Wind farm layout design suitability for Vattenfall

P/A Vattenfall N.V.

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A	2021-10-5	First issue	Christine Harkness	Eleni Tsirikou	John King
B	2021-10-6	Minor update to text	Christine Harkness	John King	John King
C	2021-12-10	Updated to include 160m rotor diameter analysis and minor updates to text	Christine Harkness	Eleni Tsirikou	John King
D	2022-07-08	Updated to include 165m rotor diameter analysis and minor updates to text	Christine Harkness	John King	John King
E	2023-05-12	Updated to include phase 2 positions and remove references to rotor diameters of 150, 155 or 160m.	Christine Harkness	John King	John King

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1 INTRODUCTION

P/A Vattenfall N.V. (the “Customer”) has invited Garrad Hassan and Partners Ltd (“DNV”) to carry out a high-level analysis on a proposed wind farm /1/. Vattenfall is developing a project in a coastal area in the Netherlands and would like DNV to assess whether the proposed project is likely to have a negative influence on existing turbines in the area and if so, if the effects could be mitigated. The purpose of this technical note is primarily for the purposes of submitting a planning application for the wind farm and isn’t intended to be a comprehensive technical analysis and therefore only details considered to be relevant for this stage of the development are taken into account.

This technical note describes the information provided by the customer, the work undertaken and high-level conclusions from the review.

2 OUTLINE OF WORK

The Customer has provided DNV with the following information for this analysis/review:

- Existing turbine layout and high-level turbine information /2/
- Proposed phase 1 and phase 2 turbine layout and high-level turbine information /3/
- A spreadsheet containing TI (ambient and characteristic) at 120m from SoDAR measurements /4/
- A spreadsheet containing the frequency distribution at 120m /5/

DNV has reviewed this information and has summarised its findings in the following sections.

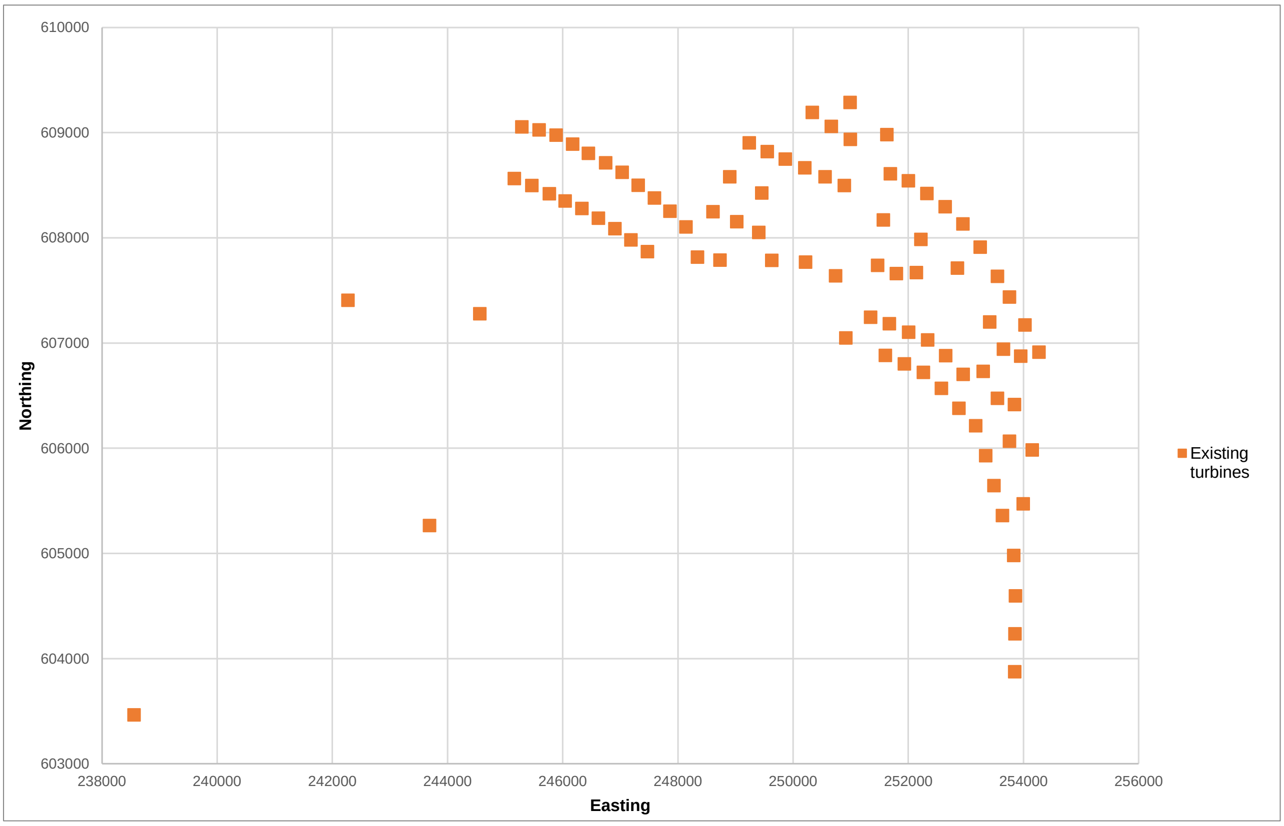
2.1 Existing turbines

The existing turbines to be investigated are located in a coastal area of the Netherlands. A total of 90 turbines are currently installed in the area. The turbines are predominantly Enercon and Vestas machines with a variety of hub height and rotor diameter configurations. The hub heights are between 40m and 141m and the rotor diameters are between 52m and 158m. An overview of the turbine types, rotor diameters and hub heights are described in Table 2-1.

Table 2-1 - Overview of existing turbines

Manufacturer	Turbine type	Power rating [kW]	Rotor diameter [m]	Hub height [m]	Total number of turbines of this type
Enercon	E-82	3000	82	98	53
Enercon	E-100	2500	100	100	2
Enercon	E-136	4500	136	132	2
Enercon	E-136	4650	136	132	1
Vestas	V90	3000	90	100	19
Vestas	V52	850	52	40	3
Vestas	V117	3450	117	92	1
Vestas	V100	2500	100	100	1
Senvion	6M	6150	126	114	2
2-B Energy	2B6	6150	140	105	1
Lagerway	L136-4.5MW	4500	136	132	2
GE	Cypress 5.8-158	5500	158	141	2
EWT	DW 54 900kW	900	54	40	1

Figure 2-1 –Existing turbine locations



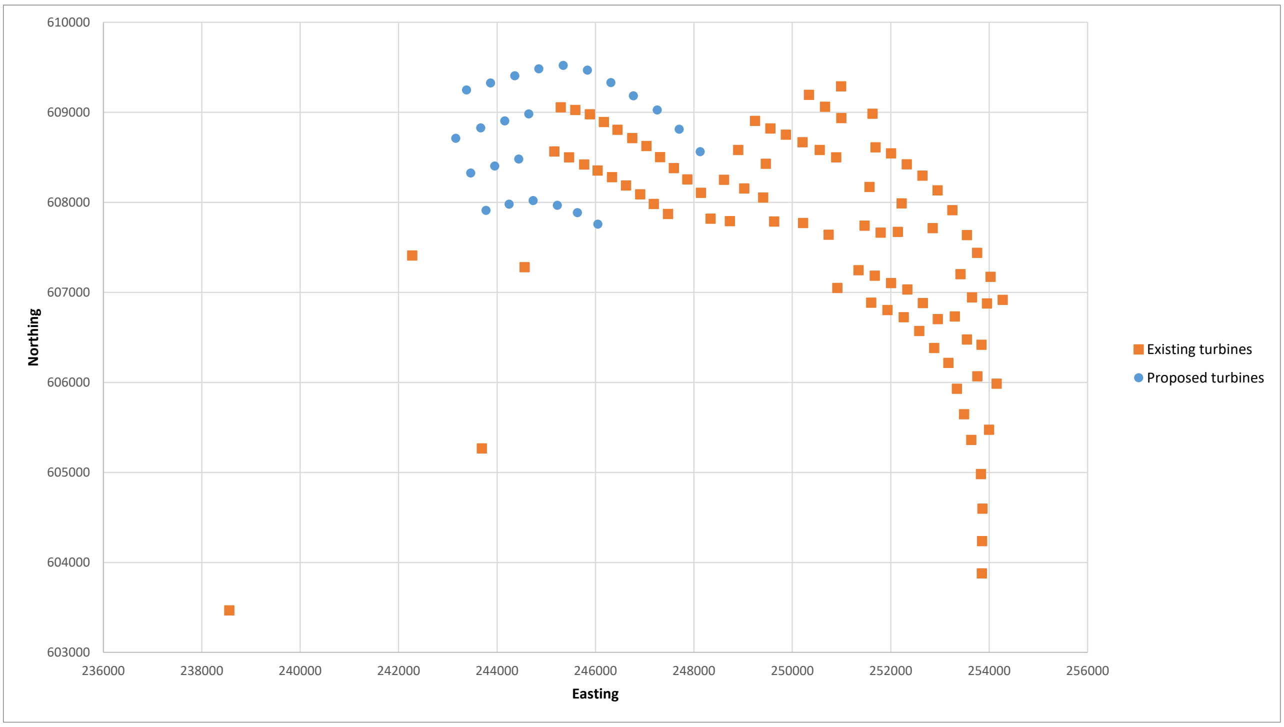
The layout of the existing turbines is shown in Figure 2-1. The layout shows that most of the existing turbines are organised into two main groups which are next to each other. The largest group which consists of 70 turbines is predominately organised into rows which run from north west to south east. There is also a smaller group which is made up of two distinctive rows to the west of the larger group which is made up of 20 turbines. There are four turbines which are quite separate from the rest of the groups which are located to the south west.

2.2 Proposed turbines

A total of 24 turbines have been proposed in the vicinity of the existing turbines. These turbines are proposed to have rotor diameters of 165m.

The layout of these turbines in relation to the existing turbines are shown in Figure 2-2. In general, the turbines are proposed to be installed to the west of the main two groups of existing turbines and they are proposed to be installed in four rows which run from west to north east.

Figure 2-2 – Proposed and existing turbine locations



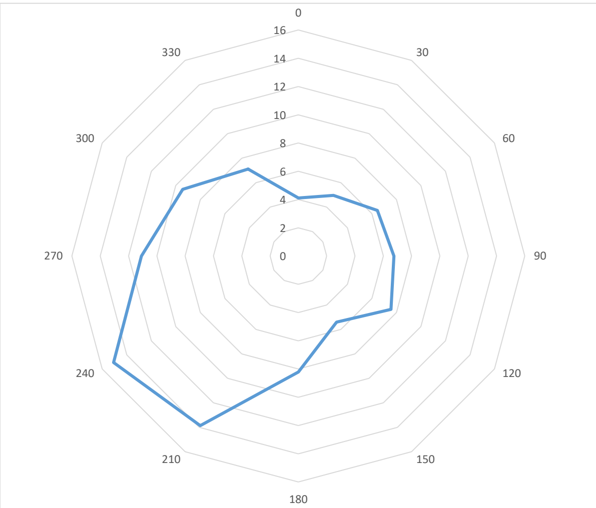
2.3 Wind climate

The Customer provided information related to the wind climate at the proposed site, a frequency distribution at 120m and TI SoDAR measurements at 120m. These are described further in the following sections. Note that other environmental information e.g. shear has not been provided to DNV so standard values were assumed for this analysis.

2.3.1 Frequency distribution

A spreadsheet containing the frequency distribution at 120m was provided to DNV /5/. The wind rose is shown is Figure 2-3. By examining the wind rose, it can be observed that the prevailing wind direction is south-west.

Figure 2-3 – Wind rose



2.3.2 Measured turbulence intensity using SoDAR

A spreadsheet containing characteristic TI at 120m from SoDAR measurements has been provided by the customer /4/. It's understood that turbulence intensity measurements using SoDAR equipment have a high uncertainty however DNV considers this type of data acceptable for this type of high-level analysis. The characteristic TI was compared against the standard turbulence classes, A, B and C. The characteristic TI was lower than turbulence class C which can be considered a low turbulence level.

It should also be noted that the purpose of this high-level analysis is to attempt to understand how the proposed turbines will affect the turbulence intensity at the existing turbines (rather than check the absolute level of the turbulence intensity), therefore DNV has assumed that the characteristic TI is applicable to all turbine locations. This means that no adjustment has been made to the TI based on the terrain complexity or due to the differing hub heights.

2.3.3 Effective turbulence intensity

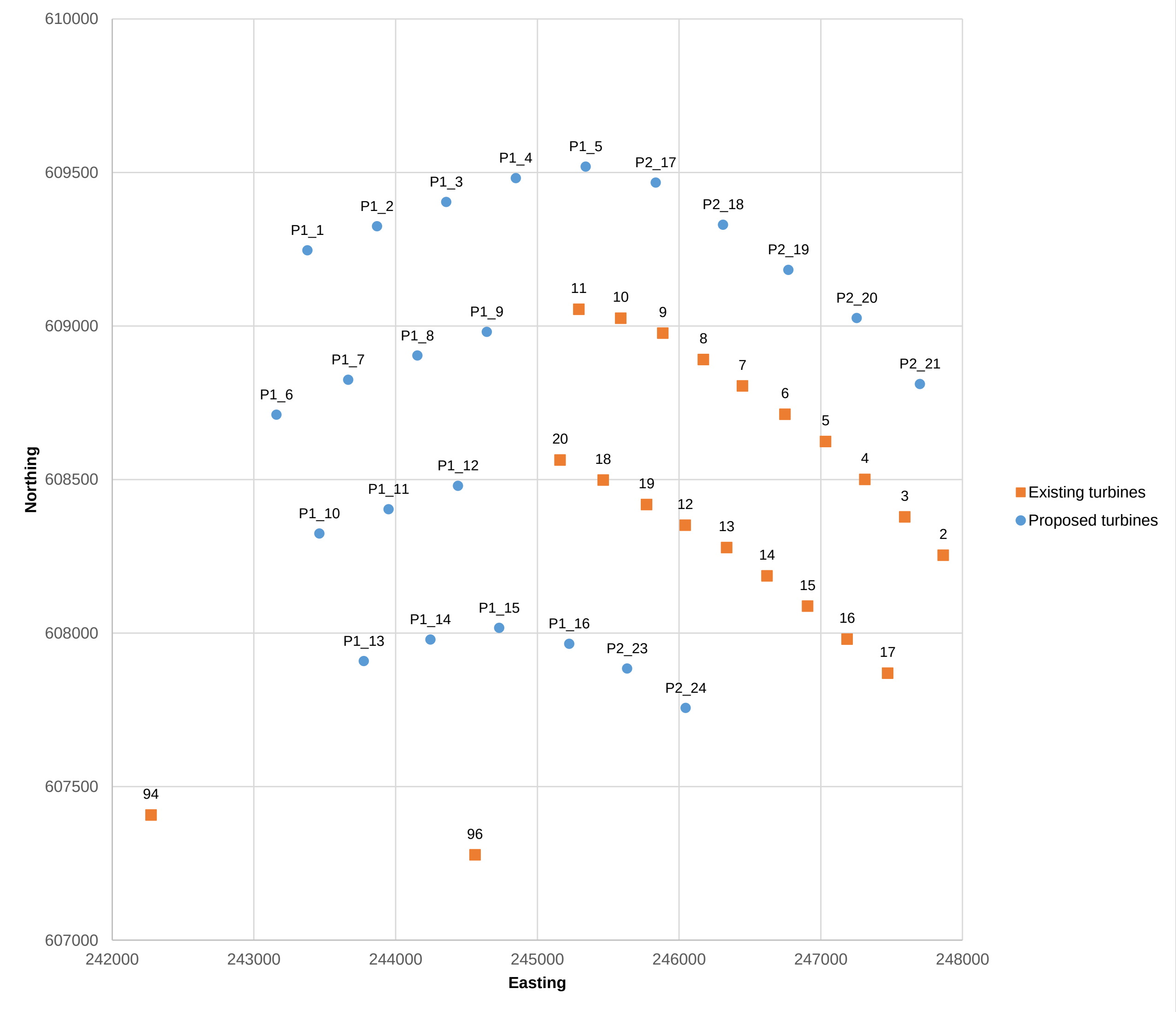
To account for the increased fatigue loading associated with turbines operating within the wake of neighbouring turbines, the Frandsen equivalent turbulence method /6/, as referenced in Annex D of the IEC 61400-1 edition 3 standard /7/ is often used. This is an empirical formulation for deriving a 'design' turbulence intensity to account for the increase in turbulence and fatigue loading experienced when in the wake of a neighbouring turbine.

The calculation of the effective turbulence intensity depends on the distance between neighbouring turbines, whereby the effective turbulence intensity will increase as the distance between turbines decreases. The relationship also states that the wake effects no longer have an effect if the neighbouring turbines are 10 diameters (10D) or more apart. The effective TI is also impacted by the inverse SN slope of structural materials and turbine thrust coefficient (Ct) curves used. Note that for this study, an inverse SN slope of 10 was used (which DNV considers a single conservative representative value for high level review) and generic Ct curves were used as turbine specific data was not available. These assumptions are considered appropriate for this high-level analysis.

2.4 Impacts of proposed turbines

A high-level analysis was carried out to investigate how much the effective turbulence would increase for the turbines closest to the proposed turbines with 165m rotor diameters. The turbines included in the analysis are shown in Figure 2-4.

Figure 2-4 – Proposed and selected existing turbines



The proposed turbines have the effect of increasing effective turbulence intensity on selected existing wind turbines in the area. This effective TI study is limited to the turbines shown in Figure 2-4 as these turbines are within 10 diameters of the proposed turbines. The remainder of the turbines which are outside 10 diameters of the proposed turbines should not experience increased turbulence.

In the existing layout (i.e. without the addition of the proposed turbines) turbine 12 from the analysed turbines has the largest effective turbulence. The results show the effective turbulence intensities for the existing turbines have increased due to the proposed turbines and in a few cases now exceed turbulence type class A. The turbines which show some exceedances are T2, T3, T5, T12 and T19. T12 shows the largest exceedances in effective TI (~5% compared to type class A) however, in general the exceedances are relatively small and occur between wind speeds of 8 and 12m/s.

An increase in effective TI results in an increase in turbine loading which has the effect of decreasing turbine lifetimes. Turbines 2, 3, 5 and 12 are Enercon E82 turbines and turbine 19 is a Vestas V90 turbine. From an online search, DNV have found that both turbine types have a turbulence class of A, which is the highest turbulence class turbines are typically designed to. While the calculated effective TIs show some exceedances above the turbine class A level, DNV expects that it is possible that there is some strength margin for these turbines beyond the design limit. Note that this should be checked in detail with the OEMs during future technical analysis when the turbine platform has been decided. DNV is also of the opinion that wind sector management could also be successfully used to negate the increase of effective turbulence. Again, this should be considered in more detail when the turbine platform has been decided for development.

2.5 Conclusions

Overall, based on DNV's experience of site suitability studies, DNV is of the opinion that the layout proposed with 165m rotor diameters is likely not to have a material impact on the loading and lifetime of the existing wind turbines in the area. DNV has carried out a high-level site suitability study using the information which the customer has provided to calculate the impact on effective turbulence on neighbouring turbines. Note that not all environmental information (e.g. shear) was available to DNV for this analysis however standard assumptions were made which were deemed appropriate for this type of high level analysis. The results of the analysis found that while there was a small overall increase in effective TI for a limited number of turbine locations which resulted in some exceedances above the turbine type class level, DNV believes that for the turbine types affected (V90 and E82) it is possible that there will be sufficient margin inherent in the turbine design and additionally that wind sector management could be used successfully to negate the increase of turbulence intensity. Considering the details which are relevant for the purposes of submitting a planning application, DNV concludes that turbines with rotor diameter 165m would be deemed suitable for the locations proposed within this technical note.

3 REFERENCES

/1/ Proposal for Provision of Garrad Hassan Turbine Engineering Services for Wind farm layout design suitability, L2C216901-UKBR-P-01-A, April 2021

/2/ Spreadsheet "EHW_Surrounding WTGs_WindStats extract_20221129 JB.xlsx", from Jan Borras Morales, 19th January 2023

/3/ Spreadsheet "LEEST069.xlsx", from Jan Borras Morales, 12th January 2023

/4/ Spreadsheet "SoDAR Ambient TI 120m_20210702 JB.xlsx", from Jan Borras Morales, 2nd July 2021

/5/ Spreadsheet "LT Freq Distribution 120m_20210702 JB.xlsx", from Jan Borras Morales, 2nd July 2021

/6/ FRANDSEN, Sten Tronæs, "Turbulence and turbulence-generated structural loading in wind turbine clusters", Risø National Laboratory, Denmark, January 2001.

/7/ IEC 61400-1 International standard, Wind Turbine Generator systems, Edition 3 – Part 1: Design requirements, August 2005, Amended 2010

About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

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