niveau de corrélation avec les données mesurées sur site et la corrélation est de bonne qualité pour les deux hauteurs sélectionnées. Les données de vent ERA5 ont donc été retenues pour réaliser l'extrapolation long terme des données mesurées à 80 m et à 120 m.

DIRECTION VENT (DEGRES)	# DONNEES DISPONIBLES	COEFFICIENT R²	OFFSET	PENTE
255-285	1169	0.83	1.20	0.88
285-315	542	0.79	0.81	0.89
315-345	385	0.61	1.17	0.79

4.3.3. Extrapolation long terme des données mesurées

Les données mesurées ont été extrapolées sur le long terme en appliquant aux données ERA5 les fonctions de transfert reprises au tableau 10 :

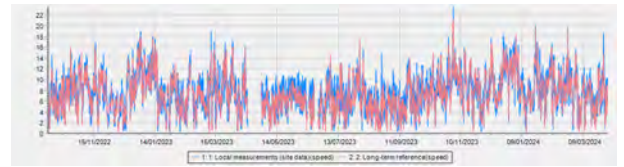
Données Mesurées Extrapolées (m/s) = [PENTE] x Données ERA5 + [Offset]

Le tableau suivant met en évidence l'impact de l'extrapolation long terme sur les données qui se manifeste par une diminution de la vitesse moyenne du vent à 80 et à 120 m, passant respectivement de 6.8 m/s à 6.2 m/s et de 7.7 m/s à 7.0 m/s après extrapolation.

Tableau 10 : Distribution des vitesses du vent, avant et après extrapolation long terme

STATION DE MESURES	PÉRIODE (JJ/MM/AAAA)	VITESSE MOYENNE (M/S)	PARAMÈTRE WEIBULL A	PARAMÈTRE WEIBULL K
Lidar 80 m	01/10/2022 – 01/04/2024	6.77	7.63	2.45
	01/01/1993 – 31/12/2023	6.24	7.04	2.39
Lidar 120 m	01/10/2022 – 01/04/2024	7.68	8.65	2.57
	01/01/1993 – 31/12/2023	6.96	7.86	2.39

Figure 3 : Corrélation entre les vitesses de vent moyennes journalières mesurées sur site à 120 m (en bleu) et les données de référence ERA5 (en rouge)



4.3.2. Corrélation des données

Les rapports de corrélation entre les données ERA5 et les données mesurées à 80 et à 120 m sont illustrés aux annexes 3 et 4. Les coefficients de corrélation et les fonctions de transfert sont fournis aux tableaux 8 et 9 pour chaque direction de vent, à 80 m et à 120 m.

Tableau 8 : Coefficient de corrélation et de régression linéaire par secteur (Lidar à 80 m – ERA5)

DIRECTION VENT (DEGRES)	# DONNEES DISPONIBLES	COEFFICIENT R²	OFFSET	PENTE
345-15	432	0.73	0.24	0.84
15-45	822	0.73	-0.25	0.97
45-75	720	0.75	-0.06	1.03
75-105	330	0.73	0.25	0.99
105-135	401	0.72	0.63	0.91
135-165	553	0.74	0.93	0.78
165-195	1335	0.79	0.41	0.85
195-225	2819	0.85	0.25	0.87
225-255	2569	0.84	0.76	0.81
255-285	1183	0.81	0.87	0.81
285-315	557	0.76	0.67	0.81
315-345	398	0.58	1.05	0.72

Tableau 9 : Coefficient de corrélation et de régression linéaire par secteur (Lidar à 120 m – ERA5)

DIRECTION VENT (DEGRES)	# DONNEES DISPONIBLES	COEFFICIENT R²	OFFSET	PENTE
345-15	426	0.71	0.46	0.89
15-45	815	0.73	-0.41	1.09
45-75	727	0.74	-0.34	1.18
75-105	319	0.76	-0.18	1.19
105-135	400	0.75	0.16	1.08
135-165	553	0.78	0.51	0.96
165-195	1332	0.80	0.58	0.95
195-225	2813	0.86	0.58	0.95
225-255	2554	0.85	0.96	0.90

5. RÉSULTATS

Les résultats de l'étude se rapportent à une année normale de vent qui est représentative du climat moyen pendant la durée d'exploitation du parc éolien.

5.1. CLIMAT LOCAL DE VENT

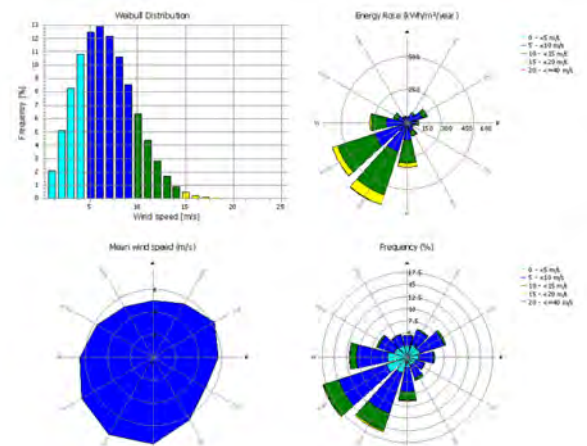
Le climat local de vent a été calculé à hauteur de nacelle des éoliennes en projet. La distribution Weibull des vitesses de vent et la rose des vents utilisées pour caractériser le climat de vent sont illustrées à l'emplacement de l'éolienne E3 en projet, à une altitude de 95 m au-dessus du sol (figure n°4).

Les graphiques indiquent que les vents dominants proviennent des secteurs sud-ouest et que les vents les plus fréquents ont une force moyenne proche de 6.0 m/s.

Tableau 11 : Vitesse moyenne et distribution des vitesses long terme (éolienne E3)

HAUTEUR (M)	VITESSE MOYENNE (M/S)	PARAMÈTRE WEIBULL A	PARAMÈTRE WEIBULL K
93	6.56	7.40	2.342
94	6.57	7.42	2.342
95	6.59	7.44	2.346

Figure 4 : Distribution des vitesses et rose énergétique à 95 m – Eolienne E3



5.2. DENSITÉ DE L'AIR

La densité de l'air a été calculée à hauteur de mât et à l'emplacement des éoliennes, à partir d'une extrapolation des températures mesurées sur site et de l'altitude du site. La densité moyenne sur le site s'élève 1.21 kg/m³ à une altitude de 95 mètres au-dessus du sol.

5.3. PRODUCTION ÉLECTRIQUE DU PROJET ÉOLIEN

La production électrique générée par le projet éolien a été calculée à partir des distributions de vitesses à hauteur de mât combinée à la courbe de puissance de l'éolienne.

Les résultats présentés au tableau 12 indiquent :

- La production électrique annuelle brute ; qui correspond à l'énergie produite par le parc éolien sans aucune pertes. Il s'agit d'une production théorique idéale.
- Les pertes de production systématiques ; qui sont décrites à la section 5.4.
- La production électrique annuelle nette ; qui est égale à la production électrique brute moins l'ensemble des pertes de production systématiques.
- L'indicateur « heures équivalent pleine charge » ; qui est égal au nombre d'heures pendant lesquelles l'éolienne devrait tourner à puissance nominale pour atteindre la production électrique nette.
- L'indicateur « facteur de charge » ; qui est le rapport entre l'énergie électrique nette produite par l'éolienne sur une période donnée et l'énergie qu'elle aurait produit si elle avait fonctionné à sa puissance nominale durant la même période.

Tableau 12 : Perspectives de production du projet éolien à Nivelles

Modèle d'éoliennes	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
Nombre d'éoliennes	6	6	6
Diamètre du rotor (m)	114	112	110
Hauteur d'axe (m)	93	94	95
Hauteur totale (m)	150	150	150
Puissance éolienne (MW)	2.6	3.3	2.2
Puissance installée du parc (MW)	15.6	19.8	13.2
Production électrique P50 brute (MWh/an)	52,777	54,340	47,881
Pertes systématiques cumulées (%)	9.6%	9.6%	9.4%
Production électrique P50 nette (MWh/an), Sans bridage	47,723	49,108	43,380
Facteur de charge (%)	34.9%	28.3%	37.5%
Heures équivalent pleine charge (h)	3,059	2,480	3,286

Tableau 13 : Pertes de production systématiques (en % de la production électrique brute)

Types de pertes	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
Effet de sillages (%)	3.8%	3.9%	3.6%
Intra parc	2.5%	2.5%	2.4%
Extra parc	1.3%	1.4%	1.3%
Indisponibilité éolienne(%)	3.0%	3.0%	3.0%
Indisponibilité raccordement %	0.3%	0.3%	0.3%
Indisponibilité réseau électrique(%)	0.3%	0.3%	0.3%
Pertes électriques (%)	2.0%	2.0%	2.0%
Pertes dues à la formation de glace (%)	0.5%	0.5%	0.5%
Hystérèse par vent fort (%)	0.0%	0.0%	0.0%
Autres pertes	0.0%	0.0%	0.0%
Pertes systématiques calculées (%)	9.6%	9.6%	9.4%

Les pertes de production sont converties en efficacité, par exemple une perte de 3 % est convertie en une efficacité de 97 % (=100%-3%). Ceci est fait pour l'ensemble de pertes considérées et pour chaque éolienne. Les différentes pertes sont finalement combinées en multipliant leur efficacité respective ce qui permet de calculer l'efficacité totale de chaque éolienne et du parc. La production nette s'obtient en multipliant l'efficacité totale par la production brute.

Les effets de sillages représentent les pertes induites par les éoliennes du parc entre elles (pertes de sillages intra-parc) ainsi que les pertes induites par les éoliennes des parcs voisins autorisés, en fonction et en projet (pertes de sillages extra-parc).

5.5. PRODUCTION ÉLECTRIQUE DÉTAILLÉE PAR ÉOLIENNE

Les productions électriques nettes et les pertes de sillage sont détaillées au tableau suivant pour les éoliennes en projet. Les pertes de sillage sont exprimées en pourcentage de la production électrique brute de l'éolienne.

Tableau 14 : Production électrique nette, vitesse moyenne et pertes de sillage détaillées par éolienne (Siemens Gamesa SG114 2.6 MW)

Modèle	Siemens Gamesa SG114 2.6 MW			
	Production nette (MWh/an)	Pertes sillage (%) Intra-parc	Pertes de sillages extra parc (%)	Vitesse du vent à hauteur de mât (m/s)
E1	8,199	1.1%	0.9%	6.65
E2	8,049	2.5%	1.0%	6.63
E3	7,842	2.8%	1.1%	6.56
E4	8,020	2.9%	1.4%	6.65
E5	7,766	3.8%	1.8%	6.59
E6	7,848	2.0%	1.7%	6.56

5.4. PERTES DE PRODUCTION SYSTÉMATIQUES

La production électrique nette est obtenue en déduisant les pertes de production systématiques de la production brute. Ces pertes ont soit été calculées, soit estimées sur base d'hypothèses réalistes :

- Effet de sillages entre éoliennes:** Pertes d'énergie liées à la diminution de l'énergie cinétique du vent en aval de l'éolienne. Les pertes de sillage ont été calculées sur le logiciel WINDPRO, avec le modèle de calcul NO Jensen PARK2 2018. Les pertes ont été calculées en tenant compte des 6 éoliennes en projet (effets de sillages intra-parc), ainsi que des parcs voisins en fonction, autorisé et en projet (effets de sillages extra-parc).
- Indisponibilité technique de l'éolienne:** Pertes de production liées aux arrêts de l'éolienne qui sont dus à la maintenance préventive ou corrective ou à des incidents techniques. Ces pertes peuvent être comparées avec les garanties de disponibilité offertes par les constructeurs qui avoisinent généralement les 97 % par an et par parc éolien (en termes de temps et non d'énergie). Ces pertes ont été estimées.
- Indisponibilité du raccordement électrique:** Pertes de production dues aux périodes d'indisponibilité de la cabine de tête, de la tête de ligne et/ou à la ligne de raccordement jusqu'au réseau électrique. Une perte standard de 0.3 %, correspondant à 24 heures d'indisponibilité par an, a été appliquée.
- Indisponibilité du réseau électrique:** Pertes de production dues aux périodes d'indisponibilité du réseau électrique. Une perte standard de 0.3 %, correspondant à 24 heures d'indisponibilité par an, a été appliquée.
- Pertes électriques:** Pertes liées au transformateur de l'éolienne et les pertes de transport jusqu'au compteur du producteur. Ces pertes ont été estimées : pertes liées au transformateur (-1%) + pertes câbles (-1%).
- Pertes liées à la formation de glace:** Pertes de production dues à une diminution des performances et mises à l'arrêt de l'éolienne suite à l'accumulation de glace sur les pales de l'éolienne. Une perte standard de 0.5% a été appliquée (système de détection classique).
- Hystérèse par vent fort:** Pertes de production lors des cycles de mises à l'arrêt et de redémarrage de l'éolienne pour les vitesses de vent proches de la vitesse de coupure de l'éolienne. D'après la distribution des vitesses de vent calculée, ces pertes peuvent être négligées.
- Contrôle de charge :** Pertes de production liées au contrôle de charge mis en place sur une ou plusieurs éoliennes du projet afin de respecter ses limites de conception. Ce contrôle de charge peut être réalisé en appliquant une régulation par secteur (wind sector management ou gestion par secteur) ou en modulant la vitesse de coupure de l'éolienne. Aucune restriction n'a été considérée pour ce projet.

Tableau 15 : Production électrique nette, vitesse moyenne et pertes de sillage détaillées par éolienne (Vestas V112 3.3 MW)

Modèle	Vestas V112 3.3 MW			
	Production nette (MWh/an)	Pertes sillage (%) Intra-parc	Pertes de sillages extra parc (%)	Vitesse du vent à hauteur de mât (m/s)
E1	8,458	1.0%	1.0%	6.66
E2	8,291	2.5%	1.0%	6.65
E3	8,055	2.8%	1.1%	6.57
E4	8,256	2.9%	1.5%	6.67
E5	7,968	4.0%	1.9%	6.61
E6	8,081	1.9%	1.7%	6.57

Tableau 16 : Production électrique nette, vitesse moyenne et pertes de sillage détaillées par éolienne (Vestas V110 2.2 MW)

Modèle	Vestas V110 2.2 MW			
	Production nette (MWh/an)	Pertes sillage (%) Intra-parc	Pertes de sillages extra parc (%)	Vitesse du vent à hauteur de mât (m/s)
E1	7,439	1.0%	0.9%	6.68
E2	7,312	2.4%	0.9%	6.67
E3	7,136	2.7%	1.0%	6.59
E4	7,289	2.7%	1.4%	6.68
E5	7,072	3.5%	1.8%	6.62
E6	7,132	1.9%	1.6%	6.59

5.6. PERTES DE PRODUCTION INDUITES PAR LES DIRECTIVES DE BRIDAGE

Les scénarios de bridage définis dans l'étude d'incidences ont été pris en compte dans cette étude afin d'évaluer leur impact sur la production du parc éolien :

- Bridage acoustique** afin de respecter les normes de bruit selon les conditions sectorielles 2021 applicables aux parcs éoliens de plus de 0.5 MW ;
- Module d'arrêt chauve-souris** afin d'arrêter l'éolienne pendant les périodes d'activité chiroptérologique ;
- Module d'arrêt ombre portée** afin d'arrêter l'éolienne lorsque l'ombre portée cause une gêne au voisinage ;
- Bridage cumulatif** lorsque l'ensemble des programmes de bridage (acoustique, module d'arrêt chauve-souris et ombre) sont d'application.

Les consignes de bridage transmises par CSD sont fournies à l'annexe 7 du rapport ainsi que la méthode de calcul pour évaluer les pertes de production. Les pertes de production induites par les programmes de bridage sont indiquées au tableau suivant.

Tableau 17 : Impact des programmes de bridage sur les perspectives de production du projet

Modèle d'éoliennes	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
Production électrique P50 nette (MWh/an), Sans bridage	47,723	49,108	43,380
Avec bridage acoustique (conditions sectorielles 2021) :			

Modèle d'éoliennes	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
Production électrique P50 nette (MWh/an)	47,568	48,907	41,559
Pertes bridage (%)	0.3%	0.4%	4.2%
Avec module d'arrêt chauve-souris :			
Production électrique P50 nette (MWh/an)	46,567	48,075	42,277
Pertes bridage (%)	2.4%	2.1%	2.5%
Avec module d'arrêt ombre :			
Production électrique P50 nette (MWh/an)	47,718	49,102	43,375
Pertes bridage (%)	0.0%	0.0%	0.0%
Avec bridage cumulé (acoustique conditions sectorielles 2021 + chauve-souris + ombre) :			
Production électrique P50 nette (MWh/an)	46,410	47,873	40,498
Pertes bridage (%)	2.8%	2.5%	6.6%

5.7. IMPACT DU PROJET SUR LES PARCS VOISINS

L'impact du projet sur les parcs voisins en fonction, autorisé et en projet, situés à ~5 km a été évalué en analysant les effets de sillages supplémentaires générés par la nouvelle éolienne. Les pertes de sillage ont été calculées sur le logiciel WINDPRO, avec le modèle de calcul NO Jensen PARK2. La méthodologie utilisée pour évaluer les pertes de production générées par le projet sur les éoliennes voisines consiste à calculer la production hypothétique de ces dernières sans le projet de Renner Energies et de la comparer avec sa production lorsque les éoliennes du projet sont prises en considération.

Les résultats exprimés en pourcentage de la production brute des éoliennes sont indiqués au tableau suivant en fonction du modèle d'éolienne considéré pour le projet de Renner Energies. La numérotation des éoliennes est identique à celle du tableau repris en Annexe 1.

Tableau 18 : Impact des différents modèles d'éoliennes retenus pour le projet de Renner Energies à Nivelles sur les parcs voisins

N°	Modèle d'éolienne	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
Parcs autorisés				
1	Genappe – Glabais – E1	2.8%	2.9%	2.6%
2	Genappe – Glabais – E2	1.7%	1.8%	1.5%
3	Genappe – Glabais – E3	2.0%	2.0%	1.8%
4	Genappe – Glabais – E4	1.2%	1.3%	1.1%
5	Genappe – Glabais – E5	1.1%	1.2%	1.0%
6	Braine l'Alleud – E1	0.1%	0.1%	0.1%
7	Braine l'Alleud – E2	0.1%	0.1%	0.1%
Parc en fonction				
8	Nivelles - Rossel	0.2%	0.2%	0.2%
Parcs en projet				
9	Nivelles (R24) - E1	0.2%	0.2%	0.2%
10	Nivelles (R24) - E2	0.2%	0.1%	0.1%
11	Nivelles (R24) - E3	0.1%	0.1%	0.1%

N°	Modèle d'éolienne	Siemens Gamesa SG114 2.6 MW	Vestas V112 3.3 MW	Vestas V110 2.2 MW
12	Ittre - E1	0.0%	0.0%	0.0%
13	Ittre - E2	0.0%	0.0%	0.0%
14	Ittre - E3	0.1%	0.1%	0.1%
15	Ittre - E4	0.1%	0.1%	0.1%
16	Ittre - E5	0.1%	0.1%	0.1%

6. CONCLUSIONS

Le climat de vent et la production annuelle du projet éolien de Renner Energies à Nivelles ont été évalués à partir d'un modèle d'écoulement du vent alimenté par des données de vent mesurées sur site pendant 18 mois à l'aide d'un LIDAR.

Les résultats de cette étude se rapportent à une année de vent normale, c.à.d. une année représentative du climat moyen pendant la durée d'exploitation du parc éolien.

A 95 m d'altitude, la vitesse moyenne du vent s'élève à 6.59 m/s (au niveau de l'éolienne E3) avec des vents dominants du secteur sud-ouest.

Les pertes de production liées aux directives de bridages cumulés varient entre 2.5% et 6.6%, selon le modèle étudié.

La production électrique annuelle nette supplémentaire générée par le projet de Renner Energies à Nivelles s'élève, en appliquant l'ensemble des directives de bridage cumulés à :

- **46.4 GWh** avec 6 éoliennes Siemens Gamesa SG114 2.6 MW;
- **47.9 GWh** avec 6 éoliennes Vestas V112 3.3 MW ;
- **40.5 GWh** avec 6 éoliennes Vestas V110 2.2 MW.

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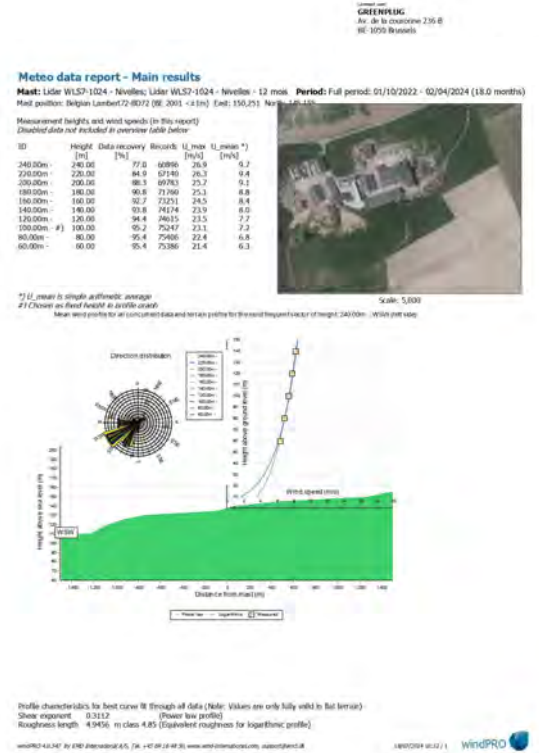
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ANNEXES

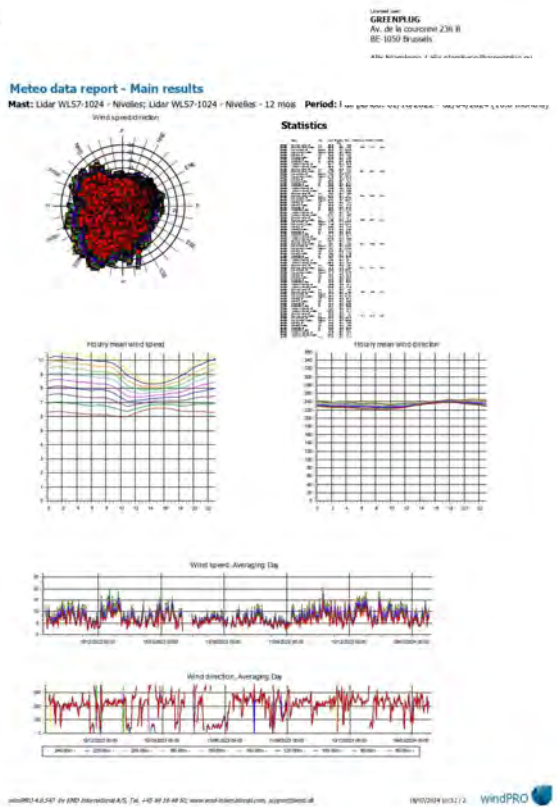
ANNEXE 1 – LISTE DES PARCS VOISINS

IDENTIFIANT	COORDONNEES X	COORDONNEES Y	STATUT	NOM	PROMOTEUR	MODELE	HAUTEUR TOTALE
1	153,104	145,686	Autorisé	Genappe – Glabais – E1	New Wind/Renner Energies	Siemens Gamesa SG132 5.0 MW	150 m
2	153,589	145,919	Autorisé	Genappe – Glabais – E2	New Wind/Renner Energies	Siemens Gamesa SG132 5.0 MW	150 m
3	153,583	145,236	Autorisé	Genappe – Glabais – E3	New Wind/Renner Energies	Siemens Gamesa SG132 5.0 MW	150 m
4	154,150	145,744	Autorisé	Genappe – Glabais – E4	New Wind/Renner Energies	Siemens Gamesa SG132 5.0 MW	150 m
5	154,232	145,249	Autorisé	Genappe – Glabais – E5	New Wind/Renner Energies	Siemens Gamesa SG132 5.0 MW	150 m
6	146,347	149,837	Autorisé	Braine l'Alleud – E1	Aspiravi	Vestas V100 2.0 MW	150 m
7	146,049	149,425	Autorisé	Braine l'Alleud – E2	Aspiravi	Vestas V100 2.0 MW	150 m
8	146,819	146,175	Exploité	Nivelles - Rossel	Luminus	Enercon E92 2.3 MW	130 m
9	148,952	141,921	Projet	Nivelles (R24) - E1	Engie/Eoly	Vestas V117 4.0 MW	150 m
10	148,726	141,558	Projet	Nivelles (R24) - E2	Engie/Eoly	Vestas V117 4.0 MW	150 m
11	148,921	140,848	Projet	Nivelles (R24) - E3	Engie/Eoly	Vestas V117 4.0 MW	150 m
12	144,709	147,919	Projet	Ittre - E1	Vents d'Houyet	Nordex N117 3.6 MW	149.4 m
13	145,077	147,744	Projet	Ittre - E2	Vents d'Houyet	Nordex N117 3.6 MW	149.4 m
14	145,421	147,520	Projet	Ittre - E3	Vents d'Houyet	Nordex N117 3.6 MW	149.4 m
15	145,763	147,283	Projet	Ittre - E4	Vents d'Houyet	Nordex N117 3.6 MW	149.4 m
16	146,326	146,977	Projet	Ittre - E5	Vents d'Houyet	Nordex N117 3.6 MW	149.4 m

ANNEXE 2 – ANALYSE DES MESURES VENT



ANNEXE 3 – CORRÉLATION MCP (80 M)



ANNEXE 6 – COURBES DES PUISSANCE

Tableau 19 : Siemens Gamesa SG114 2.6 MW

WIND SPEED (M/S)	POWER (kW)	
	MODE 0	MODE N2 (102.0 B)
3	36	36
4	137	137
5	326	326
6	607	607
7	1000	996
8	1504	1464
9	2038	1901
10	2412	2164
11	2569	2261
12	2613	2298
13	2623	2357
14	2625	2448
15	2625	2532
16	2625	2585
17	2625	2609
18	2625	2619
19	2625	2623
20	2625	2624
21	2625	2625
22	2394	2394
23	2163	2163
24	1931	1931
25	1700	1700

Tableau 20 : Vestas V112 3.3 MW

WIND SPEED (M/S)	POWER (kW)	
	MODE 0	MODE SO3 (101.3 dB)
3	22	22
3.5	73	73
4	134	134
4.5	209	209
5	302	302
5.5	415	415
6	552	552
6.5	714	714
7	906	903
7.5	1123	1109
8	1370	1330
8.5	1648	1564
9	1950	1795
9.5	2268	2015
10	2586	2219
10.5	2868	2416
11	3071	2593
11.5	3201	2749
12	3266	2864
12.5	3291	2944
13	3298	3004
13.5	3299	3056
14	3300	3099

WIND SPEED (M/S)	POWER (kW)	
	MODE 0	MODE SO3 (101.3 dB)
14.5	3300	3129
15	3300	3145
15.5	3300	3158
16	3300	3166
16.5	3300	3172
17	3300	3175
17.5	3300	3177
18	3300	3178
18.5	3300	3178
19	3300	3178
19.5	3300	3178
20	3300	3178
20.5	3300	3178
21	3300	3178
21.5	3300	3178
22	3300	3178
22.5	3300	3178
23	3300	3178
23.5	3300	3178
24	3300	3178
24.5	3300	3178
25	3300	3178

Tableau 21 : Vestas V110 2.2 MW

WIND SPEED (M/S)	POWER (kW)		
	MODE 0	MODE 1 (103.8 dB)	MODE 2 (100.6 dB)
3	37	35	38
3.5	90	86	90
4	156	151	155
4.5	235	229	233
5	330	322	328
5.5	444	433	442
6	567	554	574
6.5	735	716	741
7	928	899	930
7.5	1146	1088	1082
8	1382	1268	1137
8.5	1620	1429	1148
9	1843	1570	1150
9.5	2016	1680	1150
10	2123	1759	1150
10.5	2173	1808	1150
11	2191	1836	1150
11.5	2198	1858	1150
12	2200	1874	1150
12.5	2200	1885	1150
13	2200	1893	1150
13.5	2200	1898	1150
14	2200	1901	1150
14.5	2200	1903	1150
15	2200	1904	1150
15.5	2200	1904	1150
16	2200	1904	1150
16.5	2200	1905	1150
17	2200	1905	1150
17.5	2200	1905	1150
18	2200	1905	1150
18.5	2200	1905	1150
19	2200	1905	1150
19.5	2200	1905	1150
20	2200	1905	1150

ANNEXE 7 – IMPACT DES PROGRAMMES DE BRIDAGE SUR LA PRODUCTION DU PROJET

Le calcul des pertes de production induites par les consignes de bridage acoustique et le système d'arrêt chauve-souris & ombre est détaillé dans cette annexe.

A. Bridage acoustique

Consignes de bridage

Le bureau d'étude en charge de l'étude d'incidences a évalué la mise en place de bridages acoustiques sur les éoliennes afin de respecter les normes sonores prévues dans les conditions sectorielles 2021 relatives au parc éolien de plus de 0.5 MW. Les valeurs limites générales de niveaux de bruit sont reprises au Tableau 22.

Tableau 22 : Résumé des normes de bruit dB(A) selon les conditions sectorielles 2021

	ZONE D'IMMISSION			
	JOUR	TRANSITION	NUIT	
CONDITIONS SECTORIELLES 2021	Zone habitat et habitat à caractère rural	45	45	43
	Zones agricoles, forestières, d'espaces verts, naturelles et de parcs	45	45	43
	Toutes zones, y compris les zones visées ci-avant, lorsque le point de mesure est situé à moins de 500 m de la zone d'extraction, d'activité économique industrielle ou spécifique, ou à moins de 200 m de la zone d'activité économique mixte dans laquelle est totalement situé le parc éolien	55	50	45
	Zones de loisirs, de services publics et d'équipements communautaires	55	50	45

Tableau 23 : Programmes de bridages acoustiques définis par le bureau d'étude d'incidence

Conditions Sectorielles 2021				
Modèle		Période		
		Jour	Transition	Nuit
Siemens Gamesa SG114 2.6 MW	E1	Pas de bridages	Pas de bridages	Pas de bridages
	E2	Pas de bridages	Pas de bridages	Pas de bridages
	E3	Pas de bridages	Pas de bridages	Pas de bridages
	E4	Pas de bridages	Pas de bridages	Mode N2 – 102 dB
	E5	Pas de bridages	Pas de bridages	Pas de bridages
	E6	Pas de bridages	Pas de bridages	Pas de bridages
Vestas V112 3.3 MW	E1	Pas de bridages	Pas de bridages	Pas de bridages
	E2	Pas de bridages	Pas de bridages	Pas de bridages
	E3	Pas de bridages	Pas de bridages	Pas de bridages
	E4	Pas de bridages	Pas de bridages	Mode 3 – 101.3 dB
	E5	Pas de bridages	Pas de bridages	Pas de bridages
	E6	Pas de bridages	Pas de bridages	Pas de bridages
Vestas V110 2.2 MW	E1	Pas de bridages	Pas de bridages	Pas de bridages
	E2	Pas de bridages	Pas de bridages	Pas de bridages

Conditions Sectorielles 2021			
Modèle	Période		
	Jour	Transition	Nuit
E3	Pas de bridages	Pas de bridages	Pas de bridages
E4	Mode 1 – 103.8 dB	Mode 1 – 103.8 dB	Mode 2 – 100.6 dB
E5	Pas de bridages	Pas de bridages	Mode 2 – 100.6 dB
E6	Pas de bridages	Pas de bridages	Pas de bridages

Hypothèses

Sur base des consignes de bridage, on détermine la durée effective de chaque période de bridage auquel on fait correspondre l'utilisation d'une courbe de puissance bridée.

Les courbes de puissance bridées proviennent des fiches techniques fournies par les constructeurs et sont reprises à l'annexe 3. Pour chaque éolienne, on applique le mode de bridage le plus contraignant à toutes les plages de vitesse, ce qui est conservatif au niveau du calcul de pertes. Lorsque le mode de bridage n'est pas disponible auprès du constructeur, nous considérons l'arrêt de l'éolienne.

On considère les distributions de vitesses du vent calculées à hauteur de nacelle de l'éolienne par le modèle WAsP. On ne prend pas en compte un régime de vent différent pour les périodes où l'éolienne est bridée par rapport à la normale annuelle.

La durée des différentes périodes de bridage selon les conditions sectorielles 2021 est décrite ci-après :

- Période de jour : 42 % de l'année
- Période de transition : 25 % de l'année
- Période de nuit : 33 % de l'année

Résultats

Les résultats de production, avec et sans bridage acoustique, sont présentés aux tableaux suivants pour les 3 modèles d'éoliennes étudiés.

Tableau 24 : Impact du bridage acoustique sur la production électrique nette MWh/an du parc en projet (Siemens Gamesa SG114 2.6 MW)

EOLIENNES	SANS BRIDAGE ACOUSTIQUE	AVEC BRIDAGE CONDITIONS SECTORIELLES	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)
E1	8,199	8,199	0.0%
E2	8,049	8,049	0.0%
E3	7,842	7,842	0.0%
E4	8,020	7,864	1.9%
E5	7,766	7,766	0.0%
E6	7,848	7,848	0.0%

Tableau 25 : Impact du bridage acoustique sur la production électrique nette MWh/an du parc en projet (Vestas V112 3.3 MW)

EOLIENNES	SANS BRIDAGE ACOUSTIQUE	AVEC BRIDAGE CONDITIONS SECTORIELLES	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)
E1	8,458	8,459	0.0%
E2	8,291	8,291	0.0%
E3	8,055	8,056	0.0%
E4	8,256	8,051	2.5%
E5	7,968	7,969	0.0%
E6	8,081	8,081	0.0%

Tableau 26 : Impact du bridage acoustique sur la production électrique nette MWh/an du parc en projet (Vestas V110 2.2 MW)

EOLIENNES	SANS BRIDAGE ACOUSTIQUE	AVEC BRIDAGE CONDITIONS SECTORIELLES	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)
E1	7,439	7,439	0.0%
E2	7,312	7,312	0.0%
E3	7,136	7,136	0.0%
E4	7,289	6,101	16.3%
E5	7,072	6,437	9.0%
E6	7,132	7,132	0.0%

B. Module d'arrêt chauve-souris

Consignes de bridage

Un système d'arrêt sur l'ensemble des éoliennes du projet est recommandé durant les périodes d'activité chiroptérologique significative. Les conditions d'arrêt ont été transmises par le bureau CSD en charge de l'étude d'incidences :

Arrêt des éoliennes en projet dans les conditions cumulatives suivantes :

Période A : Du 1er avril au 31 juillet et du 16 octobre au 31 octobre de chaque année :

- Du coucher du soleil jusqu'à 6 h après ;
- Lorsque la vitesse du vent est inférieure à 6 m/s à hauteur de la nacelle;
- Lorsque la température de l'air au sol est supérieure à 10°C;
- En l'absence de précipitations.

Période B : Du 1 août au 15 octobre de chaque année :

- Entre l'heure du coucher du soleil et l'heure du lever du soleil ;
- Lorsque la vitesse du vent est inférieure à 7 m/s à hauteur de la nacelle;
- Lorsque la température de l'air au sol est supérieure à 8°C;
- En l'absence de précipitations.

Hypothèses

Sur base des consignes présentées ci-dessus, on détermine la durée effective de chaque période de bridage auquel on fait correspondre l'utilisation d'une courbe de puissance bridée. Pour la période A, on utilise une courbe de puissance bridée avec une vitesse de démarrage à 6 m/s et pour la période B, une courbe avec une vitesse de démarrage de 7 m/s.

On considère les distributions de vitesses du vent calculées à hauteur de nacelle de l'éolienne par le modèle WAsP et données au paragraphe 4.1. On ne prend pas en compte un régime de vent différent durant les périodes d'arrêt de l'éolienne par rapport à la normale annuelle. Il s'agit d'une approche conservatrice au niveau du calcul des pertes, les périodes de bridage étant en moyenne moins ventées (période estivale) que la normale annuelle.

La durée effective de chaque période est évaluée en considérant :

- les heures des levés et couchers du soleil provenant de la station d'Uccle représentatives pour le site étudié
- les données horaires de température provenant de la station météorologique de Beauvechain. On fait l'hypothèse que ces mesures de température sont représentatives des températures sur le site
- qu'il ne pleut jamais ce qui constitue une approche maximaliste en terme de pertes. Nous ne disposons pas de mesures locales de précipitations. A titre indicatif, le niveau normal de précipitations mesuré à Uccle s'élève à 850 mm par an. En considérant une pluie de faible intensité (2 mm d'eau par heure), on estime à 425 h le nombre heures par an où il pleut, soit 4.2 % du temps. L'impact du critère de précipitation sur la mise à l'arrêt de l'éolienne est considéré comme faible.

D'après les calculs, réalisés heure par heure, le module d'arrêt auquel correspond l'utilisation d'une courbe de puissance bridée sera actif :

- Période A : 6.3 % de l'année
- Période B : 8.7 % de l'année

Les calculs ne tiennent pas compte du régime transitoire de fonctionnement de l'éolienne lors des cycles de démarrage/arrêt imposés par le système de régulation chauve-souris.

Résultats

Les résultats de production, sans et avec système d'arrêt chiro, sont présentés aux tableaux suivants.

Tableau 27 : Impact du système d'arrêt chiro sur la production électrique nette MWh/an du parc en projet (Siemens Gamesa SG114 2.6 MW)

EOLIENNES	SANS SYSTEME D'ARRÊT CHIRO	AVEC SYSTEME D'ARRÊT CHIRO	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	8,199	8,009	2.3%
E2	8,049	7,858	2.4%
E3	7,842	7,648	2.5%
E4	8,020	7,827	2.4%
E5	7,766	7,568	2.5%

EOLIENNES	SANS SYSTEME D'ARRÊT CHIRO	AVEC SYSTEME D'ARRÊT CHIRO	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E6	7,848	7,656	2.4%

Tableau 28 : Impact du système d'arrêt chiro sur la production électrique nette MWh/an du parc en projet (Vestas V112 3.3 MW)

EOLIENNES	SANS SYSTEME D'ARRÊT CHIRO	AVEC SYSTEME D'ARRÊT CHIRO	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	8,458	8,289	2.0%
E2	8,291	8,121	2.1%
E3	8,055	7,881	2.2%
E4	8,256	8,083	2.1%
E5	7,968	7,791	2.2%
E6	8,081	7,910	2.1%

Tableau 29 : Impact du système d'arrêt chiro sur la production électrique nette MWh/an du parc en projet (Vestas V110 2.2 MW)

EOLIENNES	SANS SYSTEME D'ARRÊT CHIRO	AVEC SYSTEME D'ARRÊT CHIRO	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	7,439	7,258	2.4%
E2	7,312	7,131	2.5%
E3	7,136	6,950	2.6%
E4	7,289	7,105	2.5%
E5	7,072	6,883	2.7%
E6	7,132	6,949	2.6%

C. Module d'arrêt ombre portée

Consignes de bridages

Des dépassements de valeurs limites (30h/an et 30 min/jour) sont observés en situation réaliste au niveau de plusieurs récepteurs. Un système d'arrêt pour limiter l'effet de gêne liée à l'ombre portée des éoliennes et respecter les seuils d'ombrage est donc recommandé. La durée d'arrêt a été estimée par CSD en situation réaliste pour le projet sur l'ensemble des éoliennes.

Tableau 30 : Module d'arrêt pour ombre portée

EOLIEUNE	NOMBRE ANNUEL D'HEURES D'ARRÊT
E1	<1h
E2	<1h
E3	<1h
E4	<1h
E5	<1h
E6	<1h

Hypothèses

Sur base des consignes présentées ci-dessus, on détermine le pourcentage de temps de l'année durant laquelle l'éolienne doit être arrêtées.

On considère les distributions de vitesses du vent calculées à hauteur de nacelle de l'éolienne par le modèle WAsP et données à la section 4.1. On ne prend pas en compte un régime de vent différent durant les périodes d'arrêt de l'éolienne par rapport à la normale annuelle ce qui revient à supposer que les pertes d'énergie sont directement proportionnelles à la durée cumulée des arrêts de l'éolienne.

Résultats

Les pertes de production induites par le système d'arrêt ombre sont mises en évidence aux tableaux suivants.

Tableau 31 : Impact du système d'arrêt ombre sur la production électrique nette MWh/an du parc en projet (Siemens Gamesa SG114 2.6 MW)

ÉOLIENNES	SANS SYSTEME D'ARRÊT OMBRE	AVEC SYSTEME D'ARRÊT OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	8,199	8,198	0.0%
E2	8,049	8,048	0.0%
E3	7,842	7,841	0.0%
E4	8,020	8,019	0.0%
E5	7,766	7,765	0.0%
E6	7,848	7,847	0.0%

Tableau 32 : Impact du système d'arrêt ombre sur la production électrique nette MWh/an du parc en projet (Vestas V112 3.3 MW)

ÉOLIENNES	SANS SYSTEME D'ARRÊT OMBRE	AVEC SYSTEME D'ARRÊT OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	8,458	8,457	0.0%
E2	8,291	8,290	0.0%
E3	8,055	8,054	0.0%
E4	8,256	8,255	0.0%
E5	7,968	7,967	0.0%
E6	8,081	8,080	0.0%

Tableau 33 : Impact du système d'arrêt ombre sur la production électrique nette MWh/an du parc en projet (Vestas V110 2.2 MW)

ÉOLIENNES	SANS SYSTEME D'ARRÊT OMBRE	AVEC SYSTEME D'ARRÊT OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	7,439	7,438	0.0%
E2	7,312	7,311	0.0%

ÉOLIENNES	SANS SYSTEME D'ARRÊT OMBRE	AVEC SYSTEME D'ARRÊT OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E3	7,136	7,135	0.0%
E4	7,289	7,288	0.0%
E5	7,072	7,071	0.0%
E6	7,132	7,132	0.0%

D. Combinaison bridage acoustique & module d'arrêt chauve-souris & ombre

Hypothèses

On fait l'hypothèse conservatrice que les pertes ne se recouvrent pas mais se cumulent. Les pertes de production sont converties en efficacité, par exemple une perte de 3 % est convertie en une efficacité de 97 % (=100%-3%). Ceci est fait pour l'ensemble de pertes considérées. Les différentes pertes sont finalement combinées en multipliant leur efficacité respective ce qui permet de calculer l'efficacité totale du parc : Efficacité cumulée = Efficacité Bridage Acoustique x Efficacité Module Arrêt Chauve-Souris x Efficacité Module arrêt ombre.

Résultats

Les pertes de production induites par les programmes de bridage cumulés sont indiquées aux tableaux suivants.

Tableau 34 : Impact des systèmes de bridages cumulés sur la production électrique nette MWh/an du parc en projet (Siemens Gamesa SG114 2.6 MW)

ÉOLIENNES	SANS BRIDAGE	BRIDAGE ACOUSTIQUE (CONDITIONS SECTORIELLES 2021) + CHAUVÉ-SOURIS + OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	8,199	8,008	2.3%
E2	8,049	7,857	2.4%
E3	7,842	7,647	2.5%
E4	8,020	7,675	4.3%
E5	7,766	7,567	2.6%
E6	7,848	7,656	2.5%

Tableau 35 : Impact des systèmes de bridages cumulés sur la production électrique nette MWh/an du parc en projet (Vestas V112 3.3 MW)

ÉOLIENNES	SANS BRIDAGE	BRIDAGE ACOUSTIQUE (CONDITIONS SECTORIELLES 2021) + CHAUVÉ-SOURIS + OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	8,458	8,289	2.0%
E2	8,291	8,120	2.1%
E3	8,055	7,882	2.2%
E4	8,256	7,882	4.5%
E5	7,968	7,791	2.2%

ÉOLIENNES	SANS BRIDAGE	BRIDAGE ACOUSTIQUE (CONDITIONS SECTORIELLES 2021) + CHAUVÉ-SOURIS + OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E6	8,081	7,909	2.1%

Tableau 36 : Impact des systèmes de bridages cumulés sur la production électrique nette MWh/an du parc en projet (Vestas V112 3.3 MW)

ÉOLIENNES	SANS BRIDAGE	BRIDAGE ACOUSTIQUE (CONDITIONS SECTORIELLES 2021) + CHAUVÉ-SOURIS + OMBRE	
	PRODUCTION NETTE (MWh/an)	PRODUCTION NETTE (MWh/an)	PERTES (+) OU GAIN (-) DE PRODUCTION (%)
E1	7,439	7,257	2.4%
E2	7,312	7,130	2.5%
E3	7,136	6,950	2.6%
E4	7,289	5,947	18.4%
E5	7,072	6,265	11.4%
E6	7,132	6,949	2.6%

**ANNEXE C. COURBES D'EMISSION ACOUSTIQUE DES MODELES
D'EOLIENNES CONSIDERES**

Performance specification

V110-2.2 MW 50/60 Hz



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1 General description

The Vestas V110-2.2 MW 50Hz VCS & V110-2.2 MW 60Hz VCS wind turbines are pitch-regulated upwind turbines with active yaw, gearbox, and a three-blade rotor. Both turbines have a rotor diameter of 110 m with a generator rated at 2.2 MW. The turbines utilise a microprocessor pitch control system called OptiTip® and the OptiSpeed™ (variable speed) feature. With these features, the wind turbines are able to operate the rotor at variable speed (rpm), helping to maintain output at or near rated power.

General performance data for this turbine variant are available in the General specification document: 0062-4191

2 Power curve conditions

The power- and Ct curves are given with the conditions stated in the General specification 0062-4191 and in Table 2-1 below.

Conditions for power curve (at hub height)	
Wind shear	0.00-0.30 (10 minute average)
Turbulence intensity	6-12% (10 minute average)
Blades	Clean
Rain	No
Ice/snow on blades	No
Leading edge	No damage
Terrain	IEC 61400-12-1
Inflow angle (vertical)	0 ±2°

Table 2-1: Conditions for power curve

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Original Instruction: T05 0062-4195 VER 00

T05 0062-4195 Ver 00 - Approved - Exported from DMS: 2017-01-04 by MHET

Original Instruction: T05 0062-4195 VER 00

T05 0062-4195 Ver 00 - Approved - Exported from DMS: 2017-01-04 by MHET

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3 Performance

Wind m/s	Power Curve													
	Air density kg/m ³													
	1.225	0.950	0.975	1.000	1.025	1.050	1.075	1.100	1.125	1.150	1.175	1.200	1.250	1.275
3.0	37	24	25	26	27	29	30	31	32	33	34	36	38	39
3.5	90	65	67	69	71	74	76	78	81	83	85	87	92	94
4.0	156	117	121	124	128	131	135	138	142	145	149	152	159	163
4.5	235	180	185	190	195	200	205	210	215	220	225	230	240	245
5.0	330	253	260	267	275	282	289	295	302	309	316	323	337	343
5.5	444	341	351	360	370	379	388	398	407	416	426	435	453	462
6.0	567	431	444	456	469	481	494	506	518	530	543	555	579	591
6.5	735	562	578	593	609	625	641	657	673	688	704	719	750	766
7.0	928	712	732	752	772	792	811	831	851	870	890	909	947	966
7.5	1146	881	905	930	955	979	1003	1028	1052	1076	1099	1122	1169	1192
8.0	1382	1073	1102	1132	1161	1190	1218	1246	1274	1302	1329	1355	1407	1433
8.5	1619	1283	1316	1349	1382	1414	1445	1475	1505	1535	1563	1591	1644	1669
9.0	1817	1500	1534	1568	1602	1636	1664	1692	1720	1748	1771	1794	1836	1856
9.5	1950	1703	1733	1762	1792	1821	1842	1863	1884	1905	1920	1935	1961	1972
10.0	2016	1864	1884	1904	1925	1945	1957	1969	1982	1994	2001	2008	2020	2025
10.5	2038	1966	1977	1988	1999	2010	2015	2021	2026	2031	2033	2035	2040	2041
11.0	2047	2019	2024	2028	2032	2037	2038	2040	2042	2044	2045	2046	2048	2049
11.5	2050	2038	2040	2042	2044	2046	2047	2048	2048	2049	2050	2050	2050	2050
12.0	2050	2046	2047	2048	2049	2050	2050	2050	2050	2050	2050	2050	2050	2050
12.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
13.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
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14.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
14.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
15.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
15.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
16.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
16.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
17.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
17.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
18.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
18.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
19.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
19.5	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
20.0	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050

Table 3-1: V110-2.050 kW noise mode 0, power curve

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Table with columns: Wind m/s, Thrust coefficient, Air density kg/m³, and 12 numerical columns representing performance metrics.

Table 3-2: V110-2.050 kW noise mode 0, Ct values



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Table with columns: Wind m/s, Thrust coefficient, Air density kg/m³, and 12 numerical columns representing performance metrics.

Table 3-4: V110-2.100 kW noise mode 0, Ct values



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Table with columns: Wind m/s, Power Curve, Air density kg/m³, and 12 numerical columns representing performance metrics.

Table 3-3: V110-2.100 kW noise mode 0, power curve



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Table with columns: Wind m/s, Power Curve, Air density kg/m³, and 12 numerical columns representing performance metrics.

Table 3-5: V110-2.150 kW noise mode 0, power curve



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Table with columns: Wind m/s, Thrust coefficient, Air density kg/m³. Rows range from 3.0 to 20.0 m/s and 1.225 to 1.275 kg/m³.

Table 3-6: V110-2.150 kW noise mode 0, Ct values



Table with columns: Wind m/s, Thrust coefficient, Air density kg/m³. Rows range from 3.0 to 20.0 m/s and 1.225 to 1.275 kg/m³.

Table 3-8: V110-2.200 kW noise mode 0, Ct values

Table: Sound Power Level at Hub Height. Includes measurement standard (IEC 61400-11 3rd edition, 2012), max turbulence (16%), inflow angle (0 ± 2°), air density (1.225 kg/m³), and wind shear (0.0-0.4).



Table with columns: Wind m/s, Power Curve, Air density kg/m³. Rows range from 3.0 to 20.0 m/s and 1.225 to 1.275 kg/m³.

Table 3-7: V110-2.200 kW noise mode 0, power curve



Table: Sound power level at hub height. Columns: Wind Speed at Hub Height [m/s], dBA (Standard blade), dBA (with optional STE¹).

Table 3-9: Sound power level at hub height: V110-2.200, 2.150, 2.100 & 2.050 kW,

¹ Serrated Trailing Edge is an optional aero add-on for V110 blades



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RECORD OF CHANGES

Rev.	Date	Author	Description
0	27/07/18	CCORRALES	Initial Version
1	10/10/18	CCORRALES	Updated format
1.1	17/07/2019	JUDLOPEZ	Added 75m tower

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1 AIM

This document presents the power curves and noise emissions associated with the low noise operating modes of the SG 2.6-114 (all classes) wind turbine equipped with noise reduction add-ons attached to the blade.

2 SCOPE

The values in the present document are applicable to all the existing configurations for the SG 2.6-114 wind turbine, **equipped with noise reduction add-ons attached to the blade**, according to tower height. Tonality is not considered. The noise levels given in the document do not apply to high temperature versions.

3 DEFINITIONS AND ACRONYMS

- WT: Wind turbine.
- Power (P): Expressed in kW, this is the electric power obtained at the generator terminals without considering the losses in the transformer or high voltage cables of the wind turbine, or the occasional power consumption which may exist in the same to supply a component. Averaged every 10 minutes.
- Wind speed (Ws): Expressed in m/s, it is the horizontal wind component value at the height of the hub averaged every 10 minutes.
- Power curve (CdP): Represents the change in the P in accordance with the Ws for the different WT operating modes.
- FP: Full power, the power curve without NRS mode activated.
- Annual Output / Annual Energy Production (AEP): Expressed in [MWh], it is the total electrical energy produced in a WT during a one-year period, in accordance with a given CdP and a given wind distribution.
- Wind distribution: the Weibull distribution is used for different K-distribution parameters and for annual average wind speed values (W_{ave}).
- Wind speed W₁₀ [m/s]: The wind speed value, measured at 10m above ground level.
- Tower height (H): expressed in meters, is the height of the rotor centre above ground level.
- Power coefficient: C_p
- Thrust coefficient: C_t
- Noise level: The expected sound power level values, expressed in dB(A), represent the sound power that the WT emits at the height of the hub for a given wind speed. In accordance with the IEC standard, the wind speed value (W₁₀) 10 m from the ground is used.

The noise levels shown in this document are average expected values, called L_w in IEC-61400-14. To obtain the L_{wd} value, as defined in IEC-61400-14, an increase of 2 dB(A) shall be considered over said L_w values.

- dB(A): an A type frequency filter is applied, in accordance with the IEC standard.

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4 DESCRIPTION

When not specified otherwise, data in following sections is calculated using the parameters from Table 1. All power curve and annual energy production values in this document are subject to the validity ranges presented in Table 2.

Rated Power	2.625 MW
Frequency	50Hz/60Hz
Rotor Diameter	114 m
Angle of blade tip	Pitch control regulation
Air density	1.225 kg/m ³

Table 1 Parameter values for calculation of the SG 2.6-114 wind turbine power curve.

Wind Shear (10min average)	≤ 0.3
Turbulence intensity TI [%] for bin i	5% $\frac{(0.75v_i + 5.6)}{v_i} < TI < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow - [°]	-20 ≤ α ≤ +20
Grid frequency [Hz]	± 0.5 Hz

Table 2 Validity ranges of power curves for the SG 2.6-114 wind turbine power curve.

Table 3 presents the ratio of wind speed at hub height W_s [m/s] and wind speed at 10m W₁₀ [m/s], in accordance with standard IEC 61400-11, for a roughness length of 0.05m

Tower height [m]	68	80	88	93	125
Ws / W10 [m/s]	1.36	1.39	1.42	1.43	1.50

Table 3 Ratio between Ws and W10 in accordance with the IEC 61400-11 standard

5 LOW NOISE OPERATION MODES

5.1 LOW NOISE POWER CURVES

There are 2 different types of noise reduction modes.

- The noise reduction modes that limit the noise at higher wind speed (typical W₁₀ – 6-10 m/s) are indicated as N1, N2 up to N6. The noise reduction levels that correspond to the mode indication in this document are represented in table 4 below:

Mode:	FP	N1	N2	N3	N4	N5	N6
Noise level [dB(A)]	104.6	103	102	101	100	99	96.5

Table 4 Noise reduction levels at high wind speed for the SG 2.6-114 wind turbine

- The noise reduction modes that limit the noise at lower velocities (typical W₁₀ – 3-6 m/s) are indicated as NRS A, B and C. It is possible to activate any of the noise reduction modes at high wind

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speed from table 4 with a noise reduction mode at lower velocity, for example: N2 + NRS B, at the same time.

Table 5 shows the feasibility for low noise operation:

SG 2.6-114	N1	N2	N3	N4	N5	N6	NRS A	NRS B	NRS C
H = 68m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
H = 75m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
H = 80m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
H = 88m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
H = 93m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
H = 125m	No	No	No	No	No	No	Yes	Yes	Yes

Table 5 SG 2.6-114 wind turbine low noise levels

Table 6 presents the electrical power output [kW] in function of the horizontal wind speed W_s [m/s] at hub height (W_s) for different noise reduction mode settings, for tower height H = 68m.

P [kW]	H = 68m						
	Ws [m/s]	N1	N2	N3	N4	N5	N6
3	36	36	36	36	36	36	36
4	137	137	137	137	137	137	137
5	326	326	326	326	326	326	326
6	607	607	607	607	607	606	594
7	999	996	990	979	962	962	884
8	1488	1464	1430	1386	1334	1089	
9	1965	1901	1829	1750	1666	1162	
10	2257	2164	2070	1974	1879	1177	
11	2364	2261	2160	2062	1966	1185	
12	2400	2298	2200	2106	2016	1261	
13	2443	2357	2276	2197	2122	1522	
14	2505	2448	2394	2342	2293	1922	
15	2562	2532	2504	2476	2450	2270	
16	2598	2585	2572	2560	2549	2475	
17	2614	2609	2605	2600	2596	2569	
18	2621	2619	2618	2616	2614	2605	
19	2624	2623	2622	2622	2621	2618	
20	2624	2624	2624	2624	2623	2622	
21	2625	2625	2625	2625	2625	2625	
22	2394	2394	2394	2394	2394	2394	
23	2163	2163	2163	2163	2163	2163	
24	1931	1931	1931	1931	1931	1931	
25	1700	1700	1700	1700	1700	1700	

Table 6 Electric power [kW] of the SG 2.6-114 wind turbine with a tower height of 68m, calculated according to W_s [m/s] and noise level [dB(A)] (ref.: 20170519G114NRS2p625MM)

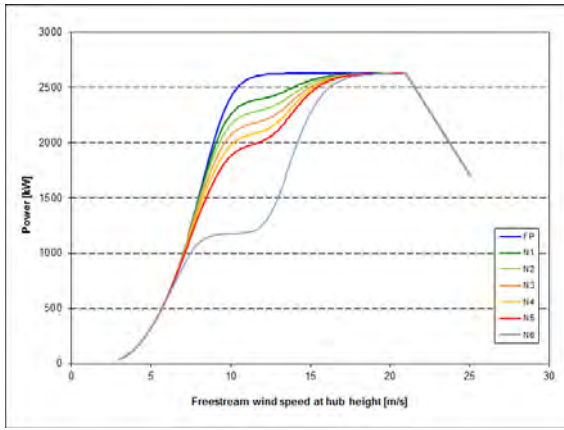


Figure 1 Power curve of the SG 2.6-114 wind turbine with tower height 68m for different versions of low noise operating mode (ref.: 20170519G114NRS2p625MW)

Table 7 presents the electrical power output [kW] in function of the horizontal wind speed W_s [m/s] at hub height (W_s) for different noise reduction mode settings, for tower height $H = 75m$.

P [kW]	H = 75m						
	W_s [m/s]	N1	N2	N3	N4	N5	N6
3	36	36	36	36	36	36	36
4	137	137	137	137	137	137	137
5	326	326	326	326	326	326	325
6	607	607	607	607	606	606	594
7	999	996	990	979	962	962	884
8	1488	1464	1430	1386	1334	1334	1089
9	1965	1901	1829	1750	1666	1666	1162
10	2257	2164	2070	1974	1879	1879	1177
11	2364	2260	2159	2060	1965	1965	1181
12	2395	2291	2191	2095	2002	2002	1223
13	2427	2334	2246	2161	2080	2080	1414
14	2483	2415	2351	2290	2231	2231	1779
15	2543	2504	2467	2432	2398	2398	2155
16	2586	2568	2550	2533	2517	2517	2409
17	2609	2601	2594	2587	2581	2581	2539
18	2619	2616	2613	2610	2608	2608	2592
19	2623	2622	2620	2619	2618	2618	2613
20	2624	2624	2623	2623	2622	2622	2620
21	2625	2625	2625	2625	2625	2625	2625
22	2394	2394	2394	2394	2394	2394	2394
23	2163	2163	2163	2163	2163	2163	2163
24	1931	1931	1931	1931	1931	1931	1931
25	1700	1700	1700	1700	1700	1700	1700

Table 7 Electric power [kW] of the SG 2.6-114 wind turbine with a tower height of 75m, calculated according to W_s [m/s] and noise level [dB(A)] (ref.: 20170519G114NRS2p625MW)

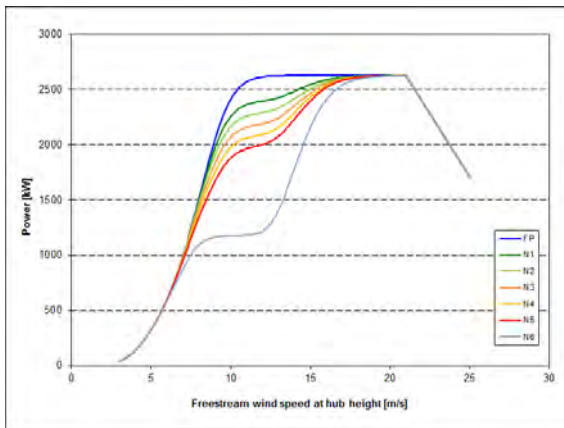


Figure 2 Power curve of the SG 2.6-114 wind turbine with tower height 75m for different versions of low noise operating mode (ref.: 20170519G114NRS2p625MW)

Table 8 presents the electrical power output [kW] in function of the horizontal wind speed W_s [m/s] at hub height (W_s) for different noise reduction mode settings, for tower height $H = 80m$.

P [kW]	H = 80m						
	W_s [m/s]	N1	N2	N3	N4	N5	N6
3	36	36	36	36	36	36	36
4	137	137	137	137	137	137	137
5	326	326	326	326	326	326	325
6	607	607	607	607	606	606	594
7	999	996	990	979	962	962	884
8	1488	1464	1430	1386	1334	1334	1089
9	1965	1901	1829	1750	1666	1666	1162
10	2257	2164	2070	1974	1879	1879	1177
11	2364	2260	2159	2060	1965	1965	1181
12	2395	2291	2191	2095	2002	2002	1223
13	2427	2334	2246	2161	2080	2080	1414
14	2483	2415	2351	2290	2231	2231	1779
15	2543	2504	2467	2432	2398	2398	2155
16	2586	2568	2550	2533	2517	2517	2409
17	2609	2601	2594	2587	2581	2581	2539
18	2619	2616	2613	2610	2608	2608	2592
19	2623	2622	2620	2619	2618	2618	2613
20	2624	2624	2623	2623	2622	2622	2620
21	2625	2625	2625	2625	2625	2625	2625
22	2394	2394	2394	2394	2394	2394	2394
23	2163	2163	2163	2163	2163	2163	2163
24	1931	1931	1931	1931	1931	1931	1931
25	1700	1700	1700	1700	1700	1700	1700

Table 8 Electric power [kW] of the SG 2.6-114 wind turbine with a tower height of 80m, calculated according to W_s [m/s] and noise level [dB(A)] (ref.: 20170519G114NRS2p625MW)

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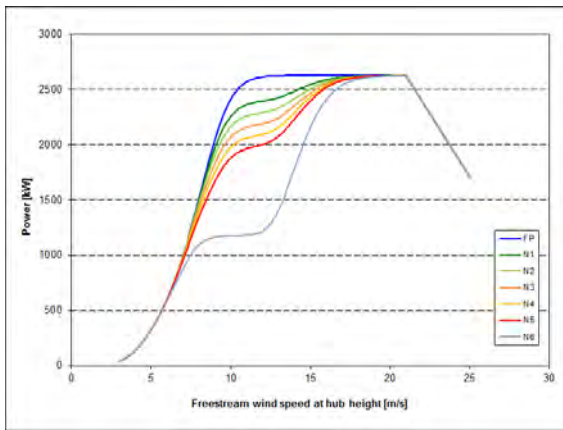


Figure 3 Power curve of the SG 2.6-114 wind turbine with tower height 80m for different versions of low noise operating mode (ref.: 20170519G114NRS2p625MW)

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Table 9 presents the electrical power output [kW] in function of the horizontal wind speed W_s [m/s] at hub height (W_s) for different noise reduction mode settings, for tower height $H = 88m$.

P [kW]	H = 88m						
	W_s [m/s]	N1	N2	N3	N4	N5	N6
3	36	36	36	36	36	36	36
4	137	137	137	137	137	137	137
5	326	326	326	326	326	326	326
6	607	607	607	607	606	594	594
7	999	996	990	979	962	884	884
8	1488	1464	1430	1386	1334	1089	1089
9	1965	1901	1829	1750	1666	1162	1162
10	2257	2164	2070	1974	1879	1177	1177
11	2363	2260	2158	2060	1965	1180	1180
12	2394	2288	2187	2090	1997	1208	1208
13	2420	2324	2232	2143	2059	1361	1361
14	2470	2397	2327	2260	2196	1696	1696
15	2531	2486	2444	2403	2364	2080	2080
16	2578	2556	2535	2514	2495	2362	2362
17	2605	2595	2586	2577	2569	2515	2515
18	2617	2613	2609	2606	2603	2582	2582
19	2622	2620	2619	2617	2616	2608	2608
20	2624	2623	2622	2622	2621	2618	2618
21	2625	2625	2625	2625	2625	2625	2625
22	2394	2394	2394	2394	2394	2394	2394
23	2163	2163	2163	2163	2163	2163	2163
24	1931	1931	1931	1931	1931	1931	1931
25	1700	1700	1700	1700	1700	1700	1700

Table 9 Electric power [kW] of the SG 2.6-114 wind turbine with a tower height of 88m, calculated according to W_s [m/s] and noise level [dB(A)] (ref.: 20170519G114NRS2p625MW)

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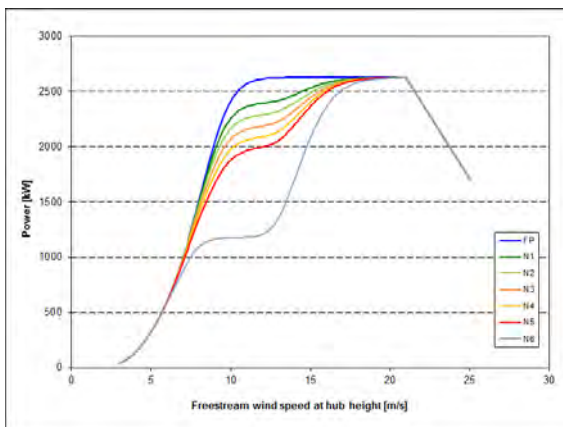


Figure 4 Power curve of the SG 2.6-114 wind turbine with tower height 88m for different versions of low noise operating mode (ref.: 20170519G114NRS2p625MW)

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Table 10 presents the electrical power output [kW] in function of the horizontal wind speed W_s [m/s] at hub height (W_s) for different noise reduction mode settings, for tower height $H = 93m$.

P [kW]	H = 93m						
	W_s [m/s]	N1	N2	N3	N4	N5	N6
3	36	36	36	36	36	36	36
4	137	137	137	137	137	137	137
5	326	326	326	326	326	326	326
6	607	607	607	607	606	594	594
7	999	996	990	979	962	884	884
8	1488	1464	1430	1386	1334	1089	1089
9	1965	1901	1829	1750	1666	1162	1162
10	2257	2164	2070	1974	1879	1177	1177
11	2363	2260	2158	2060	1965	1180	1180
12	2394	2288	2187	2090	1997	1208	1208
13	2416	2318	2224	2135	2049	1334	1334
14	2463	2386	2313	2243	2176	1649	1649
15	2523	2475	2429	2385	2343	2034	2034
16	2573	2548	2525	2502	2480	2331	2331
17	2602	2591	2581	2571	2561	2499	2499
18	2616	2611	2607	2603	2599	2575	2575
19	2621	2619	2618	2616	2614	2605	2605
20	2623	2623	2622	2621	2620	2617	2617
21	2625	2625	2625	2625	2625	2625	2625
22	2394	2394	2394	2394	2394	2394	2394
23	2163	2163	2163	2163	2163	2163	2163
24	1931	1931	1931	1931	1931	1931	1931
25	1700	1700	1700	1700	1700	1700	1700

Table 10 Electric power [kW] of the SG 2.6-114 wind turbine with a tower height of 93m, calculated according to W_s [m/s] and noise level [dB(A)] (ref.: 20170519G114NRS2p625MW)

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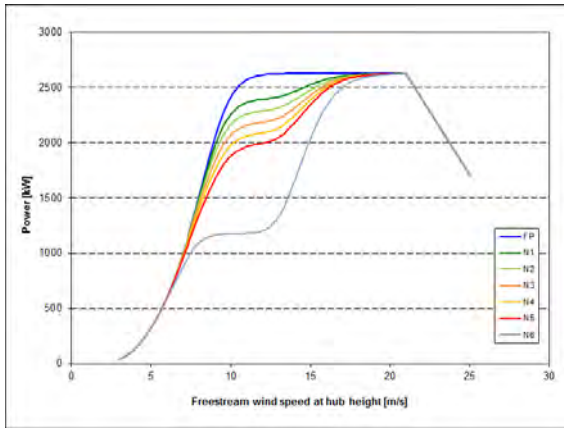


Figure 5 Power curve of the SG 2.6-114 wind turbine with tower height 93m for different versions of low noise operating mode (ref.: 20170519G114NRS2p625MW)

Table 11 presents the power output [kW] of the SG 2.6-114 for different noise reduction modes at low wind speed NRS A, B and C. The power output is represented against wind speed at hub height W_s [m/s]. For these modes, the power output does not vary with tower height H.

P [kW]	H = 68m / 75m / 80m / 88m / 93m / 125m		
	W_s [m/s]	NRS A	NRS B
3	36	36	36
4	137	137	137
5	324	322	321
6	603	593	579
7	995	979	954
8	1500	1485	1453
9	2037	2029	2006
10	2412	2409	2401
11	2569	2569	2567
12	2613	2613	2613
13	2623	2623	2623
14	2625	2625	2625
15	2625	2625	2625
16	2625	2625	2625
17	2625	2625	2625
18	2625	2625	2625
19	2625	2625	2625
20	2625	2625	2625
21	2625	2625	2625
22	2394	2394	2394
23	2163	2163	2163
24	1931	1931	1931
25	1700	1700	1700

Table 11: Power output [kW] of the SG 2.6-114 wind turbine, calculated according to W_s [m/s] for different noise reduction modes at low wind speeds NRS A, B and C. (ref.: 20170519G114NRS2p625MW)

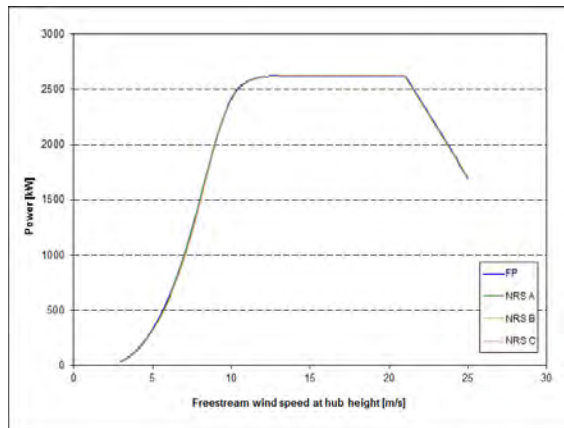


Figure 6 Power curve of the SG 2.6-114 wind turbine with tower height 68m, 80m, 88m, 93m and 125m for different versions of low noise operating modes at low wind speeds NRS A, B and C. (ref.: 20170519G114NRS2p625MW)

5.2 ANNUAL ENERGY PRODUCTION FOR THE LOW NOISE OPERATION MODES

Table 12 presents the annual energy output [MWh] for the SG 2.6-114 wind turbine calculated with different Weibull distribution parameters W_{we} [m/s] and K, for a tower height of 68m and different noise reduction modes.

P [MWh]	W_{we} [m/s]	H = 68m				
		6.5	7.0	7.5	8.0	8.5
N1	K = 1.5	8075	8867	9582	10217	10772
	K = 2.0	8345	9387	10357	11249	12057
	K = 2.5	8361	9579	10717	11768	12729
N2	K = 1.5	7891	8667	9368	9994	10542
	K = 2.0	8143	9154	10098	10969	11763
	K = 2.5	8166	9337	10434	11451	12385
N3	K = 1.5	7697	8456	9146	9761	10302
	K = 2.0	7927	8907	9826	10678	11457
	K = 2.5	7953	9077	10133	11117	12027
N4	K = 1.5	7493	8237	8913	9520	10055
	K = 2.0	7697	8647	9541	10374	11141
	K = 2.5	7721	8797	9814	10767	11654
N5	K = 1.5	7280	8008	8672	9270	9799
	K = 2.0	7453	8372	9243	10059	10814
	K = 2.5	7469	8500	9479	10402	11268
N6	K = 1.5	5823	6432	7005	7533	8014
	K = 2.0	5821	6513	7199	7875	8531
	K = 2.5	5850	6532	7211	7894	8584

Table 12 Annual energy production for the SG 2.6-114 wind turbine with tower height 68m for different Weibull parameters W_{we} [m/s], Weibull K parameter and different noise reduction modes. (ref.: 20170519G114NRS2p625MW)

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Table 13 presents the annual energy output [MWh] for the SG 2.6-114 wind turbine calculated with different Weibull distribution parameters W_{ave} [m/s] and K , for a tower height of 75m and different noise reduction modes.

P [MWh]		H = 75m				
W_{ave} [m/s]		6.5	7.0	7.5	8.0	8.5
N1	K = 1.5	8062	8852	9564	10197	10751
	K = 2.0	8336	9375	10341	11228	12033
	K = 2.5	8356	9571	10705	11751	12707
N2	K = 1.5	7872	8644	9343	9965	10510
	K = 2.0	8130	9136	10074	10939	11728
	K = 2.5	8160	9325	10416	11425	12352
N3	K = 1.5	7672	8427	9112	9723	10261
	K = 2.0	7910	8883	9794	10639	11412
	K = 2.5	7944	9061	10109	11083	11983
N4	K = 1.5	7463	8201	8872	9473	10004
	K = 2.0	7675	8616	9502	10326	11085
	K = 2.5	7710	8779	9785	10726	11601
N5	K = 1.5	7244	7965	8624	9216	9740
	K = 2.0	7427	8337	9197	10003	10748
	K = 2.5	7457	8478	9445	10354	11206
N6	K = 1.5	5739	6332	6890	7406	7875
	K = 2.0	5760	6428	7090	7742	8376
	K = 2.5	5819	6478	7127	7778	8435

Table 13 Annual energy production for the SG 2.6-114 wind turbine with tower height 75m for different Weibull parameters W_{ave} [m/s], Weibull K parameter and different noise reduction modes. (ref.: 20170519G114NRS2p625MM)

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Table 14 presents the annual energy output [MWh] for the SG 2.6-114 wind turbine calculated with different Weibull distribution parameters W_{ave} [m/s] and K , for a tower height of 80m and different noise reduction modes.

P [MWh]		H = 80m				
W_{ave} [m/s]		6.5	7.0	7.5	8.0	8.5
N1	K = 1.5	8062	8852	9564	10197	10751
	K = 2.0	8336	9375	10341	11228	12033
	K = 2.5	8356	9571	10705	11751	12707
N2	K = 1.5	7872	8644	9343	9965	10510
	K = 2.0	8130	9136	10074	10939	11728
	K = 2.5	8160	9325	10416	11425	12352
N3	K = 1.5	7672	8427	9112	9723	10261
	K = 2.0	7910	8883	9794	10639	11412
	K = 2.5	7944	9061	10109	11083	11983
N4	K = 1.5	7463	8201	8872	9473	10004
	K = 2.0	7675	8616	9502	10326	11085
	K = 2.5	7710	8779	9785	10726	11601
N5	K = 1.5	7244	7965	8624	9216	9740
	K = 2.0	7427	8337	9197	10003	10748
	K = 2.5	7457	8478	9445	10354	11206
N6	K = 1.5	5739	6332	6890	7406	7875
	K = 2.0	5760	6428	7090	7742	8376
	K = 2.5	5819	6478	7127	7778	8435

Table 14 Annual energy production for the SG 2.6-114 wind turbine with tower height 80m for different Weibull parameters W_{ave} [m/s], Weibull K parameter and different noise reduction modes. (ref.: 20170519G114NRS2p625MM)

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Table 15 presents the annual energy output [MWh] for the SG 2.6-114 wind turbine calculated with different Weibull distribution parameters W_{ave} [m/s] and K , for a tower height of 88m and different noise reduction modes.

P [MWh]		H = 88m				
W_{ave} [m/s]		6.5	7.0	7.5	8.0	8.5
N1	K = 1.5	8055	8843	9554	10186	10739
	K = 2.0	8331	9368	10332	11217	12020
	K = 2.5	8354	9567	10699	11742	12694
N2	K = 1.5	7861	8631	9328	9948	10492
	K = 2.0	8123	9126	10061	10923	11708
	K = 2.5	8156	9319	10406	11411	12334
N3	K = 1.5	7659	8410	9093	9702	10238
	K = 2.0	7901	8870	9777	10617	11386
	K = 2.5	7940	9053	10097	11065	11960
N4	K = 1.5	7446	8180	8849	9447	9975
	K = 2.0	7664	8600	9480	10300	11054
	K = 2.5	7705	8769	9770	10704	11572
N5	K = 1.5	7224	7941	8596	9185	9706
	K = 2.0	7414	8318	9172	9971	10711
	K = 2.5	7451	8467	9427	10328	11172
N6	K = 1.5	5692	6276	6825	7333	7796
	K = 2.0	5728	6382	7030	7668	8289
	K = 2.5	5803	6450	7084	7716	8354

Table 15 Annual energy production for the SG 2.6-114 wind turbine with tower height 88m for different Weibull parameters W_{ave} [m/s], Weibull K parameter and different noise reduction modes. (ref.: 20170519G114NRS2p625MM)

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Table 16 presents the annual energy output [MWh] for the SG 2.6-114 wind turbine calculated with different Weibull distribution parameters W_{ave} [m/s] and K , for a tower height of 93m and different noise reduction modes.

P [MWh]		H = 93m				
W_{ave} [m/s]		6.5	7.0	7.5	8.0	8.5
N1	K = 1.5	8051	8838	9549	10180	10732
	K = 2.0	8328	9364	10327	11211	12012
	K = 2.5	8353	9564	10695	11737	12688
N2	K = 1.5	7856	8624	9320	9939	10482
	K = 2.0	8119	9120	10053	10914	11697
	K = 2.5	8155	9316	10401	11404	12324
N3	K = 1.5	7651	8401	9082	9690	10224
	K = 2.0	7895	8862	9767	10605	11372
	K = 2.5	7938	9049	10090	11056	11947
N4	K = 1.5	7437	8169	8835	9432	9959
	K = 2.0	7658	8591	9468	10285	11036
	K = 2.5	7702	8764	9761	10692	11556
N5	K = 1.5	7213	7928	8580	9167	9687
	K = 2.0	7407	8307	9158	9954	10691
	K = 2.5	7448	8461	9417	10314	11154
N6	K = 1.5	5665	6244	6788	7292	7750
	K = 2.0	5710	6356	6996	7626	8240
	K = 2.5	5795	6435	7060	7682	8308

Table 16 Annual energy production for the SG 2.6-114 wind turbine with tower height 93m for different Weibull parameters W_{ave} [m/s], Weibull K parameter and different noise reduction modes. (ref.: 20170519G114NRS2p625MM)

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Table 17 presents the annual energy output [MWh] for the SG 2.6-114 wind turbine calculated with different Weibull distribution parameters W_{we} [m/s] and K, for tower heights of 68m, 80m, 88m, 93m and 125m and different noise reduction modes at low wind speeds NRS A, B and C.

P [MWh]		H = 68m / 75m / 80m / 88m / 93m / 125m				
W_{we} [m/s]		6.5	7.0	7.5	8.0	8.5
NRS A	K = 1.5	8376	9200	9941	10597	11168
	K = 2.0	8659	9762	10784	11717	12558
	K = 2.5	8641	9948	11169	12291	13309
NRS B	K = 1.5	8341	9166	9907	10563	11135
	K = 2.0	8614	9718	10740	11675	12518
	K = 2.5	8587	9894	11117	12241	13262
NRS C	K = 1.5	8277	9101	9842	10500	11073
	K = 2.0	8530	9633	10657	11593	12439
	K = 2.5	8485	9791	11015	12143	13168

Table 17 Annual energy production for the SG 2.6-114 wind turbine for different Weibull parameters W_{we} [m/s], Weibull K parameter and different noise reduction modes at low wind speeds NRS A, B and C. (ref.: 20170519G114NRS2p625MM)

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5.3 NOISE CURVES

Table 18 represents the noise curves of the SG 2.6-114 wind turbine for different noise reduction modes in function of W_{10} [m/s] and W_s [m/s] for the 68m tower.

		H = 68m									
W_{10} [m/s]	W_s [m/s]	N1 [dB(A)]	N2 [dB(A)]	N3 [dB(A)]	N4 [dB(A)]	N5 [dB(A)]	N6 [dB(A)]	NRS A [dB(A)]	NRS B [dB(A)]	NRS C [dB(A)]	
3	4.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
3.5	4.8	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
4	5.4	94.3	94.3	94.3	94.3	94.3	94.3	94.3	93.1	93.1	
4.5	6.1	97.2	97.2	97.2	97.2	97.2	96.5	96.3	95.2	94.1	
5	6.8	99.7	99.7	99.7	99.7	99.7	99.7	96.5	97.8	96.7	
5.5	7.5	101.8	101.8	101.8	101.8	101.8	99.7	96.5	100.9	98.9	
6	8.2	103	102	101	100	99	96.5	102.9	101.9	100.9	
6.5	8.8	103	102	101	100	99	96.5	104.6	103.7	102.7	
7	9.5	103	102	101	100	99	96.5	104.6	104.6	104.6	
7.5	10.2	103	102	101	100	99	96.5	104.6	104.6	104.6	
8	10.9	103	102	101	100	99	96.5	104.6	104.6	104.6	
8.5	11.6	103	102	101	100	99	96.5	104.6	104.6	104.6	
9	12.2	103	102	101	100	99	96.5	104.6	104.6	104.6	
9.5	12.9	103	102	101	100	99	96.5	104.6	104.6	104.6	
10	13.6	103	102	101	100	99	96.5	104.6	104.6	104.6	

Table 18 Noise curves of the SG 2.6-114 wind turbine for a tower height of 68m (ref.: 20170519G114NRS2p625MM)

Table 19 represents the noise curves of the SG 2.6-114 wind turbine for different noise reduction modes in function of W_{10} [m/s] and W_s [m/s] for the 68m tower.

		H = 75m									
W_{10} [m/s]	W_s [m/s]	N1 [dB(A)]	N2 [dB(A)]	N3 [dB(A)]	N4 [dB(A)]	N5 [dB(A)]	N6 [dB(A)]	NRS A [dB(A)]	NRS B [dB(A)]	NRS C [dB(A)]	
3	4.2	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
3.5	4.9	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
4	5.6	95	95	95	95	95	95	94	93.1	93.1	
4.5	6.3	97.8	97.8	97.8	97.8	97.8	96.5	96.9	95.9	94.8	
5	7.0	100.3	100.3	100.3	100	99	96.5	99.4	98.4	97.3	
5.5	7.7	102.4	102	101	100	99	96.5	101.5	100.6	99.5	
6	8.4	103	102	101	100	99	96.5	103.5	102.5	101.5	
6.5	9.1	103	102	101	100	99	96.5	104.6	104.6	103.3	
7	9.8	103	102	101	100	99	96.5	104.6	104.6	104.6	
7.5	10.5	103	102	101	100	99	96.5	104.6	104.6	104.6	
8	11.2	103	102	101	100	99	96.5	104.6	104.6	104.6	
8.5	11.9	103	102	101	100	99	96.5	104.6	104.6	104.6	
9	12.6	103	102	101	100	99	96.5	104.6	104.6	104.6	
9.5	13.3	103	102	101	100	99	96.5	104.6	104.6	104.6	
10	13.9	103	102	101	100	99	96.5	104.6	104.6	104.6	

Table 19 Noise curves of the SG 2.6-114 wind turbine for a tower height of 68m (ref.: 20170519G114NRS2p625MM)

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Table 20 represents the noise curves of the SG 2.6-114 wind turbine for different noise reduction modes in function of W_{10} [m/s] and W_s [m/s] for the 80m tower.

		H = 80m									
W_{10} [m/s]	W_s [m/s]	N1 [dB(A)]	N2 [dB(A)]	N3 [dB(A)]	N4 [dB(A)]	N5 [dB(A)]	N6 [dB(A)]	NRS A [dB(A)]	NRS B [dB(A)]	NRS C [dB(A)]	
3	4.2	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
3.5	4.9	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
4	5.6	95	95	95	95	95	95	94	93.1	93.1	
4.5	6.3	97.8	97.8	97.8	97.8	97.8	96.5	96.9	95.9	94.8	
5	7.0	100.3	100.3	100.3	100	99	96.5	99.4	98.4	97.3	
5.5	7.7	102.4	102	101	100	99	96.5	101.5	100.6	99.5	
6	8.4	103	102	101	100	99	96.5	103.5	102.5	101.5	
6.5	9.1	103	102	101	100	99	96.5	104.6	104.6	103.3	
7	9.8	103	102	101	100	99	96.5	104.6	104.6	104.6	
7.5	10.5	103	102	101	100	99	96.5	104.6	104.6	104.6	
8	11.2	103	102	101	100	99	96.5	104.6	104.6	104.6	
8.5	11.9	103	102	101	100	99	96.5	104.6	104.6	104.6	
9	12.6	103	102	101	100	99	96.5	104.6	104.6	104.6	
9.5	13.3	103	102	101	100	99	96.5	104.6	104.6	104.6	
10	13.9	103	102	101	100	99	96.5	104.6	104.6	104.6	

Table 20 Noise curves of the SG 2.6-114 wind turbine for a tower height of 80m (ref.: 20170519G114NRS2p625MM)

Table 21 represents the noise curves of the SG 2.6-114 wind turbine for different noise reduction modes in function of W_{10} [m/s] and W_s [m/s] for the 88m tower.

		H = 88m									
W_{10} [m/s]	W_s [m/s]	N1 [dB(A)]	N2 [dB(A)]	N3 [dB(A)]	N4 [dB(A)]	N5 [dB(A)]	N6 [dB(A)]	NRS A [dB(A)]	NRS B [dB(A)]	NRS C [dB(A)]	
3	4.2	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
3.5	5.0	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
4	5.7	95.4	95.4	95.4	95.4	95.4	95.4	94.4	93.4	93.1	
4.5	6.4	98.2	98.2	98.2	98.2	98.2	96.5	97.2	96.2	95.1	
5	7.1	100.6	100.6	100.6	100	99	96.5	99.7	98.7	97.7	
5.5	7.8	102.8	102	101	100	99	96.5	101.9	100.9	99.9	
6	8.5	103	102	101	100	99	96.5	103.8	102.9	101.8	
6.5	9.2	103	102	101	100	99	96.5	104.6	104.6	103.6	
7	9.9	103	102	101	100	99	96.5	104.6	104.6	104.6	
7.5	10.6	103	102	101	100	99	96.5	104.6	104.6	104.6	
8	11.3	103	102	101	100	99	96.5	104.6	104.6	104.6	
8.5	12.0	103	102	101	100	99	96.5	104.6	104.6	104.6	
9	12.7	103	102	101	100	99	96.5	104.6	104.6	104.6	
9.5	13.5	103	102	101	100	99	96.5	104.6	104.6	104.6	
10	14.2	103	102	101	100	99	96.5	104.6	104.6	104.6	

Table 21 Noise curves of the SG 2.6-114 wind turbine for a tower height of 88m (ref.: 20170519G114NRS2p625MM)

SIEMENS Gamesa RENEWABLE ENERGY	GENERAL CHARACTERISTICS MANUAL	Code: GD385965-en	Rev: 1
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Title: SG 2.6-114 LOW NOISE MODES (NRS)			

Table 22 represents the noise curves of the SG 2.6-114 wind turbine for different noise reduction modes in function of W_{10} [m/s] and W_s [m/s] for the 93m tower.

		H = 93m									
W_{10} [m/s]	W_s [m/s]	N1 [dB(A)]	N2 [dB(A)]	N3 [dB(A)]	N4 [dB(A)]	N5 [dB(A)]	N6 [dB(A)]	NRS A [dB(A)]	NRS B [dB(A)]	NRS C [dB(A)]	
3	4.3	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
3.5	5.0	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1	
4	5.7	95.6	95.6	95.6	95.6	95.6	95.6	94.6	93.6	93.1	
4.5	6.4	98.4	98.4	98.4	98.4	98.4	96.5	97.5	96.5	95.4	
5	7.1	100.8	100.8	100.8	100	99	96.5	99.9	98.9	97.9	
5.5	7.9	103	102	101	100	99	96.5	102.1	101.1	100.1	
6	8.6	103	102	101	100	99	96.5	103.9	103.1	102	
6.5	9.3	103	102	101	100	99	96.5	104.6	104.6	103.8	
7	10.0	103	102	101	100	99	96.5	104.6	104.6	104.6	
7.5	10.7	103	102	101	100	99	96.5	104.6	104.6	104.6	
8	11.4	103	102	101	100	99	96.5	104.6	104.6	104.6	
8.5	12.1	103	102	101	100	99	96.5	104.6	104.6	104.6	
9	12.9	103	102	101	100	99	96.5	104.6	104.6	104.6	
9.5	13.6	103	102	101	100	99	96.5	104.6	104.6	104.6	
10	14.3	103	102	101	100	99	96.5	104.6	104.6	104.6	

Table 22 Noise curves of the SG 2.6-114 wind turbine for a tower height of 93m (ref.: 20170519G114NRS2p625MM)

Table 23 represents the noise curves of the SG 2.6-114 wind turbine for different noise reduction modes in function of W_{10} [m/s] and W_s [m/s] for the 125m tower.

		H = 125m				
W_{10} [m/s]	W_s [m/s]	NRS A [dB(A)]	NRS B [dB(A)]	NRS C [dB(A)]		
3	4.5	93.1	93.1	93.1		
3.5	5.2	93.1	93.1	93.1		
4	6.0	95.8	94.7	93.6		
4.5	6.7	98.6	97.6	96.5		
5	7.5	101	100	99		
5.5	8.2	103.1	102.2	101.1		
6	9.0	104.6	104.6	103.1		
6.5	9.7	104.6	104.6	104.6		
7	10.5	104.6	104.6</			

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2016-04-29

General Specification
V112-3.3/3.45 MW 50/60 Hz BWC



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Table of contents listing sections 5.4 to 14, including Floors, Platforms, Standing, and Working Places; Service Lift; Climbing Facilities; Moving Parts, Guards, and Blocking Devices; Environment; Design Codes; Colours; Operational Envelope and Performance Guidelines; Type Approvals and Available Hub Heights; Operational Envelope and Performance Guidelines; and Appendices.

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Table of contents listing sections 1 to 5.3, including General Description; Mechanical Design (Rotor, Blades, Blade Bearing, Pitch System, Hub, Main Shaft, Main Bearing Housing, Main Bearing, Gearbox, Generator Bearings, High-Speed Shaft Coupling, Yaw System, Crane, Towers, Nacelle Bedplate and Cover, Thermal Conditioning System, Generator and Converter Cooling, Gearbox and Hydraulic Cooling, Transformer Cooling, Nacelle Cooling, Optional Air Intake Hatches); Electrical Design (Generator, Converter, HV Transformer, IEC 50 Hz/60 Hz version, Ecodesign - IEC 50 Hz/60 Hz version, IEEE 60Hz version, HV Cables, HV Switchgear, IEC 50/60Hz version, IEEE 60Hz version, AUX System, Wind Sensors, Vestas Multi Processor (VMP) Controller, Uninterruptible Power Supply (UPS)); Turbine Protection Systems (Braking Concept, Short Circuit Protections, Overspeed Protection, Arc Detection, Smoke Detection, Lightning Protection of Blades, Nacelle, Hub and Tower, EMC, Earthing, Corrosion Protection); and Safety (Access, Escape, Rooms/Working Areas).

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Table of contents listing sections 14.1 to 14.8.3, including Mode 0, Mode 2, Mode 3, Mode 4, Mode 5, Mode 8, and Mode 3.0 MW Derated Mode, with sub-sections for Power Curves, Noise Curves, and C, Values.

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Blades	
Type Description	Airfoil shells bonded to supporting beam
Blade Length	54.65 m
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT)
Blade Connection	Steel roots inserted
Airfoils	High-lift profile
Maximum Chord	4.0 m

Table 2-2: Blades data

2.3 Blade Bearing

The blade bearings are double-row four-point contact ball bearings.

Blade Bearing	
Lubrication	Grease

Table 2-3: Blade bearing data

2.4 Pitch System

The turbine is equipped with a pitch system for each blade and a distributor block, all located in the hub. Each pitch system is connected to the distributor block with flexible hoses. The distributor block is connected to the pipes of the hydraulic rotating transfer unit in the hub by means of three hoses (pressure line, return line and drain line).

Each pitch system consists of a hydraulic cylinder mounted to the hub and a piston rod mounted to the blade bearing via a torque arm shaft. Valves facilitating operation of the pitch cylinder are installed on a pitch block bolted directly onto the cylinder.

Pitch System	
Type	Hydraulic
Number	1 per blade
Range	-9° to 90°

Table 2-4: Pitch system data

Hydraulic System	
Main Pump	Two redundant internal-gear oil pumps
Pressure	260 bar
Filtration	3 µm (absolute)

Table 2-5: Hydraulic system data.



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1 General Description

The Vestas V112-3.3/3.45 MW 50/60 Hz BWC wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V112-3.3/3.45 MW 50/60 Hz BWC turbine has a rotor diameter of 112 m and a rated output power of 3.3/3.45 MW.

The turbine utilises the OptiTip® concept and a power system based on an induction generator and full-scale converter. With these features, the wind turbine is able to operate the rotor at variable speed and thereby maintaining the power output at or near rated power even in high wind speed.

At low wind speed, the OptiTip® concept and the power system work together to maximise the power output by operating at the optimal rotor speed and pitch angle.

Operating the turbine with 3.45 MW Power Mode is achieved by extended derate strategy and reduced reactive power capability compared with 3.3 MW operation.

The turbine is also able to operate in 3.0 MW Derated Mode.

2 Mechanical Design

2.1 Rotor

The V112-3.3/3.45 MW 50/60 Hz BWC wind turbine is equipped with a 112-meter rotor consisting of three blades and a hub. The blades are controlled by the microprocessor pitch control system OptiTip®. Based on the prevailing wind conditions, the blades are continuously positioned to optimise the pitch angle.

Rotor	
Diameter	112 m
Swept Area	9852 m ²
Speed, Dynamic Operation Range	6.2-17.7
Rotational Direction	Clockwise (front view)
Orientation	Upwind
Tilt	6°
Hub Coning	4°
No. of Blades	3
Aerodynamic Brakes	Full feathering

Table 2-1: Rotor data

2.2 Blades

The blades are made of carbon and fibreglass and consist of two airfoil shells bonded to a supporting beam.



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2.5 Hub

The hub supports the three blades and transfers the reaction loads to the main bearing and the torque to the gearbox. The hub structure also supports blade bearings and pitch cylinders.

Hub	
Type	Cast ball shell hub
Material	Cast iron

Table 2-6: Hub data

2.6 Main Shaft

The main shaft transfers the reaction forces to the main bearing and the torque to the gearbox.

Main Shaft	
Type Description	Hollow shaft
Material	Cast iron

Table 2-7: Main shaft data

2.7 Main Bearing Housing

The main bearing housing covers the main bearing and is the first connection point for the drive train system to the bedplate.

Main Bearing Housing	
Material	Cast iron

Table 2-8: Main bearing housing data

2.8 Main Bearing

The main bearing carries all thrust loads.

Main Bearing	
Type	Double-row spherical roller bearing
Lubrication	Automatic grease lubrication

Table 2-9: Main bearing data

2.9 Gearbox

The main gear converts the low-speed rotation of the rotor to high-speed generator rotation.

The disc brake is mounted on the high-speed shaft. The gearbox lubrication system is a pressure-fed system.



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Gearbox	
Type	Planetary stages + one helical stage
Gear House Material	Cast
Lubrication System	Pressure oil lubrication
Backup Lubrication System	Oil sump filled from external gravity tank
Total Gear Oil Volume	1000-1200
Oil Cleanliness Codes	ISO 4406-/15/12
Shaft Seals	Labyrinth

Table 2-10: Gearbox data

2.10 Generator Bearings

The bearings are grease lubricated and grease is supplied continuously from an automatic lubrication unit.

2.11 High-Speed Shaft Coupling

The coupling transmits the torque of the gearbox high-speed output shaft to the generator input shaft.

The coupling consists of two 4-link laminate packages and a fibreglass intermediate tube with two metal flanges.

The coupling is fitted to two-armed hubs on the brake disc and the generator hub.

2.12 Yaw System

The yaw system is an active system based on a robust pre-tensioned plain yaw-bearing concept with PETP as friction material.

Yaw System	
Type	Plain bearing system
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yawing Speed (50 Hz)	0.45°/sec.
Yawing Speed (60 Hz)	0.55°/sec.

Table 2-11: Yaw system data

Yaw Gear	
Type	Multiple stages geared
Ratio Total	944:1
Rotational Speed at Full Load	1.4 rpm at output shaft

Table 2-12: Yaw gear data

Type Description	Material
Nacelle Cover	GRP
Bedplate Front	Cast iron
Bedplate Rear	Girder structure

Table 2-15: Nacelle bedplate and cover data

2.16 Thermal Conditioning System

The thermal conditioning system consists of a few robust components:

- The Vestas CoolerTop® located on top of the rear end of the nacelle. The CoolerTop® is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle.
- The Liquid Cooling System, which serves the gearbox, hydraulic systems, generator and converter is driven by an electrical pumping system.
- The transformer forced air cooling comprised of an electrical fan.

2.16.1 Generator and Converter Cooling

The generator and converter cooling systems operate in parallel. A dynamic flow valve mounted in the generator cooling circuit divides the cooling liquid flow. The cooling liquid removes heat from the generator and converter unit using a free-air flow radiator placed on the top of the nacelle. In addition to the generator, converter unit and radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

2.16.2 Gearbox and Hydraulic Cooling

The gearbox and hydraulic cooling systems are coupled in parallel. A dynamic flow valve mounted in the gearbox cooling circuit divides the cooling flow. The cooling liquid removes heat from the gearbox and the hydraulic power unit through heat exchangers and a free-air flow radiator placed on the top of the nacelle. In addition to the heat exchangers and the radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

2.16.3 Transformer Cooling

The transformer is equipped with forced-air cooling. The ventilator system consists of a central fan, located below the converter and an air duct leading the air to locations beneath and between the high voltage and low voltage windings of the transformer.

2.16.4 Nacelle Cooling

Hot air generated by mechanical and electrical equipment is dissipated from the nacelle by a fan system located in the nacelle.

2.16.5 Optional Air Intake Hatches

Specific air intakes in the nacelle can optionally be fitted with hatches which can be operated as a part of the thermal control strategy. In case of lost grid to the turbine, the hatches will automatically be closed.

2.13 Crane

The nacelle houses the internal safe working load (SWL) service crane. The crane is a single system hoist.

Crane	
Lifting Capacity	Maximum 800 kg

Table 2-13: Crane data

2.14 Towers

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. The towers are designed with the majority of internal welded connections replaced by magnet supports to create a predominantly smooth-walled tower.

Magnets provide load support in a horizontal direction and internals, such as platforms, ladders, etc., are supported vertically (that is, in the gravitational direction) by a mechanical connection. The smooth tower design reduces the required steel thickness, rendering the tower lighter compared to one with all internals welded to the tower shells.

Available hub heights are listed in the Performance Specification for each turbine variant. Designated hub heights include a distance from the foundation section to the ground level of approximately 0.2 m depending on the thickness of the bottom flange and a distance from tower top flange to centre of the hub of 2.2 m.

Towers	
Type	Cylindrical/conical tubular

Table 2-14: Tower structure data

2.15 Nacelle Bedplate and Cover

The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel. The roof section is equipped with wind sensors and skylights. The skylights can be opened from inside the nacelle to access the roof and from outside to access the nacelle. Access from the tower to the nacelle is through the yaw system.

The nacelle bedplate is in two parts and consists of a cast iron front part and a girder structure rear part. The front of the nacelle bedplate is the foundation for the drive train and transmits forces from the rotor to the tower through the yaw system. The bottom surface is machined and connected to the yaw bearing and the yaw gears are bolted to the front nacelle bedplate.

The crane girders are attached to the top structure. The lower beams of the girder structure are connected at the rear end. The rear part of the bedplate serves as the foundation for controller panels, the cooling system and transformer. The nacelle cover is installed on the nacelle bedplate.

3 Electrical Design

3.1 Generator

The generator is a three-phase asynchronous induction generator with cage rotor that is connected to the grid through a full-scale converter.

The generator housing allows the circulation of cooling air within the stator and rotor. The air-to-water heat exchange occurs in an external heat exchanger.

Generator	
Type	Asynchronous with cage rotor
Rated Power [P _N]	3650 kW
Frequency [f _N]	0-100 Hz
Voltage, Stator [U _{NS}]	3 x 750 V (at rated speed)
Number of Poles	4/6
Winding Type	Form with VPI (Vacuum Pressurized Impregnation)
Winding Connection	Star or Delta
Rated rpm	1450-1550 rpm
Overspeed Limit Acc. to IEC (2 minutes)	2400 rpm
Generator Bearing	Hybrid/ceramic
Temperature Sensors, Stator	3 PT100 sensors placed at hot spots and 3 as back-up
Temperature Sensors, Bearings	1 per bearing
Insulation Class	F or H
Enclosure	IP54

Table 3-1: Generator data

3.2 Converter

The converter is a full-scale converter system controlling both the generator and the power quality delivered to the grid.

The converter consists of 3 machine-side converter units and 3 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency AC power from the generator into fixed frequency AC power with desired active and reactive power levels (and other grid connection parameters) suitable for the grid. The converter is located in the nacelle and has a grid side voltage rating of 650 V. The generator side voltage rating is up to 750 V dependent on generator speed.

Converter	
Rated Apparent Power [S _N]	4400 kVA
Rated Grid Voltage	3 x 650 V
Rated Generator Voltage	3 x 750 V
Rated Grid Current	3900 A (≤30°C ambient) / 3950 (≤20°C ambient)
Rated Generator Current	3400 A (≤30°C ambient) / 3450 (≤20°C ambient)
Enclosure	IP54

Table 3-2: Converter data

3.3 HV Transformer

The step-up HV transformer is located in a separate locked room in the back of the nacelle.

The transformer is a three-phase, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side unless otherwise specified.

The transformer comes in different versions depending on the market where it is intended to be installed.

- For 50 Hz regions the transformer is as default designed according to IEC standards. However on special request, a 60 Hz transformer based on IEC standards could also be delivered. Refer to Table 3-3.
- For turbines installed in Member States of the European Union, it is required to fulfil the Ecodesign regulation No 548/2014 set by the European Commission. Refer to Table 3-4.
- For 60 Hz regions the transformer is as default designed mainly according to IEEE standards but on areas not covered by IEEE standards, the design is also based on parts of the IEC standards. Refer to Table 3-5.

3.3.1 IEC 50 Hz/60 Hz version

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1.
Cooling method	AF
Rated power	4000 kVA
Rated voltage, turbine side	U _m 1.1kV
Rated voltage, grid side	U _m 12.0kV U _m 24.0kV U _m 36.0kV U _m 41.5kV
Insulation level AC / LI / LIC	U _m 1.1kV 3 ¹ / - / - kV U _m 12.0kV 28 ¹ / 75 / 75 kV

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3.3.2 Ecodesign - IEC 50 Hz/60 Hz version

Transformer	
Type description	Ecodesign dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1, Commission Regulation No 548/2014.
Cooling method	AF
Rated power	4000 kVA
Rated voltage, turbine side	U _m 1.1kV
Rated voltage, grid side	U _m 12.0kV U _m 24.0kV U _m 36.0kV U _m 40.5kV
Insulation level AC / LI / LIC	U _m 1.1kV 3 ¹ / - / - kV U _m 12.0kV 28 ¹ / 75 / 75 kV U _m 24.0kV 50 ¹ / 125 / 125 kV U _m 36.0kV 70 ¹ / 170 / 170 kV U _m 40.5kV 80 ¹ / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60 Hz
Vector group	Dyn5 / YNyn0
Peak Efficiency Index (PEI) ²	Ecodesign requirement
U _m 12.0kV	> 99.348
U _m 24.0kV	> 99.348
U _m 36.0kV	> 99.348
U _m 40.5kV	> 99.158
No-load loss ²	U _m 12.0kV < 5800 W U _m 24.0kV < 5800 W U _m 36.0kV < 5800 W U _m 40.5kV < 6900 W
Load loss @ rated power HV, 120°C ²	U _m 12.0kV < 29300 W U _m 24.0kV < 29300 W U _m 36.0kV < 29300 W U _m 40.5kV < 37850 W
No-load reactive power ³	~25 kVAr
Full load reactive power ³	~370 kVAr
No-load current ³	~0.5 %
Positive sequence short-circuit impedance @ rated power, 120°C ⁴	~0.8 %
Positive sequence short-circuit resistance @ rated power, 120°C ³	~8.2 %
Zero sequence short-circuit impedance @ rated power, 120°C ³	~0.7 %
Zero sequence short-circuit resistance @ rated power, 120°C ³	~0.7 %

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Transformer	
U _m 24.0kV	50 ¹ / 125 / 125 kV
U _m 36.0kV	70 ¹ / 170 / 170 kV
U _m 41.5kV	80 ¹ / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60Hz
Vector group	Dyn5 / YNyn0
No-load loss ²	~6.0 kW
Load loss @ rated power HV, 120°C ²	~30.1 kW
No-load reactive power ²	~16 kVAr
Full load reactive power ²	~345 kVAr
No-load current ²	~0.5 %
Positive sequence short-circuit impedance @ rated power, 120°C ³	~9.0 %
Positive sequence short-circuit resistance @ rated power, 120°C ²	~0.8 %
Zero sequence short-circuit impedance @ rated power, 120°C ²	~8.2 %
Zero sequence short-circuit resistance @ rated power, 120°C ²	~0.7 %
Inrush peak current ²	Dyn5 6-9 x I _n YNyn0 8-12 x I _n
Half crest time ²	~0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤ 90 K
Max altitude ⁴	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤ 9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 3-3: Transformer data for IEC 50 Hz/60 Hz version

- NOTE**
- ¹@1000m. According to IEC 60076-11, AC test voltage is altitude dependent. All values are preliminary.
 - ²Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
 - ³Subjected to standard IEC tolerances. All values are preliminary.
 - ⁴Transformer max altitude may be adjusted to match turbine location.

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Transformer	
Inrush peak current ³	Dyn5 6-9 x I _n YNyn0 8-12 x I _n
Half crest time ³	~ 0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤ 90 K
Max altitude ⁵	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤ 10000 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 3-4: Transformer data for Ecodesign IEC 50 Hz/60 Hz version.

- NOTE**
- ¹@1000m. According to IEC 60076-11, AC test voltage is altitude dependent. All values are preliminary.
 - ²For Ecodesign transformers, PEI is the legal requirement and is calculated according to the Commission Regulation based on rated power, no-load and load losses. Losses are maximum values and will not simultaneously occur in a specific design as this will be non-compliant with the PEI requirement. All values are preliminary.
 - ³Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
 - ⁴Subjected to standard IEC tolerances. All values are preliminary.
 - ⁵Transformer max altitude may be adjusted to match turbine location.

3.3.3 IEEE 60Hz version

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	UL 1562, CSA C22.2 No. 47, IEEE C57.12, IEC 60076-11, IEC 60076-16, IEC 61936-1.
Cooling method	AFA
Rated power	4000 kVA
Rated voltage, turbine side	N _{LL} 1.2 kV
Rated voltage, grid side	N _{LL} 15.0 kV N _{LL} 25.0 kV
	0.650 kV 10.0-15.0 kV 15.1-25.0 kV

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Original Instruction: T05 0058-5119 VER 00

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Transformer	
N _{LL} 34.5 kV	25.1-34.5 kV
Insulation level AC / LI & LIC	
N _{LL} 1.2 kV	4 ¹ / +10 kV
N _{LL} 15.0 kV	34 ¹ / +95 kV
N _{LL} 25.0 kV	50 ¹ / +125 kV
N _{LL} 34.5 kV	70 ¹ / (+150 & -170) or +170 kV
Off-circuit tap changer	
Frequency	±2 x 2.5 %
Vector group	60 Hz
No-load loss ²	Dyn5 / YNyn0
Load loss @ rated power HV, 120°C ²	~6.0 kW
No-load reactive power ²	~30.1 kW
Full load reactive power ²	~16 kVAr
No-load current ²	~345 kVAr
Positive sequence short-circuit impedance @ rated power, 120°C ³	~0.5 %
Positive sequence short-circuit resistance @ rated power, 120°C ²	~9.0 %
Zero sequence short-circuit impedance @ rated power, 120°C ²	~0.7 %
Zero sequence short-circuit resistance @ rated power, 120°C ²	~8.3 %
Zero sequence short-circuit resistance @ rated power, 120°C ²	~0.7 %
Inrush peak current ²	
	Dyn5 6-9 x I _n
	YNyn0 8-12 x I _n
Half crest time ²	~ 0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤ 90 K
Max altitude ⁴	2000 m
Insulation class	150°C
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤ 9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 3-5: Transformer data for IEEE 60 Hz version

- NOTE**
- ¹ @1000m. According to IEEE C57.12, AC test voltage is altitude dependent. All values are preliminary.
 - ² Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
 - ³ Subjected to standard IEEE C57.12 tolerances. All values are preliminary.
 - ⁴ Transformer max altitude may be adjusted to match turbine location.



HV Switchgear	Basic	Streamline	Standard
IEC standards	○	⊙	⊙
IEEE standards	⊙	○	⊙
Vacuum circuit breaker panel	○	⊙	⊙
Overcurrent, short-circuit and earth fault protection	⊙	⊙	⊙
Disconnecter / earthing switch in circuit breaker panel	○	⊙	⊙
Voltage Presence Indicator System for circuit breaker	○	⊙	⊙
Voltage Presence Indicator System for grid cables	○	⊙	⊙
Double grid cable connection	○	⊙	⊙
Triple grid cable connection	○	○	○
Preconfigured relay settings	○	⊙	⊙
Turbine safety system integration	○	⊙	⊙
Redundant trip coil circuits	○	⊙	⊙
Trip coil supervision	○	⊙	⊙
Pendant remote control from outside of tower	○	⊙	⊙
Sequential energization	○	⊙	⊙
Reclose blocking function	○	⊙	⊙
Heating elements	○	⊙	⊙
Trapped-key interlock system for circuit breaker panel	○	⊙	⊙
UPS power back-up for protection circuits	○	⊙	⊙
Motor operation of circuit breaker	○	⊙	⊙
Cable panel for grid cables (configurable)	○	⊙	⊙
Switch disconnector panels for grid cables – max three panels (configurable)	○	⊙	⊙
Earthing switch for grid cables	○	⊙	⊙
Internal arc classification	○	⊙	⊙
Supervision on MCB's	○	⊙	⊙
Motor operation of switch disconnector	○	○	○
SCADA ready	○	○	○
SCADA operation of circuit breaker	○	○	○
SCADA operation of switch disconnector	○	○	○

Table 3-7: HV switchgear variants and features.



3.4 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the HV switchgear located at the bottom of the tower. The high-voltage cable is a four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
High-Voltage Cable Insulation Compound	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
Conductor Cross Section	3 x 70 / 70 mm ²
Maximum Voltage	24 kV for 10.0-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage

Table 3-6: HV cables data

3.5 HV Switchgear

A gas insulated switchgear is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This ensures all protection devices are fully operational whenever high voltage components in the turbine are energised. The earthing switch of the circuit breaker contains a trapped-key interlock system with its counterpart installed on the access door to the transformer room in order to avoid unauthorized access to the transformer room during live condition.

The switchgear is available in three variants with increasing features, see Table 3-7. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class. The electrical parameters of the switchgear are seen in Table 3-8 for the IEC version and in Table 3-9 for the IEEE version.



3.5.1 IEC 50/60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200, IEC 60694
Insulation medium	SF ₆
Rated voltage	
	U, 24.0kV 10.0-22.0 kV
	U, 36.0kV 22.1-33.0 kV
	U, 40.5kV 33.1-36.0 kV
Rated insulation level AC // LI	
Common value / across isolation distance	
	U, 24.0kV 50 / 60 // 125 / 145 kV
	U, 36.0kV 70 / 80 // 170 / 195 kV
	U, 40.5kV 85 / 90 // 185 / 215 kV
Rated frequency	50 Hz / 60 Hz
Rated normal current	630 A
Rated Short-time withstand current	
	U, 24.0kV 20 kA
	U, 36.0kV 25 kA
	U, 40.5kV 25 kA
Rated peak withstand current 50 / 60 Hz	
	U, 24.0kV 50 / 52 kA
	U, 36.0kV 62.5 / 65 kA
	U, 40.5kV 62.5 / 65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	
	U, 24.0kV IAC A FLR 20 kA, 1 s
	U, 36.0kV IAC A FLR 25 kA, 1 s
	U, 40.5kV IAC A FLR 25 kA, 1 s
Connection interface	Outside cone plug-in bushings, IEC interface C1.
Loss of service continuity category	LSC2
Ingress protection	
	Gas tank IP 65
	Enclosure IP 2X
	LV cabinet IP 3X
Corrosion class	C3

Table 3-8: HV switchgear data for IEC version.

3.5.2 IEEE 60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
Insulation medium	SF ₆
Rated voltage	
	U, 38.0kV 22.1-36.0 kV



HV Switchgear	
Rated insulation level AC / LI	70 / 150 kV
Rated frequency	60 Hz
Rated normal current	600 A
Rated Short-time withstand current	25 kA
Rated peak withstand current	65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	IAC A FLR 25 kA, 1 s
Connection interface grid cables	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
Ingress protection	
	Gas tank NEMA 4X / IP 65
	Enclosure NEMA 2 / IP 2X
	LV cabinet NEMA 2 / IP 3X
Corrosion class	C3

Table 3-9: HV switchgear data for IEEE version.

3.6 AUX System

The AUX system is supplied from a separate 650/400 V transformer located in the nacelle inside the converter cabinet. All motors, pumps, fans and heaters are supplied from this system.

All 230 V consumers are supplied from a 400/230 V transformer located in the tower base.

Power Sockets	
Single Phase (Nacelle and Tower Platforms)	230 V (16 A)/110 V (16 A)/ 2 x 55 V (16 A)
Three Phase (Nacelle and Tower Base)	3 x 400 V (16 A)

Table 3-10: AUX system data

3.7 Wind Sensors

The turbine is either equipped with two ultrasonic wind sensors or optional one ultrasonic wind sensor and one mechanical wind vane and anemometer. The sensors have built-in heaters to minimise interference from ice and snow. The wind sensors are redundant, and the turbine is able to operate with one sensor only.

3.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the VMP8000 control system. VMP8000 is a multiprocessor control system comprised of main controller, distributed control nodes, distributed IO nodes and ethernet switches and other network equipment. The main controller is placed in the tower bottom of the turbine. It runs the control algorithms of the turbine, as well as all IO communication.



NOTE For alternative backup times, consult Vestas.

4 Turbine Protection Systems

4.1 Braking Concept

The main brake on the turbine is aerodynamic. Stopping the turbine is done by full feathering the three blades (individually turning each blade). Each blade has a hydraulic accumulator to supply power for turning the blade.

In addition, there is a mechanical disc brake on the high-speed shaft of the gearbox with a dedicated hydraulic system. The mechanical brake is only used as a parking brake and when activating the emergency stop buttons.

4.2 Short Circuit Protections

Breakers	Breaker for Aux. Power. (not settled)	Breaker for Converter Modules (not settled)
Breaking Capacity, Icu, Ics	TBD	TBD
Making Capacity, Icm	TBD	TBD

Table 4-1: Short circuit protection data

4.3 Overspeed Protection

The generator rpm and the main shaft rpm are registered by inductive sensors and calculated by the wind turbine controller to protect against overspeed and rotating errors.

The safety-related partition of the VMP8000 control system monitors the rotor rpm. In case of an overspeed situation, the safety-related partition of the VMP8000 control system activates the emergency feathered position (full feathering) of the three blades independently of the non-safety related partition of VMP8000 control system.

Overspeed Protection	
Sensors Type	Inductive
Trip Level (variant dependent)	17.66 (rotor rpm) / 2000 (generator rpm)

Table 4-2: Overspeed protection data

4.4 Arc Detection

The turbine is equipped with an Arc Detection system including multiple optical arc detection sensors placed in the HV transformer compartment and the converter cabinet. The Arc Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if an arc is detected.



The communications network is a time triggered Ethernet network (TTEthernet).

The VMP8000 control system serves the following main functions:

- Monitoring and supervision of overall operation.
- Synchronizing of the generator to the grid during connection sequence.
- Operating the wind turbine during various fault situations.
- Automatic yawing of the nacelle.
- OptiTip® - blade pitch control.
- Reactive power control and variable speed operation.
- Noise emission control.
- Monitoring of ambient conditions.
- Monitoring of the grid.
- Monitoring of the smoke detection system.

3.9 Uninterruptible Power Supply (UPS)

During grid outage, an UPS system will ensure power supply for specific components.

The UPS system is built by 3 subsystems:

1. 230V AC UPS for all power backup to nacelle and hub control systems
2. 24V DC UPS for power backup to tower base control systems and optional SCADA Power Plant Controller.
3. 230V AC UPS for power backup to internal lights in tower and nacelle. Internal light in the hub is fed from built-in batteries in the light armature.

UPS	Standard	Optional
Backup Time		
Control System* (230V AC and 24V DC UPS)	15 min	Up to 400 min**
Internal Lights (230V AC UPS)	30 min	60 min***
Optional SCADA Power Plant Controller (24V DC UPS)	N/A	48 hours****

Table 3-11: UPS data

*The control system includes: the turbine controller (VMP8000), HV switchgear functions, and remote control system.

**Requires upgrade of the 230V UPS for control system with extra batteries.

***Requires upgrade of the 230V UPS for internal light with extra batteries.

****Requires upgrade of the 24V DC UPS with extra batteries.



4.5 Smoke Detection

The turbine is equipped with a Smoke Detection system including multiple smoke detection sensors placed in the nacelle (above the disc brake), in the transformer compartment, in main electrical cabinets in the nacelle and above the HV switchgear in the tower base. The Smoke Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if smoke is detected.

4.6 Lightning Protection of Blades, Nacelle, Hub and Tower

The Lightning Protection System (LPS) helps protect the wind turbine against the physical damage caused by lightning strikes. The LPS consists of five main parts:

- Lightning receptors. All lightning receptor surfaces on the blades including the Solid Metal Tips (SMT) are unpainted as standard.
- Down conducting system (a system to conduct the lightning current down through the wind turbine to help avoid or minimise damage to the LPS itself or other parts of the wind turbine).
- Protection against overvoltage and overcurrent.
- Shielding against magnetic and electrical fields.
- Earthing system.

Lightning Protection Design Parameters	Protection Level I
Current Peak Value	i_{max} [kA] 200
Impulse Charge	$Q_{impulse}$ [C] 100
Long Duration Charge	Q_{long} [C] 200
Total Charge	Q_{total} [C] 300
Specific Energy	W/R [MJ/Ω] 10
Average Steepness	di/dt [kA/μs] 200

Table 4-3: Lightning protection design parameters

NOTE The Lightning Protection System is designed according to IEC standards (see section 7 Design Codes, p. 28).

4.7 EMC

The turbine and related equipment fulfils the EU Electromagnetic Compatibility (EMC) legislation:

- DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.



4.8 Earthing

The Vestas Earthing System consists of a number of individual earthing electrodes interconnected as one joint earthing system.

The Vestas Earthing System includes the TN-system and the Lightning Protection System for each wind turbine. It works as an earthing system for the medium voltage distribution system within the wind farm.

The Vestas Earthing System is adapted for the different types of turbine foundations. A separate set of documents describe the earthing system in detail, depending on the type of foundation.

In terms of lightning protection of the wind turbine, Vestas has no separate requirements for a certain minimum resistance to remote earth (measured in ohms) for this system. The earthing for the lightning protection system is based on the design and construction of the Vestas Earthing System.

A primary part of the Vestas Earthing System is the main earth bonding bar placed where all cables enter the wind turbine. All earthing electrodes are connected to this main earth bonding bar. Additionally, equipotential connections are made to all cables entering or leaving the wind turbine.

Requirements in the Vestas Earthing System specifications and work descriptions are minimum requirements from Vestas and IEC. Local and national requirements, as well as project requirements, may require additional measures.

4.9 Corrosion Protection

Classification of corrosion protection is according to ISO 12944-2.

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5-M	C3
Hub	C5-M	C3
Tower	C5-I	C3

Table 4-4: Corrosion protection data for nacelle, hub, and tower

5 Safety

The safety specifications in this section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and its agents taking all appropriate safety precautions, including but not limited to (a) complying with all applicable safety, operation, maintenance, and service agreements, instructions, and requirements, (b) complying with all safety-related laws, regulations, and ordinances, and (c) conducting all appropriate safety training and education.

5.1 Access

Access to the turbine from the outside is through a door located at the entrance platform approximately 3 meter above ground level. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift. Access to the nacelle from the top platform is by ladder. Access to the transformer room

5.8 Lights

The turbine is equipped with lights in the tower, nacelle, transformer room, and hub.

There is emergency light in case of the loss of electrical power.

5.9 Emergency Stop

There are emergency stop buttons in the nacelle, hub and bottom of the tower.

5.10 Power Disconnection

The turbine is equipped with breakers to allow for disconnection from all power sources during inspection or maintenance. The switches are marked with signs and are located in the nacelle and bottom of the tower.

5.11 Fire Protection/First Aid

A handheld 5-6 kg CO₂ fire extinguisher, first aid kit and fire blanket are required to be located in the nacelle during service and maintenance.

- A handheld 5-6 kg CO₂ fire extinguisher is required only during service and maintenance activities, unless a permanently mounted fire extinguisher located in the nacelle is mandatorily required by authorities.
- First aid kits are required only during service and maintenance activities.
- Fire blankets are required only during non-electrical hot work activities.

5.12 Warning Signs

Warning signs placed inside or on the turbine must be reviewed before operating or servicing the turbine.

5.13 Manuals and Warnings

The Vestas Corporate OH&S Manual and manuals for operation, maintenance and service of the turbine provide additional safety rules and information for operating, servicing or maintaining the turbine.

6 Environment

6.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2004. The following chemicals are used in the turbine:

- Anti-freeze to help prevent the cooling system from freezing.
- Gear oil for lubricating the gearbox.
- Hydraulic oil to pitch the blades and operate the brake.
- Grease to lubricate bearings.
- Various cleaning agents and chemicals for maintenance of the turbine.

in the nacelle is controlled with a lock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

5.2 Escape

In addition to the normal access routes, alternative escape routes from the nacelle are through the crane hatch, from the spinner by opening the nose cone, or from the roof of the nacelle. Rescue equipment is placed in the nacelle.

The hatch in the roof can be opened from both the inside and outside.

Escape from the service lift is by ladder.

An emergency response plan, placed in the turbine, describes evacuation and escape routes.

5.3 Rooms/Working Areas

The tower and nacelle are equipped with power sockets for electrical tools for service and maintenance of the turbine.

5.4 Floors, Platforms, Standing, and Working Places

All floors have anti-slip surfaces.

There is one floor per tower section.

Rest platforms are provided at intervals of 9 metres along the tower ladder between platforms.

Foot supports are placed in the turbine for maintenance and service purposes.

5.5 Service Lift

The turbine is delivered with a service lift installed as an option.

5.6 Climbing Facilities

A ladder with a fall arrest system (rigid rail) is installed through the tower.

There are anchor points in the tower, nacelle and hub, and on the roof for attaching fall arrest equipment (full-body harness).

Over the crane hatch there is an anchor point for the emergency descent equipment.

Anchor points are coloured yellow and are calculated and tested to 22.2 kN.

5.7 Moving Parts, Guards, and Blocking Devices

All moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to block the rotor and drive train.

Blocking the pitch of the cylinder can be done with mechanical tools in the hub.

7 Design Codes

7.1 Design Codes – Structural Design

The turbine design has been developed and tested with regard to, but not limited to, the following main standards:

Design Codes	
Nacelle and Hub	IEC 61400-1 Edition 3 EN 50308
Tower	IEC 61400-1 Edition 3 Eurocode 3
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2
Gearbox	ISO 81400-4
Generator	IEC 60034
Transformer	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
Lightning Protection	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006 IEC 61400-24:2010
Rotating Electrical Machines	IEC 34
Safety of Machinery, Safety-related Parts of Control Systems	IEC 13849-1
Safety of Machinery – Electrical Equipment of Machines	IEC 60204-1

Table 7-1: Design codes

8 Colours

8.1 Nacelle Colour

Colour of Vestas Nacelles	
Standard Nacelle Colour	RAL 7035 (light grey)
Standard Logo	Vestas

Table 8-1: Colour, nacelle

8.2 Tower Colour

Colour of Vestas Tower Section		
	External:	Internal:
Standard Tower Colour	RAL 7035 (light grey)	RAL 9001 (cream white)

Table 8-2: Colour, tower

8.3 Blade Colour

Blade Colour	
Standard Blade Colour	RAL 7035 (light grey). All lightning receptor surfaces on the blades including the Solid Metal Tips (SMT) are unpainted as standard.
Tip-End Colour Variants	RAL 2009 (traffic orange), RAL 3020 (traffic red)
Gloss	< 30% DS/EN ISO 2813

Table 8-3: Colour, blades

9 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

9.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	All
Ambient Temperature Interval (Standard Temperature Turbine)	-40° to +50°C

Table 9-1: Extreme design parameters



9.4 Operational Envelope – Temperature and Altitude Derating in 3.45 MW Power Mode

Figure 9-2 shows the corresponding derating chart for 3.45 MW Power Mode.

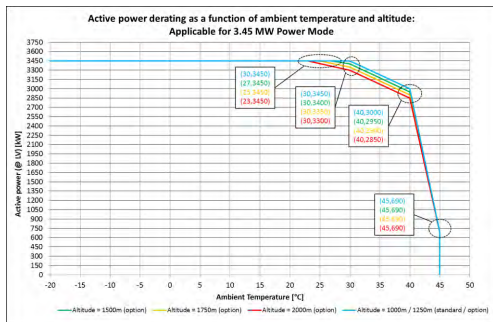


Figure 9-2: Temperature and altitude derated operation for 3.45 MW Power Mod.

9.5 Operational Envelope – Temperature and Altitude Derating in 3.0 MW Derated Mode

Figure 9-3 shows the corresponding derating chart for 3.0 MW Derated Mode.

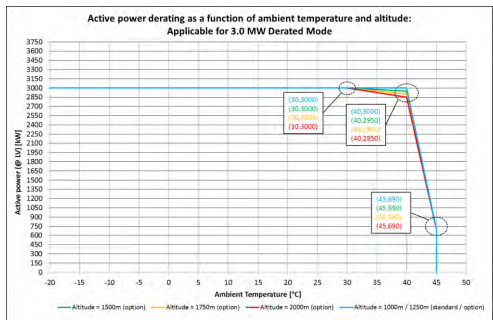


Figure 9-3: Temperature and altitude derated operation for 3.0 MW Derated Mode.



9.2 Operational Envelope – Temperature and Altitude

Values below refer to hub height and are determined by the sensors and control system of the turbine.

Operational Envelope – Temperature	
Ambient Temperature Interval (Standard Turbine)	-20° to +45°C
Ambient Temperature Interval (Low Temperature Turbine)	-30° to +45°C

Table 9-2: Operational envelope – temperature

NOTE The wind turbine will stop producing power at ambient temperatures above 45°C. For the low temperature options of the wind turbine, consult Vestas.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

9.3 Operational Envelope – Temperature and Altitude Derating in 3.3 MW Mode 0

Values below refer to hub height and are determined by the sensors and control system of the turbine.

At ambient temperatures above an altitude-specific threshold (+30°C for ≤1250 m.a.s.l.), the turbine will maintain derated production in 3.3 MW Mode 0 as shown in Figure 9-1.

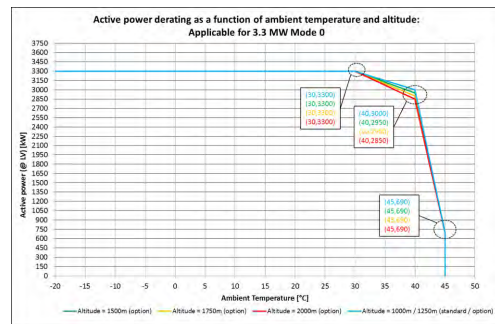


Figure 9-1: Temperature and altitude derated operation for 3.3 MW Mode 0.



9.6 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
Nominal Phase Voltage	[U _{NP}]	650 V
Nominal Frequency	[f _N]	50/60 Hz
Maximum Frequency Gradient		±4 Hz/sec.
Maximum Negative Sequence Voltage		3% (connection) 2% (operation)
Minimum Required Short Circuit Ratio at Turbine HV Connection		5.0
Maximum Short Circuit Current Contribution		1.05 p.u. (continuous) 1.45 p.u. (peak)

Table 9-3: Operational envelope – grid connection

The generator and the converter will be disconnected if*:

Protection Settings	
Voltage Above 110% of Nominal for 3600 Seconds	715 V
Voltage Above 121% of Nominal for 2 Seconds	787 V
Voltage Above 136% of Nominal for 0.150 Seconds	884 V
Voltage Below 90% of Nominal for 60 Seconds	585 V
Voltage Below 80% of Nominal for 10 Seconds	520 V
Frequency is Above 106% of Nominal for 0.2 Seconds	53/63.6 Hz
Frequency is Below 94% of Nominal for 0.2 Seconds	47/56.4 Hz

Table 9-4: Generator and converter disconnecting values

NOTE * Over the turbine lifetime, grid drop-outs are to occur at an average of no more than 50 times a year.

** The turbine may be configured for continuous operation @ +/- 13 % voltage. Reactive power capability is limited for these widened settings (See section 10.4). All protection settings are preliminary and subject to change.



9.7 Operational Envelope – Reactive Power Capability in 3.3 MW Mode 0

The 3.3 MW turbine has a reactive power capability in Mode 0 on the low voltage side of the HV transformer as illustrated in Figure 9-4:

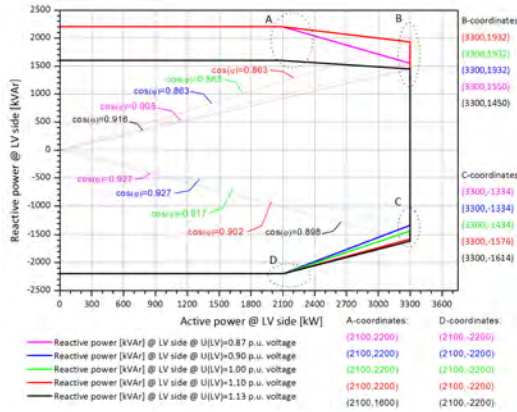


Figure 9-4: Reactive power capability for 3.3 MW Mode 0.

When operating at 3.3 MW in Mode 0 at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.91$ capacitive @ $U(HV) = 0.87$ p.u. voltage
- $\cos\phi(HV) = 0.91/0.91$ capacitive/inductive @ $U(HV) = 0.89$ p.u. voltage
- $\cos\phi(HV) = 0.90/0.89$ capacitive/inductive @ $U(HV) = 0.90$ p.u. voltage
- $\cos\phi(HV) = 0.90/0.88$ capacitive/inductive @ $U(HV) = 1.00$ p.u. voltage
- $\cos\phi(HV) = 0.91/0.89$ capacitive/inductive @ $U(HV) = 1.10$ p.u. voltage
- $\cos\phi(HV) = 0.95/0.89$ capacitive/inductive @ $U(HV) = 1.13$ p.u. voltage

Reactive power is produced by the full-scale converter. Traditional capacitors are, therefore, not used in the turbine.

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE All reactive power capability values are preliminary and subject to change.

3.3 MW Mode 0 derates above +30°C ambient temperature for ≤ 1250 m.a.s.l. according to Figure 9-1.

9.9 Operational Envelope – Reactive Power Capability in 3.45 MW Reactive Power Optimized Mode (QO1)

An optional, extended reactive power capability is available with 3.45 MW Reactive Power Optimized Mode (QO1) when ambient temperature is below +20°C for ≤ 1250 m.a.s.l. The reactive power capability is as seen in Figure 9-6:

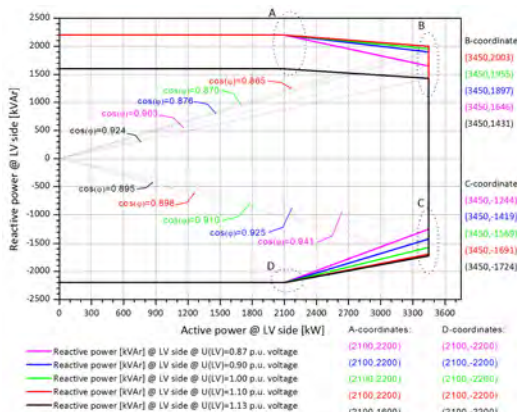


Figure 9-6: Reactive power capability for 3.45 MW Reactive Power Optimized Mode (QO1).

When operating at 3.45 MW in Reactive Power Optimized Mode (QO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.92$ capacitive @ $U(HV) = 0.87$ p.u. voltage
- $\cos\phi(HV) = 0.92/0.91$ capacitive/inductive @ $U(HV) = 0.89$ p.u. voltage
- $\cos\phi(HV) = 0.91/0.90$ capacitive/inductive @ $U(HV) = 0.90$ p.u. voltage
- $\cos\phi(HV) = 0.90/0.88$ capacitive/inductive @ $U(HV) = 1.00$ p.u. voltage
- $\cos\phi(HV) = 0.94/0.87$ capacitive/inductive @ $U(HV) = 1.10$ p.u. voltage
- $\cos\phi(HV) = 0.97/0.87$ capacitive/inductive @ $U(HV) = 1.13$ p.u. voltage

NOTE All reactive power capability values are preliminary and subject to change.

3.45 MW Reactive Power Optimized Mode (QO1) derates reactive power linearly above +20°C ambient temperature for ≤ 1250 m.a.s.l. to converge with the reactive power capability of 3.45 MW Power Mode in Figure 9-5 at +30°C.

9.8 Operational Envelope – Reactive Power Capability in 3.45 MW Power Mode

The reactive power capability in 3.45 MW Power Mode on the low voltage side of the HV transformer is as illustrated in Figure 9-5:

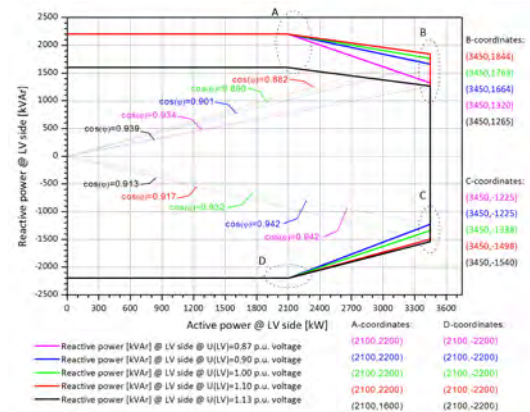


Figure 9-5: Reactive power capability for 3.45 MW Power Mode.

When operating at 3.45 MW Power Mode at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.95$ capacitive @ $U(HV) = 0.87$ p.u. voltage
- $\cos\phi(HV) = 0.94/0.94$ capacitive/inductive @ $U(HV) = 0.88$ p.u. voltage
- $\cos\phi(HV) = 0.93/0.91$ capacitive/inductive @ $U(HV) = 0.90$ p.u. voltage
- $\cos\phi(HV) = 0.92/0.90$ capacitive/inductive @ $U(HV) = 1.00$ p.u. voltage
- $\cos\phi(HV) = 0.95/0.89$ capacitive/inductive @ $U(HV) = 1.10$ p.u. voltage
- $\cos\phi(HV) = 0.98/0.89$ capacitive/inductive @ $U(HV) = 1.13$ p.u. voltage

NOTE All reactive power capability values are preliminary and subject to change.

3.45 MW Power Mode derates above +30°C ambient temperature for ≤ 1250 m.a.s.l. according to Figure 9-2.

9.10 Operational Envelope – Reactive Power Capability in 3.0 MW Derated Mode

The reactive power capability for the 3.0 MW Derated Mode is as illustrated in Figure 9-7:

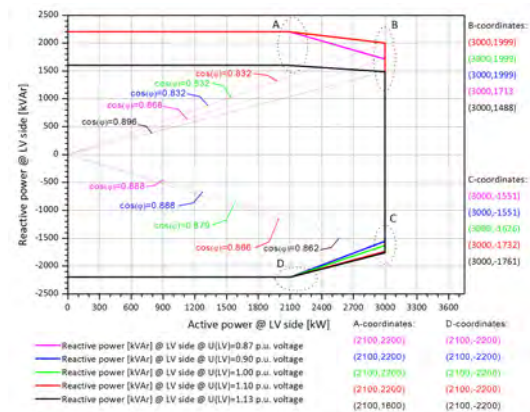


Figure 9-7: Reactive power capability for 3.0 MW Derated Mode.

When operating at 3.0 MW Derated Mode at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.88$ capacitive @ $U(HV) = 0.87$ p.u. voltage
- $\cos\phi(HV) = 0.88/0.87$ capacitive/inductive @ $U(HV) = 0.89$ p.u. voltage
- $\cos\phi(HV) = 0.87/0.85$ capacitive/inductive @ $U(HV) = 0.90$ p.u. voltage
- $\cos\phi(HV) = 0.87/0.85$ capacitive/inductive @ $U(HV) = 1.00$ p.u. voltage
- $\cos\phi(HV) = 0.88/0.86$ capacitive/inductive @ $U(HV) = 1.10$ p.u. voltage
- $\cos\phi(HV) = 0.92/0.86$ capacitive/inductive @ $U(HV) = 1.13$ p.u. voltage

NOTE All reactive power capability values are preliminary and subject to change.

3.0 MW Derated Mode derates above +30°C ambient temperature for ≤ 1250 m.a.s.l. according to Figure 9-3.

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9.11 Performance – Fault Ride Through

The turbine is equipped with a full-scale converter to gain better control of the wind turbine during grid faults. The turbine control system continues to run during grid faults.

The turbine is designed to stay connected during grid disturbances within the voltage tolerance curve as illustrated:

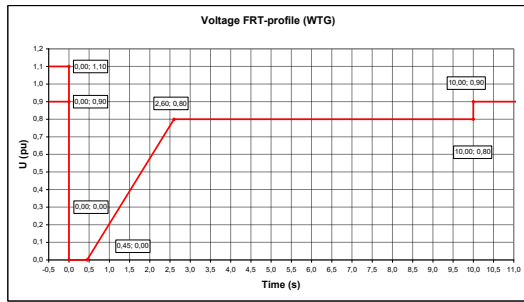


Figure 9-8: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.

For grid disturbances outside the tolerance curve in Figure 9-8, the turbine will be disconnected from the grid.

NOTE All fault ride through capability values are preliminary and subject to change.

Power Recovery Time	
Power Recovery to 90% of Pre-Fault Level	Maximum 0.1 seconds

Table 9-5: Power recovery time

9.12 Performance – Reactive Current Contribution

The reactive current contribution depends on whether the fault applied to the turbine is symmetrical or asymmetrical.

NOTE All reactive current contribution values are preliminary and subject to change.

9.12.1 Symmetrical Reactive Current Contribution

During symmetrical voltage dips, the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the measured grid voltage.

The default value gives a reactive current part of 1 p.u. of the rated active current at the high voltage side of the HV transformer. Figure 9-9 indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level.

As seen in Figure 9-9, the default current injection slope is 2% reactive current increase per 1% voltage decrease. The slope can be parameterized between 0 and 10 to adapt to site specific requirements.

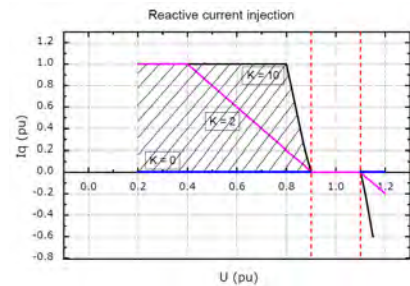


Figure 9-9: Reactive current injection

9.12.2 Asymmetrical Reactive Current Contribution

The injected current is based on the measured positive sequence voltage and the used K-factor. During asymmetrical voltage dips, the reactive current injection is limited to approximate 0.4 p.u. to limit the potential voltage increase on the healthy phases.

9.13 Performance – Multiple Voltage Dips

The turbine is designed to handle re-closure events and multiple voltage dips within a short period of time due to the fact that voltage dips are not evenly distributed during the year. For example, the turbine is designed to handle 10 voltage dips of duration of 200 ms, down to 20% voltage, within 30 minutes.

9.14 Performance – Active and Reactive Power Control

The turbine is designed for control of active and reactive power via the VestasOnline® SCADA system.

Maximum Ramp Rates for External Control	
Active Power	0.1 p.u./sec for max. power level change of 0.3 p.u. 0.3 p.u./sec for max. power level change of 0.1 p.u.
Reactive Power	20 p.u./sec

Table 9-6: Active/reactive power ramp rates (values are preliminary)

To support grid stability the turbine is capable to stay connected to the grid at active power references down to 10 % of nominal power for the turbine. For active power references below 10 % the turbine may disconnect from the grid.

9.15 Performance – Voltage Control

The turbine is designed for integration with VestasOnline® voltage control by utilising the turbine reactive power capability.

9.16 Performance – Frequency Control

The turbine can be configured to perform frequency control by decreasing the output power as a linear function of the grid frequency (over frequency). Dead band and slope for the frequency control function are configurable.

9.17 Distortion – Immunity

The turbine is able to connect with a pre-connection (background) voltage distortion level at the grid interface of 8% and operate with a post-connection voltage distortion level of 8%.

9.18 Main Contributors to Own Consumption

The consumption of electrical power by the wind turbine is defined as the power used by the wind turbine when it is not providing energy to the grid. This is defined in the control system as Production Generator 0 (zero).

The components in Table 9-7 have the largest influence on the own consumption of the wind turbine (the average own consumption depends on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.).

The VMP8000 control system has a hibernate mode that reduces own consumption when possible. Similarly, cooling pumps may be turned off when the turbine idles.

Main contributors to Own Consumption	
Hydraulic Motor	2 x 15 kW (master/slave)
Yaw Motors	Maximum 18 kW in total
Water Heating	10 kW
Water Pumps	2.2 + 4.0 kW
Oil Heating	7.9 kW
Oil Pump for Gearbox Lubrication	10 kW
Controller Including Heating Elements for the Hydraulics and all Controllers	Approximately 3 kW
HV Transformer No-load Loss	See section 3.3 HV Transformer, p. 13

Table 9-7: Main contributors to own consumption data (values are preliminary).

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10 Type Approvals and Available Hub Heights

The standard turbine is type certified according to the certification standards and available hub heights listed below:

Certification	Wind Class	Hub Height
IEC61400-22	IEC IIA	84 m / 94 m
	IEC IIA	119 m
DIBt 2012	WZ3, GKII, TKA	140 m
	WZ4, GKI, TKA	94 m / 119 m

Table 10-1: Type approval data and available hub heights

11 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

11.1 Climate and Site Conditions

The standard turbine is designed for the wind climate conditions listed below. Values refer to hub height.

Extreme Design Parameters		
Wind Climate	IEC IIA	
Extreme Wind Speed (10 min average), V_{50}	42.5 m/s	
Survival Wind Speed (3 s gust), V_{50}	59.5 m/s	
Extreme Design Parameters for Towers designed according to DIBt 2012		
Hub Height	HH 94 m / 119 m (DIBt 2012)	HH 140 m (DIBt 2012)
Extreme Wind Speed (10 min average), V_{50}	46.32 m/s / 47.65 m/s	41.95 m/s
Survival Wind Speed (3 s gust), V_{50}	64.85 m/s / 66.71 m/s	58.73 m/s

Table 11-1: Extreme design parameters

Average Design Parameters	
Wind Climate	IEC IIA
Wind Speed (10 min average), V_{ave} (3.3 MW rating)	8.5 m/s
Weibull Scale Factor, C (3.3 MW rating)	9.59 m/s
Wind Speed (10 min average), V_{ave} (3.45 MW rating)	8.5 m/s
Weibull Scale Factor, C (3.45 MW rating)	9.59 m/s

Table 11-1: Average design parameters

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Average Design Parameters		
Wind Climate	IEC IIA	
Weibull Shape Factor, k	2.0	
Turbulence Intensity According to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s) I_{ref} (90% quantile)	18%	
Wind shear, α	0.20	
Inflow Angle (vertical)	8°	
Average Design Parameters for Towers designed according to DIBt 2012		
Hub Height	HH 94 m / 119 m (DIBt 2012)	HH 140 m (DIBt 2012)
Wind Speed, V_{ave} (3.3 MW rating)	8.34 m/s / 8.58 m/s	7.55 m/s
Wind Speed, V_{ave} (3.45 MW rating)	8.34 m/s / 8.58 m/s	7.55 m/s
Turbulence Intensity, I_{ref}	16%	16%

Table 11-2: Average design parameters

11.1.1 Complex Terrain

Classification of complex terrain according to IEC 61400-1:2005 Chapter 11.2. For sites classified as complex, appropriate measures are to be included in site assessment. Positioning of each turbine must be verified via Vestas Site Check.

11.1.2 Altitude

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

11.1.3 Wind Power Plant Layout

Turbine spacing is to be evaluated site-specifically. Spacing below two rotor diameters (2D) may require sector-wise curtailment.

NOTE As evaluation of climate and site conditions is complex, consult Vestas for every project. If conditions exceed the above parameters, Vestas must be consulted.

11.2 Operational Envelope – Wind

Values refer to hub height and are determined by the sensors and control system of the turbine.

Hub height	84 m / 94 m / 119 m / 140 m
Cut-In, V_{in}	3 m/s
Cut-Out (10 min expon. avg.), V_{out}	25.0 m/s
Re-Cut In (10 min exponential avg.)	23.0 m/s

Table 11-3: Operational envelope – wind - IEC



Available Noise Modes for V112-3.3 MW		
Available Power Modes / Derated Modes for V112		
Mode	Maximum Noise Level	Standard/Option
3.45 MW	105.8 dB	Standard
	104.4 dB	Option
3.0 MW	105.8 dB	Standard
	104.4 dB	Option

Table 11-5: Available noise performance

NOTE All optional noise reduced operational modes requires special blade configuration with serrated trailing edge.

The noise/power modes are available for the hub heights listed in table tower structure data in section 10 Type Approvals and Available Hub Heights, p. 40, except for noise mode 4 which is not available for hub height 119 m (DIBt).

For further details on Noise Modes, see section 14 Appendices, p. 46, or contact Vestas Wind Systems A/S.



11.3 Operational Envelope – Conditions for Power Curve and C_t Values (at Hub Height)

Consult Section 14 Appendices, p. 46 for power curves and C_t values.

Conditions for Power Curve and C_t Values (at Hub Height)	
Wind Shear, α	0.00-0.30 (10 minute average)
Turbulence Intensity, I	6-12% (10 minute average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow Angle (Vertical)	0 ±2°
Grid Voltage	Nominal Voltage ±2.5%
Grid Frequency	Nominal Frequency ±0.5 Hz
Grid Reactive Power (at LV-side of turbine transformer)	Power Factor 1.0

Table 11-4: Conditions for power curve and C_t values

11.4 Noise modes

The noise modes listed below are available for the turbine.

Available Noise Modes for V112-3.3 MW		
Mode	Maximum Noise Level	Standard/Option
0	105.8 dB	Standard
	104.4 dB	Option
2	104.5 dB	Standard
	103.2 dB	Option
3	102.3 dB	Standard
	101.3 dB	Option
4	100.9 dB	Standard
	100.0 dB	Option
5	104.2 dB	Standard
	103.1 dB	Option
8	99.4 dB	Standard
	98.1 dB	Option



12 Drawings

12.1 Structural Design – Illustration of Outer Dimensions

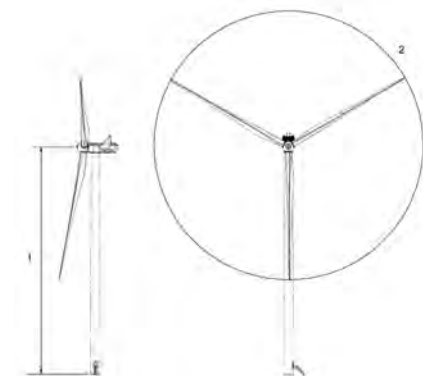


Figure 12-1: Illustration of outer dimensions – structure

- 1 Hub heights: See section 10 Type Approvals and Available Hub Heights, p. 40
- 2 Rotor diameter: 112 m

12.2 Structural Design – Side View Drawing



Figure 12-2: Side-view drawing



13 General Reservations, Notes and Disclaimers

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The general specifications described in this document apply to the current version of the V112-3.3/3.45 MW wind turbine. Updated versions of the V112-3.3/3.45 MW wind turbine, which may be manufactured in the future, may differ from these general specifications.
Vestas recommends that the grid be as close to nominal as possible with limited variation in frequency and voltage.
A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements and codes of standards.
This document, General Description, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.

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14.1.2 Ct Values, Noise Mode 0

Table with columns for Wind speed [m/s] and Air density kg/m³, and rows for Ct values from 3.0 to 25.0 across various air density conditions.

Table 14-2: C_t values, noise mode 0



14 Appendices

14.1 Mode 0

14.1.1 Power Curves, Noise Mode 0

Table with columns for Wind speed [m/s] and Air density [kg/m³], and rows for power curves from 3.0 to 25.0 across various air density conditions.

Table 14-1: Power curve, noise mode 0



14.1.3 Noise Curves, Noise Mode 0

Table with columns for Wind speed at hub height [m/s], Sound Power Level at Hub Height [dBA] (Blades without optional serrated trailing edge), and Sound Power Level at Hub Height [dBA] (Blades with optional serrated trailing edge). Rows for noise curves from 3 to 20.

Table 14-3: Noise curves, noise mode 0



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14.2 Mode 2

14.2.1 Power Curves, Noise Mode 2

Table with columns for Wind speed [m/s] and Air density [kg/m³] (1.225 to 1.275). Rows show power curves for various wind speeds from 3.0 to 25.0 m/s.

Table 14-4: Power curve, noise mode 2



14.2.3 Noise Curves, Noise Mode 2

Table with columns for Wind speed at hub height [m/s], Sound Power Level at Hub Height [dBA] (Blades without optional serrated trailing edge), and Sound Power Level at Hub Height [dBA] (Blades with optional serrated trailing edge). Rows show noise curves for wind speeds from 3 to 20 m/s.

Table 14-6: Noise curves, noise mode 2



14.2.2 C_t Values, Noise Mode 2

Table with columns for Wind speed [m/s] and Air density [kg/m³] (1.225 to 1.275). Rows show C_t values for various wind speeds from 3.0 to 25.0 m/s.

Table 14-5: C_t values, noise mode 2



14.3 Mode 3

14.3.1 Power Curves, Noise Mode 3

Table with columns for Wind speed [m/s] and Air density [kg/m³] (1.225 to 1.275). Rows show power curves for various wind speeds from 3.0 to 25.0 m/s.

Table 14-7: Power curve, noise mode 3



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14.3.2 C_t Values, Noise Mode 3

Table with columns for Wind speed [m/s] and Air density kg/m³. The table contains a grid of C_t values for various wind speeds and air densities.

Table 14-8: C_t values, noise mode 3

14.4 Mode 4

14.4.1 Power Curves, Noise Mode 4

Table with columns for Wind speed [m/s] and Air density [kg/m³]. The table contains power curve data for various wind speeds and air densities.

Table 14-10: Power curve, noise mode 4

14.3.3 Noise Curves, Noise Mode 3

Table with columns for Wind speed at hub height [m/s], Sound Power Level at Hub Height [dBA], and Sound Power Level at Hub Height [dBA]. The table shows noise curves for different wind speeds and hub heights.

Table 14-9: Noise curves, noise mode 3

14.4.2 C_t Values, Noise Mode 4

Table with columns for Wind speed [m/s] and Air density kg/m³. The table contains C_t values for various wind speeds and air densities.

Table 14-11: C_t values, noise mode 4

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14.4.3 Noise Curves, Noise Mode 4

Table with 3 columns: Wind speed at hub height [m/s], Sound Power Level at Hub Height [dBA] (Blades without optional serrated trailing edge), and Sound Power Level at Hub Height [dBA] (Blades with optional serrated trailing edge). Rows range from 3 to 20 m/s.

Table 14-12: Noise curves, noise mode 4

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14.5.2 C_i Values, Noise Mode 5

Table with 13 columns for Air density [kg/m³] (1.225 to 1.275) and 13 rows for Wind speed [m/s] (3.0 to 25.0). Values represent C_i values for noise mode 5.

Table 14-14: C_i values, noise mode 5

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14.5 Mode 5

14.5.1 Power Curves, Noise Mode 5

Table with 13 columns for Air density [kg/m³] (1.225 to 1.275) and 20 rows for Wind speed [m/s] (3.0 to 25.0). Values represent power curves for noise mode 5.

Table 14-13: Power curve, noise mode 5

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14.5.3 Noise Curves, Noise Mode 5

Table with 3 columns: Wind speed at hub height [m/s], Sound Power Level at Hub Height [dBA] (Blades without optional serrated trailing edge), and Sound Power Level at Hub Height [dBA] (Blades with optional serrated trailing edge). Rows range from 3 to 20 m/s.

Table 14-15: Noise curves, noise mode 5

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14.6 Mode 8

14.6.1 Power Curves, Noise Mode 8

Table with 14 columns (Wind speed [m/s] and Air density [kg/m³] values) and 25 rows of power curve data for Mode 8.

Table 14-16: Power curve, noise mode 8



14.6.3 Noise Curves, Noise Mode 8

Table with 3 columns (Wind speed at hub height [m/s], Sound Power Level at Hub Height [dBA] for blades without optional serrated trailing edge, and Sound Power Level at Hub Height [dBA] for blades with optional serrated trailing edge) and 19 rows of noise curve data for Mode 8.

Table 14-18: Noise curves, noise mode 8



14.6.2 C_i Values, Noise Mode 8

Table with 14 columns (Wind speed [m/s] and Air density [kg/m³] values) and 25 rows of C_i values for Noise Mode 8.

Table 14-17: C_i values, noise mode 8



14.7 3.45 MW Power Mode

14.7.1 Power Curves, 3.45 MW Power Mode

Table with 14 columns (Wind speed [m/s] and Air density [kg/m³] values) and 25 rows of power curve data for 3.45 MW Power Mode.

Table 14-19: Power curves, 3.45 MW Power Mode



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14.7.2 C_i Values, 3.45 MW Power Mode

Table with 14 columns for air density (1.225 to 1.275 kg/m³) and 20 rows for wind speed (3.0 to 25.0 m/s). Values represent C_i coefficients.

Table 14-20: C_i values, 3.45 MW Power Mode

14.7.3 Noise Curves, 3.45 MW Power Mode

Table with 3 columns: Wind speed at hub height [m/s], Sound Power Level at Hub Height [dB(A)] (Blades without optional serrated trailing edge), and Sound Power Level at Hub Height [dB(A)] (Blades with optional serrated trailing edge). Rows for wind speeds 3 to 20 m/s.

Table 14-21: Noise curves, 3.45 MW Power Mode



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14.8 3.0 MW Derated Mode

14.8.1 Power Curves, 3.0 MW Derated Mode

Table with 14 columns for air density (1.225 to 1.275 kg/m³) and 20 rows for wind speed (3.0 to 25.0 m/s). Values represent power curves.

Table 14-19: Power curves, 3.0 MW Derated Mode



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14.8.2 C_i Values, 3.0 MW Derated Mode

Table with 14 columns for air density (1.225 to 1.275 kg/m³) and 20 rows for wind speed (3.0 to 25.0 m/s). Values represent C_i coefficients.

Table 14-20: C_i values, 3.0 MW Derated Mode



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14.8.3 Noise Curves, 3.0 MW Derated Mode

Sound Power Level at Hub Height, 3.0 MW Derated Mode		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] (Blades without optional serrated trailing edge)	Sound Power Level at Hub Height [dBA] (Blades with optional serrated trailing edge)
3	91.3	91.1
4	91.9	91.5
5	94.2	93.4
6	97.3	96.3
7	100.6	99.5
8	103.4	102.3
9	105.8	104.4
10	105.8	104.4
11	105.8	104.4
12	105.8	104.4
13	105.8	104.4
14	105.8	104.4
15	105.8	104.4
16	105.8	104.4
17	105.8	104.4
18	105.8	104.4
19	105.8	104.4
20	105.8	104.4

Table 14-21: Noise curves, 3.0 MW Derated Mode

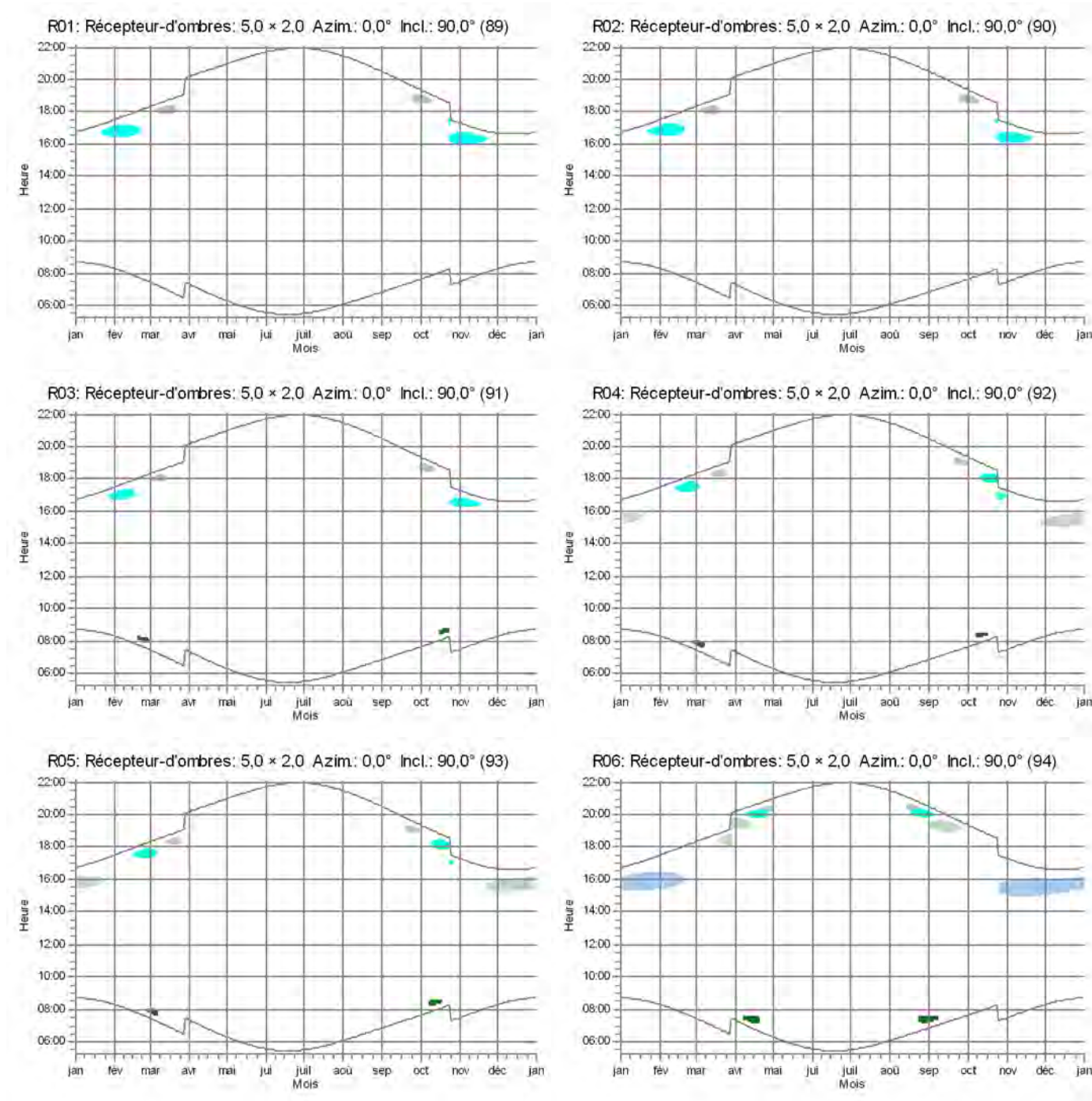
Original Instruction: T05 0058-5119 VER 00

T05 0058-5119 Ver 00 - Approved - Exported from DMS: 2016-05-12 by GIRCH

ANNEXE D. CALENDRIER GRAPHIQUE D'OMBRAGE

SHADOW - Calendrier graphique par récepteur

Calcul: Rec_Genappe_NoBrid

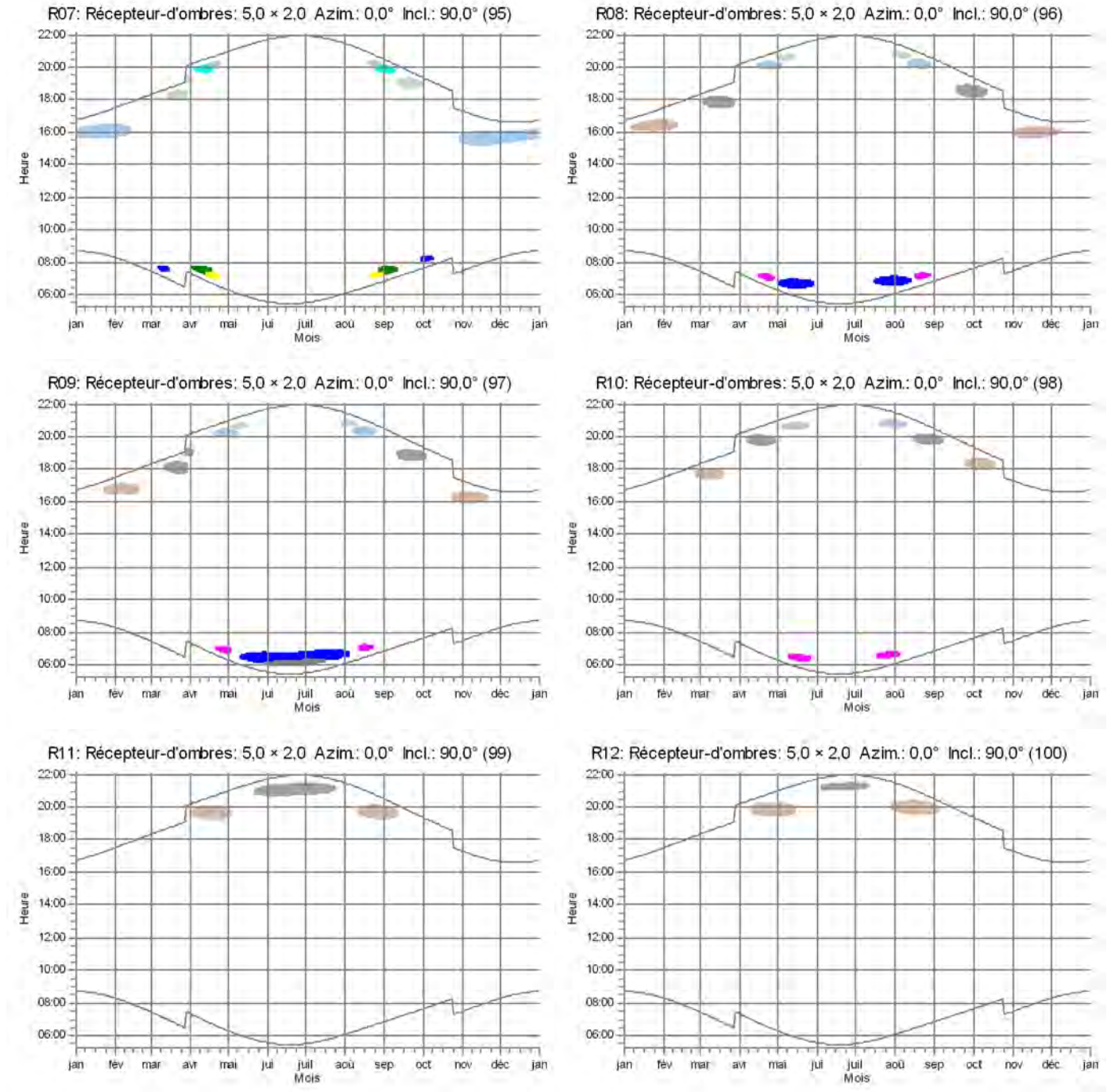


Eoliennes

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|---|--|

SHADOW - Calendrier graphique par récepteur

Calcul: Rec_Genappe_NoBrid

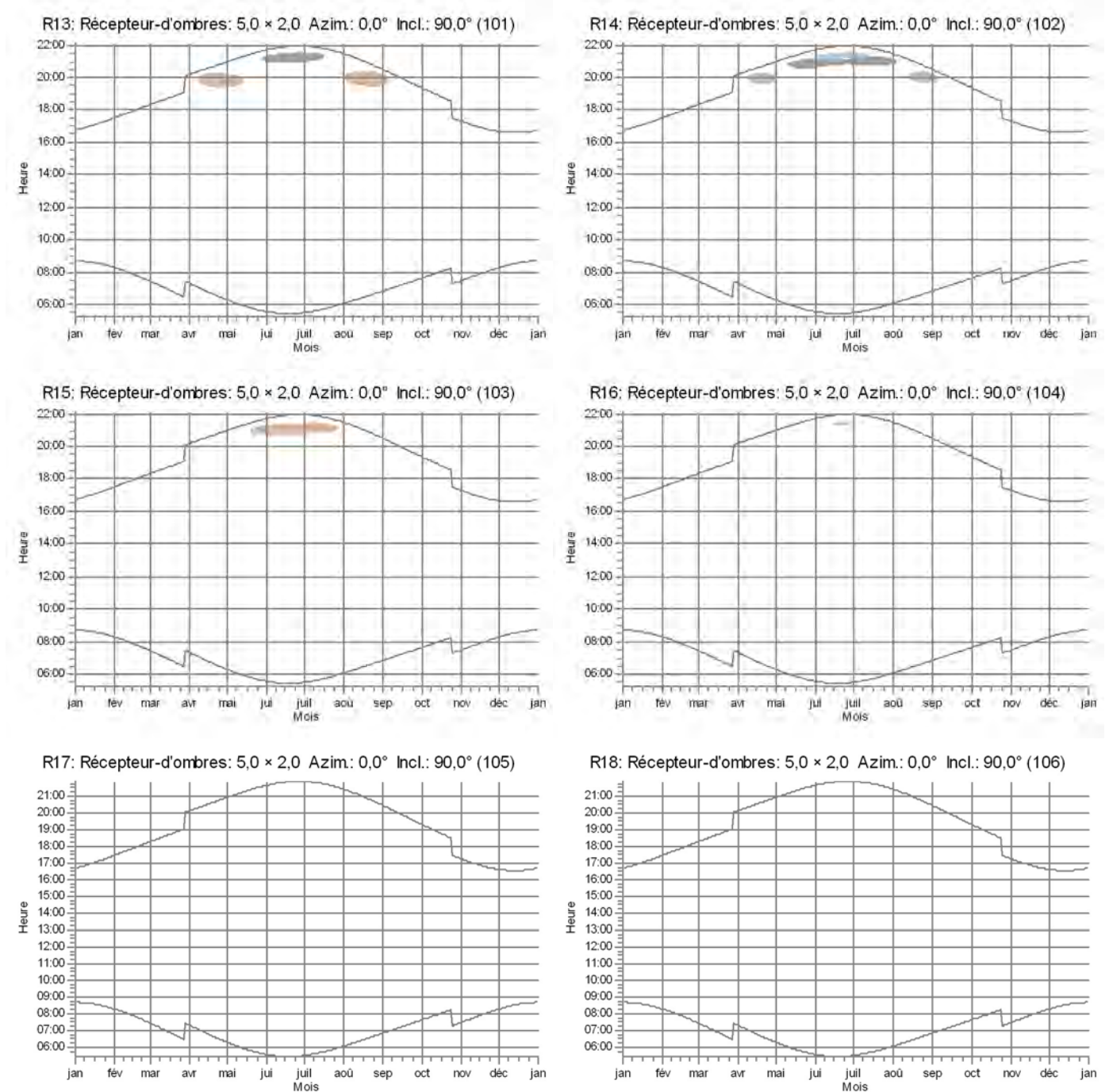


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|---|--|
| <ul style="list-style-type: none"> 1: SENVION 3.2M114VG 3200 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (30) 2: SENVION 3.2M114VG 3200 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (31) 3: SENVION 3.2M114VG 3200 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (32) 4: SENVION 3.2M114VG 3200 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (33) 5: SENVION 3.2M114VG 3200 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (34) 12: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (79) | <ul style="list-style-type: none"> 13: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (80) 14: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (81) 15: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (82) 16: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (83) 17: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (84) |
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SHADOW - Calendrier graphique par récepteur

Calcul: Rec_Genappe_NoBrid



Eoliennes

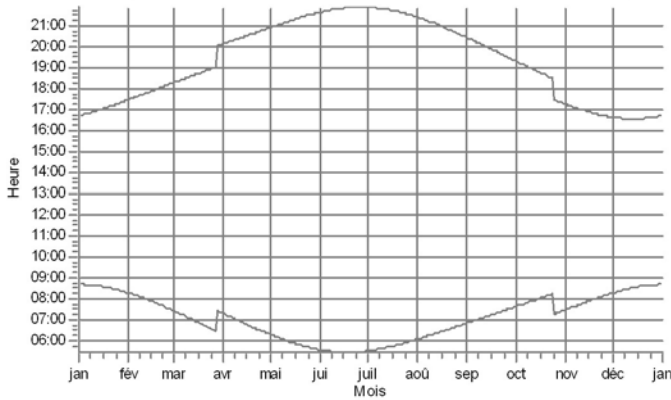
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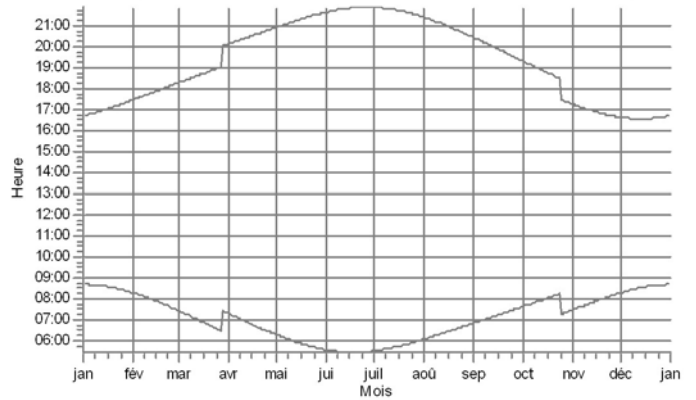
SHADOW - Calendrier graphique par récepteur

Calcul: Rec_Genappe_NoBrid

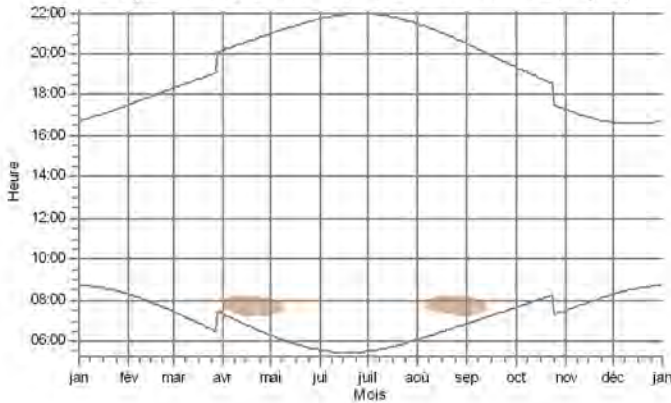
R19: Récepteur-d'ombres: 5,0 × 2,0 Azim: 0,0° Incl.: 90,0° (107)



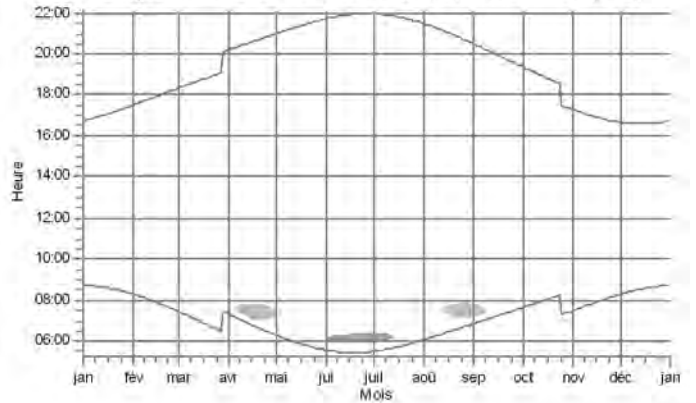
R20: Récepteur-d'ombres: 5,0 × 2,0 Azim: 0,0° Incl.: 90,0° (108)



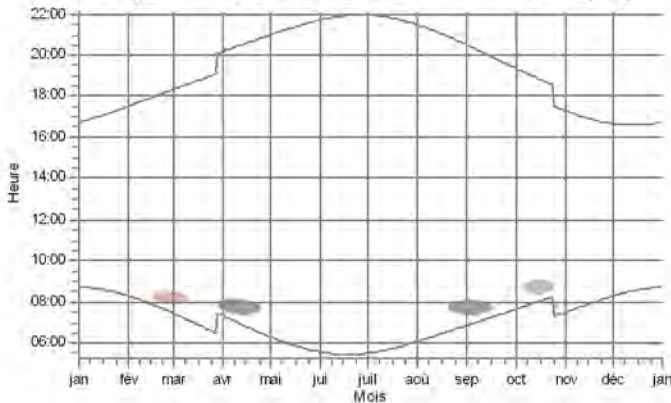
R21: Récepteur-d'ombres: 5,0 × 2,0 Azim: 0,0° Incl.: 90,0° (109)



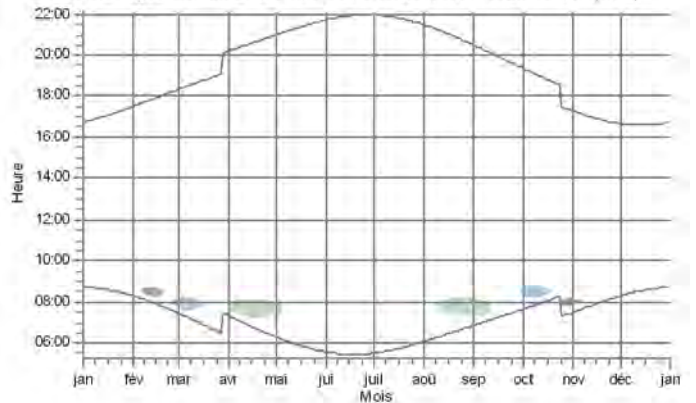
R22: Récepteur-d'ombres: 5,0 × 2,0 Azim: 0,0° Incl.: 90,0° (110)



R23: Récepteur-d'ombres: 5,0 × 2,0 Azim: 0,0° Incl.: 90,0° (111)



R24: Récepteur-d'ombres: 5,0 × 2,0 Azim: 0,0° Incl.: 90,0° (112)



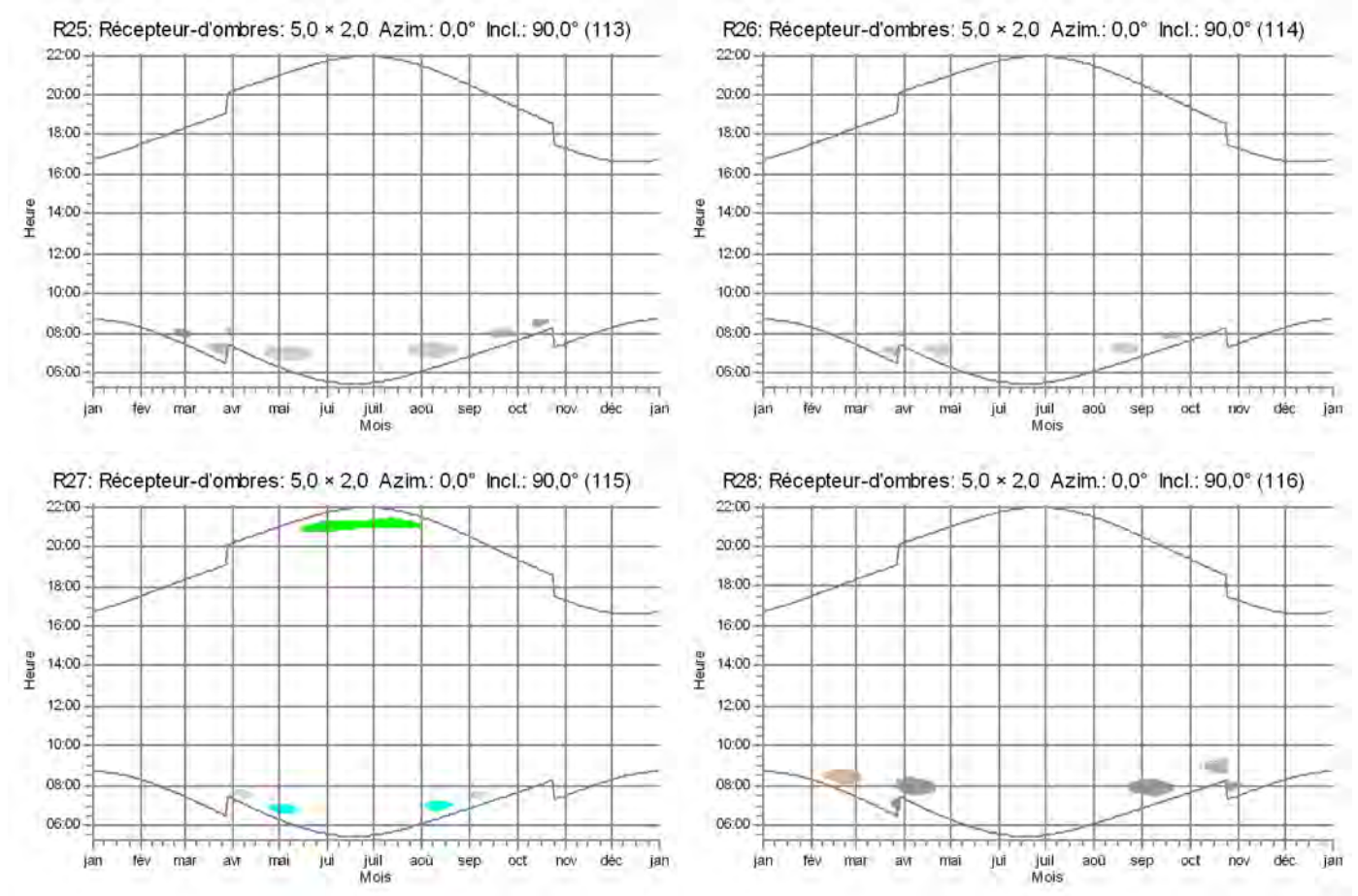
Eoliennes

- 14: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (81)
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- 16: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (83)
- 17: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyeu: 93,0 m (TOT: 150,0 m) (84)

SHADOW - Calendrier graphique par récepteur


Calcul: Rec_Genappe_NoBrid



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	14: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyen: 93,0 m (TOT: 150,0 m) (81)		17: Siemens Gamesa MODIF SG 2.6-114 2625 114.0 IOI moyen: 93,0 m (TOT: 150,0 m) (84)

**ANNEXE E. FICHES TECHNIQUES DES CONSTRUCTEURS
RELATIVES AU 'SHADOW MODULE**

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		Date: 28/04/14	Page 1 of 13
Type of Documentation: STD - Support	Title: GAMESA ENVIRONMENTAL MANAGER GD	Approval process: Electronic: PDM Flow + Translation	Author: LEF Revised: MDI Approved: AJMINEZ
Deliverable: S12			

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RECORD OF CHANGES

Rev.	Date	Author	Description
0	06/03/2014	LEF/MDI	Initial version published.
1	22/04/2014	LEF/MDI	Correction in section 8.1.

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1. PURPOSE

The purpose of this document is to provide a general description of the Gamesa Environmental Manager system. This system incorporates different applications aimed at environmental protection into a single system. By offering this product, Gamesa ultimately seeks to achieve optimum integration of wind turbines into a wind farm's surroundings. The Gamesa Environmental Manager is an optional tool for Gamesa's SCADA, WindNet® [1].

The solutions described herein are necessary to optimize energy production, guarantee the economic viability of the wind farm, while complying with the environmental protection requirements demanded by the client or imposed by the country or region's environmental standards.

This document does not seek to provide a detailed description of how to use the Gamesa Environmental Manager system or its tools. This information can be found in its User Manual.

Likewise, a description of the technical capacities and features of the sensors and components installed on site and/or Gamesa wind turbines is also beyond the scope of this document. This information is part of the technical documentation of each wind turbine model.

2. SCOPE

This document applies to the Gamesa Environmental Manager system that integrates environmental protection tools, compatible with the Gamesa's SCADA system, WindNet® [1] and the entire range of wind turbines in Gamesa's catalog.

3. ACRONYMS AND ABBREVIATIONS

WTG	Wind Turbine Generator.
NRS®	Noise Reduction System
GEM	Gamesa Environmental Manager
OPC DA	OLE for Process Control: protocol used to exchange information among industrial applications. DA stands for Data Access; this protocol has been designed for communicating values almost in real-time.
PLC	Programmable Logic Controller.
SCADA	Supervisory Control and Data Acquisition.

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4. GENERAL DESCRIPTION

At a wind farm facility, as well as considering the physical and electrical safeguards for its wind turbines and installations, special attention must be paid to the safety and comfort of the population and/or fauna that coexists with the wind farm.

Each wind farm must be properly integrated with the specific conditions of its environment and comply with local environmental protection regulations. To that end, Gamesa offers the Gamesa Environmental Manager system as part of its SCADA product catalog. This system encompasses the following tools in a single application, all of which are optional and configurable:

- Wake Control System
- Noise Reduction System (NRS®)
- Shadow Control System
- Ice Detection System
- Bat Shield System

Integration of the Gamesa Environmental Manager system into the wind farm's SCADA allows you to take advantage of the communication capacities and remote access interfaces of Gamesa's SCADA system. In this way, information from the contracted environmental tools is available to the wind farm operator both at the local control post and at any remote point through the SCADA client interface.

Generally, the status of each wind turbine is displayed on the main SCADA screen through the use of colors. If the wind turbine is in Pause mode, the display tells you whether the command to shutdown has come from one of the environmental controls that have been set up. All applications are compatible with each other so that, when a wind turbine is shutdown by an environmental tool, it cannot be re-started by a different application until the conditions giving rise to the Pause have disappeared.

It is worth highlighting that the environmental tools will cause a loss of production when they order a wind turbine to Pause or a limitation of its generation capacity. In any case, the control algorithms have been designed to optimize loss of production at a wind farm.

Although the design of the Gamesa Environmental Manager system encompasses all environmental control tools, only those environmental applications that have been specifically contracted by the wind farm's operator/client will be installed. Information specific to these applications will be displayed via the corresponding menu/button on the main SCADA client screen.

The overview screen of the Gamesa Environmental Manager displays a summarized status of each tool that has been set up. For each application, the screen displays:

- o Tool enabled (green LED).
- o Tool disabled (gray LED).
- o Internal application error (red LED).
- o Access to the Details Screen displaying specific data from the environmental application.

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The Gamesa Environmental Manager system also uses the Gamesa SCADA system's advanced storing and information processing management to record in its database all shutdown periods and the commands/information sent by each tool. This allows the user to list periods of temporary unavailability by environmental protection, thereby obtaining statistics and reports.

In addition to these general SCADA system reports, the Gamesa Environmental Manager system includes a log engine. For each environmental control, an independent log is generated for recording the values of wind direction, speed, temperature and so forth as well as actions generated by the tool. The logs generated by the system are stored in a local server folder.

Environmental protection algorithms are unattended processes; i.e. they require no operation whatsoever from the farm operator beyond initial set up and normal supervision.

The following sections provide an overview of the system's setup capacities, together with the specific purpose, setup and operating of each environmental protection tool integrated into the Gamesa Environmental Manager.

4.1. SETUP FEATURES

The global system and each of the tools is set up upon installation by Gamesa personnel via a setup application.

There are various setup options:

- Global system setup and specific setup for each wind turbine.
- Specific operating setup for each environmental control.

The setups are recorded in the SCADA database and can be monitored via SCADA screens.

The key setup parameters include:

- Configurable hysteresis in wind direction sector: For each tool that works by sectors and for each wind turbine, you can, at any time, set up a hysteresis control within the wind direction control in order to reduce the number of wind turbine operations.
- Configurable hysteresis in wind speed: For each tool that considers wind speed and for each wind turbine, you can, at any time, set up a hysteresis control within the wind speed control in order to reduce the number of wind turbine operations.
- Optimization of adjustment for wind farms that have gusty winds: This allows you to filter wind speed measurements by eliminating abrupt variations. This in turn affords more effective control over Run/Pause operations on wind turbines.
- Minimum time between Run/Pause operations: This allows you to set a timeout between wind turbine pause and start-up operations, thus preventing excessive wear in highly variable conditions. Setup takes just a few seconds.
- Wind measurements from weather masts: If absolute wind direction measurements for the wind turbines are unavailable, the tool can retrieve the speed and direction measurements obtained from the weather mast integrated in the nearest SCADA (with a certain loss of precision depending on the distance from the mast).

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- Setup precision: the tool affords the following setup precision:
 - Wind speed: 0.1 m/s.
 - Wind direction: 1°.
 - Time for calendar setup: 1 second.
- Copy of the setup between wind turbines: Once a setup has been created, it can be copied from one wind turbine to another and modified if required, thereby facilitating repetitive setup of several wind turbines.

5. GENERAL DESCRIPTION OF THE WAKE CONTROL SYSTEM

As a general rule, the design of a wind farm is optimized by considering the available land and prevailing wind. This enables an increase in total wind farm efficiency. However, in certain wind direction sectors, situations may arise in which a wind turbine is operating in a wake.

Wind turbine in a wake is defined as a situation in which the wind turbine is exposed to highly turbulent wind. Continuous operation of a wind turbine in a wake may lead to increased stress and loads on the main structural components of the wind turbine. The purpose of the Wake Control Tool is to detect such situations and safeguard the wind turbines' structural integrity.

At a wind farm, situations in which a wind turbine is affected by wakes may be caused by two types of obstacles:

- Wakes produced by a permanent object such as a hill, tree, etc.
- Wakes caused by the rotating blades of the preceding wind turbine (upwind). This situation generally arises when the following conditions occur simultaneously:
 - Wind direction is approximately perpendicular to the prevailing wind at the wind farm.
 - Minimum distance between wind turbines is less than the recommended design distance.

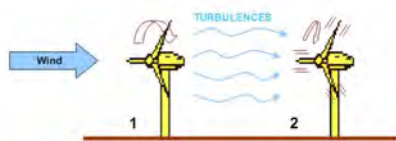


Fig. 1. Wind turbine No. 2 affected by a wake caused by Wind turbine No. 1.

The setup of the tool allows you to differentiate between Wake Sectors, used for detecting turbulence caused by permanent obstacles, and the Wind Turbine Wake Sectors setup, used for detecting turbulence caused by adjacent wind turbines. The tool is able to work with either setup, or both at the same time.

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When considering permanent elements, such as a hill or tree standing in the area around the wind farm, the control application monitors whether a wind turbine has entered a specific sector and range of wind speed that requires the wind turbine to be set to Pause. Such control can also be used for preventing blade damage caused by turbulence from hills and nearby cliffs or walls that create wind turbulence.

The tool constantly monitors the wind and wind direction of each wind turbine. When, as per setup, in-wake operation is detected, the tool sends Pause commands to the affected wind turbines. Once wind speed and wind direction conditions have shifted beyond the activation range, the tool automatically re-starts the affected wind turbines.

When considering wakes from adjacent wind turbines, given that wind turbine shutdown leads to loss of production, the wake control tool also considers the status of those wind turbines that may cause wakes, minimizing the total number of wind turbines paused by the tool in order to optimize the wind farm's total energy production.



Fig. 2. Wind turbine No. 2 paused to avoid wakes caused by Wind turbine No. 1.

Fig. 2 shows a situation in which wind turbine no. 2 is in a wake caused by wind turbine no. 1, which is running. In this situation, the algorithm sends a Pause command to wind turbine no. 2.



Fig. 3. Wind turbine no. 2 not paused as there is no turbulence.

Fig. 3 shows a situation in which wind turbine no. 1 is not running, so wind turbine no. 2 is not deemed to be in a wake situation.

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5.1. SETUP FEATURES

The system differentiates between two types of wake: those produced by permanent obstacles and those created by turbulence caused by the adjacent wind turbine. To detect each in-wake operating situation, the Wake Control algorithm must be correctly set up. This section summarizes the main parameters of this application's particular setup:

- Wakes caused by permanent obstacles. The following parameters are set up for each wind turbine:
 - Wind speed ranges: You can establish as many wind speed bands as necessary.
 - Wind direction sectors: You can establish as many wind direction sectors as necessary.
- Wakes caused by adjacent wind turbines. The following parameters are set up for each wind turbine:
 - Wind speed ranges: You can establish as many wind speed bands as necessary.
 - Wind direction sectors: You can establish as many wind direction sectors as necessary.
 - Once the wind direction sectors and wind speed have been defined, you select the wind turbines that cause wakes affecting the wind turbine being set up.

5.2. INSTALLATION / OPERATION REQUIREMENTS

In order to activate the Wake Control tool at a wind farm, the following conditions must be met:

1. A basic Gamesa SCADA system [1] with Gamesa Environmental Manager set up and operational.
2. A wind farm infrastructure based on Ethernet in compliance with Gamesa specifications [2].
3. Site report on the specific setup for each wind farm.

6. GENERAL DESCRIPTION OF THE NOISE REDUCTION SYSTEM

All operational wind turbines create noise, whether by aerodynamic causes (airflow on the blades) or mechanical noise (caused by the mechanical parts of the generator). International legislation establishes the methods for measuring noise, and noise levels must be declared by the manufacturer for each model of wind turbine:

- IEC 61400-11: Wind turbine systems – Acoustic noise measurement techniques. Definition of how to measure noise on a wind turbine.
- IEC 61400-14: Wind turbines – Declaration of the apparent sound power level. Definition of how to declare the noise generated by a wind turbine.

In order to comply with the current legislation, different low-noise operating modes are set up for Gamesa wind turbines according to the wind turbine model. In accordance with the standards, Gamesa publishes these noise levels within the technical information of each wind turbine product. These operation modes reduce the acoustic levels emitted by the wind turbine, with a reduction of the rotor speed and a change of the optimal angle of the blade, which leads to a lower amount of power generated.

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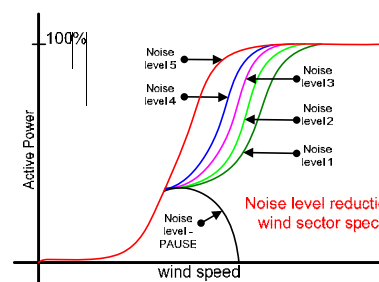


Fig. 4. Concept of low-noise power curves

The wind farm promoter/designer is responsible conducting the noise impact study of the wind farm environment, using the technical information of each Gamesa wind turbine. The study should reflect the appropriate wind turbine noise setup in order to comply with local regulations.

The purpose of the Noise Reduction System developed by Gamesa is to control the noise levels at which each wind turbine should operate according to the acoustic impact study that has been conducted. Controlling the noise level emitted by each wind turbine reduces the total noise emission at a wind farm. This function means that wind turbines can be installed close to urban areas, limiting the environmental impact that they cause around them.

The noise reduction system is a GAMESA trademark registered under the acronym NRS® which consists of two separate parts: the application set up within the Gamesa Environmental Manager in the SCADA system and an algorithm correctly set up in each wind turbine's controller, as schematically shown in the following figure:

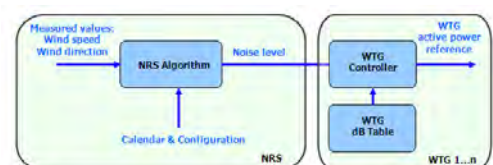



Fig. 5. Noise reduction system conceptual schema

Control will be equipped with a calendar-timetable which, once set up, displays the times of the year and day when the tool should be operational. It also takes into account whether various environmental factors are being met at the same time in order to act accordingly; i.e. sending different noise levels (including Pause mode) to the affected wind turbine via SCADA.

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Via the SCADA overview screen, wind turbines running at lower noise levels will be identified by the RUN_L status. The tool's details screen displays each wind turbine's current noise level.

Device	State	Potencia	V(viento)	D(Dirección)	NivelRuido
A 1	Run	2.033,0	17,3	49,0	5
A 2	Run	2.023,0	17,2	49,0	5
A 3	Run	2.108,0	17,9	49,0	5
A 4	Run	2.019,0	17,2	49,0	5
A 5	Run	2.098,0	17,8	49,0	5
A 6	Run	2.005,0	17,0	49,0	5

Fig. 6. Example of noise level status indication for each wind turbine.

The NRS® application is an unattended process; i.e. it requires no operation whatsoever from the farm operator beyond initial setup. Information regarding the tool is available in the SCADA interface.

6.1. SETUP FEATURES


In addition to the common setup of the Gamesa Environmental Manager, the NRS® system must be correctly set up as per the wind farm's acoustic impact study. The main system setup parameters are summarized below:

- Time periods: As many time periods as desired can be established. An annual update can be established for each one or let a single setup carry across from one year to the next. Repetition can be based on the day of the week and/or time of day for complete flexibility.
- Wind direction sectors: You can establish as many wind direction sectors as necessary.
- Wind speed ranges: You can establish as many wind speed ranges as necessary.
- Noise levels (including Pause command): For each wind turbine, period, wind sector and wind speed, the corresponding noise level is setup, or Pause command if necessary. The available noise levels are defined in the technical documentation for each installed wind turbine model.

6.2. INSTALLATION / OPERATION REQUIREMENTS

For the correct performance of the Noise Control System, NRS®, the following conditions must be met at the wind farm:

1. A basic Gamesa SCADA system [1] with Gamesa Environmental Manager set up and operational.
2. A wind farm infrastructure based on Ethernet in compliance with Gamesa specifications [2].
3. Form about the system's specific configuration, for each wind farm.
4. Control version of each wind turbine set up with the noise levels according to the wind farm's noise report.

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7. GENERAL DESCRIPTION OF THE SHADOW CONTROL SYSTEM

Within the Gamesa Environmental Manager, Gamesa offers the Shadow Control System as an optional tool for the SCADA system. The purpose of this system is to manage the shutdown times of wind turbines in the event of intermittent shadows on buildings next to the wind farm produced by the moving blades of wind turbines blocking out sunlight.

By monitoring sunlight and calculating the probability of shadows being projected according to the position of the wind turbine, the application allows you to reduce the environmental impact of a wind turbine in densely populated areas.

The shadow control tool's internal algorithm processes the information received from the wind turbines and a light sensor and, depending on the operation calendar and the parameters that have been set up, it sends a Pause command to those wind turbines most likely to project shadows.

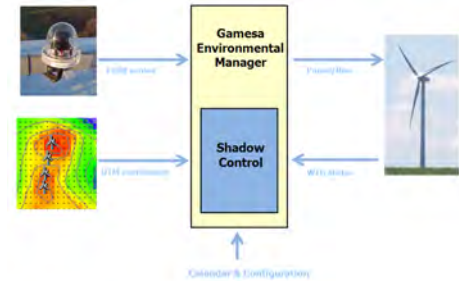



Fig. 7. Shadow control system conceptual schema

The light sensor is supplied and installed by Gamesa. Generally, it is installed in one wind turbine at the wind farm.

7.1. SETUP FEATURES

In addition to the common setup of the Gamesa Environmental Manager, the Shadow Control System must be correctly set up as per the wind farm's impact study. The main setup parameters for this control are summarized below:

- Time periods: As many time periods as desired can be established for setting up the operation calendar. An annual update can be established for each one or let a single setup carry across from one year to the next. Repetition can be based on the day of the week and/or time of day for complete flexibility.

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- Position (UTM coordinates) of wind turbines controlled by the tool.
- Position (UTM coordinates) of elements that the tool must safeguard.

Once the wind farm is operational and the tool has been correctly set up, the SCADA system controls the status of wind turbines under its control as per the configured parameters.

7.2. INSTALLATION / OPERATION REQUIREMENTS

For the correct performance of the Shadow Control System at a wind farm, the following conditions must be met:

1. A basic Gamesa SCADA system [1] with Gamesa Environmental Manager set up and operational.
2. A wind farm infrastructure based on Ethernet in compliance with Gamesa specifications [2].
3. Form about the system's specific configuration, for each wind farm.
4. Existence of a light sensor reading acquired by SCADA. This reading could come from a single wind turbine or several, or from an external device installed at the substation that must be integrated with SCADA.

8. GENERAL DESCRIPTION OF THE ICE DETECTION SYSTEM

The system allows wind turbines to be operated according to the likelihood of a build-up of ice on blades and structures. Furthermore, it provides resources for designing wind farms that respect local or regional restrictions as regards detecting the build-up of ice while optimizing production at the wind farm.

Gamesa offers the Ice Detection System as an optional feature for the SCADA system. The purpose of this system is to reduce the risk of damage or impact on personal safety in the wind turbine's environment, optimizing the cost of material at a wind farm. The System allows a number of ice sensors to be installed, less than the number of installed wind turbines, as the information from a single ice sensor lets you manage a configurable group of wind turbines.

Within this context, a master wind turbine is defined as one with an ice sensor installed, thereby becoming reference information for the group of wind turbines. The tool allows you to define standby master wind turbines for cases when the actual master wind turbine suffers communication failure or has an ice sensor error. However, once communication with master wind turbine has been reinstated, said wind turbine will become the active master in the group once more.

Likewise, slave wind turbines are defined as those with no ice sensor and are set up to receive Forced Pause orders via SCADA when ice is detected. Upon receiving this instruction, the wind turbine's control system activates the corresponding alarm, switching to local reset. In other words, the same function is maintained as in the case where the wind turbine's control system receives the information from a sensor installed on a wind turbine.

At each wind farm, the client decides which control groups are to be set up in the Ice Detection System. For each group, the client must decide which is to be the master wind turbine and which are to be the controlled slave wind turbines. Once Gamesa personnel have completed the setup, the operator can include/exclude a wind turbine in the control tool.

As a safeguard, the control algorithm considers the ambient temperature in order to avoid unnecessary commands in the event of sporadic errors in the information received.

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8.1. SETUP FEATURES

In addition to the common setup of the Gamesa Environmental Manager, the Ice Detection System must be correctly set up. The main setup parameters for this control are summarized below:

- Master Wind Turbine: A wind turbine equipped with an ice sensor.
- Slave Wind Turbine: A wind turbine not equipped with an ice sensor.
- Groups of wind turbines: For each group, you must set up which wind turbine is master and which are slaves. You can also set up a master wind turbine from another group that can send ice sensor information in the event of communication failure in the original master wind turbine.
- Ambient temperature of the wind turbine below a specific configurable level (temperature level configured in accordance with local environmental restrictions).
- Hysteresis: To avoid control instability when the ambient temperature fluctuates, a hysteresis is introduced into the control algorithm to ensure safe and stable operation.

8.2. INSTALLATION / OPERATION REQUIREMENTS

For the correct performance of the Ice Detection System at a wind farm, the following conditions must be met:

1. A basic Gamesa SCADA system [1] with Gamesa Environmental Manager set up and operational.
2. A wind farm infrastructure based on Ethernet in compliance with Gamesa specifications [2].
3. An ice sensor, set up and operating on an ice detecting master wind turbine.
4. Control version of each wind turbine set up according to the operating mode (slave/master) of the wind turbine.

9. GENERAL DESCRIPTION OF THE BAT SHIELD SYSTEM

In order to encourage the installation of wind turbines in areas that are a natural habitat for bats, Gamesa has developed a Bat Shield 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 Gamesa's Bat Shield tool is to control boundary conditions in order to reduce the risk of impact on bats. Whenever the specific conditions for the existence of bats are met, the tool requests wind turbine Pause mode.

As soon as one of the conditions is no longer met, and always considering the configured hysteresis values, the affected wind turbine will return to its initial status prior to being shutdown by the tool.

On the application's detail screen, you can monitor the general status of the tool, deactivate or activate control and find out the light level.

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9.1. SETUP FEATURES

The main system setup parameters are summarized below:

- **Calendar (days-times):** It allows you to set up a calendar with periods in which to operate or not operate.
- **Temperature limit (°C):** It allows you to set the temperature beyond which the bat control will activate.
- **Light limit (Lumen):** It allows you to set a threshold for the amount of light beyond which the bat control will activate/deactivate.
- **Wind speed ranges (m/s):** It allows you to set different wind speed bins.
- **Wind direction sectors (°):** It allows you to set as many wind direction sectors as necessary.
- **Minimum time for meeting conditions (s):** It allows you to set a time frame in which all the previous conditions must be met before executing an action on the wind turbines.
- **Configurable hysteresis:** The tool allows you to set up an hysteresis for parameters, not only relating to wind speed and direction, but also temperature and light level so as to limit the number of operations on wind turbines.

9.2. INSTALLATION / OPERATION REQUIREMENTS

For the correct performance of the Bat Shield System at a wind farm, the following conditions must be met:

1. A basic Gamesa SCADA system [1] with Gamesa Environmental Manager set up and operational.
2. A wind farm infrastructure based on Ethernet in compliance with Gamesa specifications [2].
3. Existence of a light sensor reading acquired by the SCADA system.

10. REFERENCES

- [1] GD180446-EN General description of the SCADA System.
 [2] GD174017-EN General description of SCADA boundary points.