November 2023

Lifetime estimates

Hitra1 wind park

Project: Application for extended concession for Hitra 1 **Country**: Norway

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Elaborated by	Date	Checked by	Issue date	Rev no	Comments
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OU	26/10/2023	TR	26/10/2023	00	First Issue

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1 Introduction

This document presents lifetime estimates for Hitra 1 wind farm, and comparisons towards similar evaluations for the Smøla wind farm. The Hitra 1 and Smøla 2 turbines Bonus 2.3 MW B40 are of type IEC class IA, as documented in the turbine type certificate [1] and the statement of compliances [2] [3], all documents issued by DNV. It is the Site Compliance/Load Response tool in WindPRO that is used for the assessment [4]. This is based on a response surface method based on pre-run aero-elastic simulations. This model has no detailed knowledge about the turbine components but compares the actual load case with the assumption of the turbine life to be exactly 20 years under IEC IA conditions (mean wind speed of 10 m/s, Iref=0.16 and air density=1.225 kg/m^3) [5]. The model runs DLC 1.2 “Power production” (Design Load Case), which covers the fatigue during normal operation, which is typically the most critical load case, but extreme loads which are not covered in load response can also be design driving for wind turbines. By experience, the results from WindPRO load response tends to be slightly more conservative than dedicated aero-elastic simulations carried out by the manufacturer using the actual turbine components as input. Another experience is that the old turbines tend to have a larger margin towards the design limit than what is typically true today. This gives an additional margin in the expected turbine lifetime.

2 Design value comparison

The relevant design values of IEC IA are compared to the actual values for the wind farms Hitra 1 and Smøla 2 in Table 1. The table shows that there is good margin on the mean wind speed level for all three alternative configurations. A bit higher wind speed at Hitra 1 compared to Smøla 2, but this is partly compensated by the lower air density at Hitra 1. On average there is also some margin on the turbulence conditions, but for the most exposed turbines, the turbulence conditions are slightly higher than the standard. The k-parameter, the wind shear and the flow inclination are less important, but their values are fine.

Design parameters	IEC IA	Hitra 1 with Hitra 2			Hitra 1 wo Hitra 2			Smøla 2		
		Max	Min	Average	Max	Min	Average	Max	Min	Average
Mean wind speed [m/s]	10.0	8.2	7.2	7.8	8.2	7.2	7.8	7.7	7.3	7.4
k-parameter [-]	2.00	1.96	1.87	1.94	1.96	1.87	1.94	1.76	1.70	1.73
Iref [-]	0.16									
TI90 at 15 m/s [%]	18.0%	19.0%	14.0%	16.9%	19.0%	14.0%	16.3%	19.0%	14.0%	16.6%
Air density [kg/m^3]	1.225	1.223	1.217	1.220	1.223	1.217	1.220	1.254	1.250	1.252
Wind shear [-]	0.20	0.14	0.06	0.09	0.13	0.05	0.09	0.18	0.14	0.16
Flow inclination [º]	±8.0	5.1	-5.1	1.9	5.2	-4.3	2.6	-0.1	-2.3	-0.9

***Table 1**: Design value comparisons between IEC IA [5] and design conditions at Hitra 1 and Smøla 2 (with IEC IA turbines, but named Bonus B82 2.3 MW 2300-400 at Hitra 1 and Siemens SWT-2.3-82 VS at Smøla 2, the reason for this name change is that Bonus was bought by Siemens in 2004).*

3 Modelled lifetime results

A summary of the modelled lifetime result for Hitra 1 wind farm is given in Table 2. We have evaluated load estimates both with and without the Hitra 2 wind farm as neighboring turbines, as the Hitra 2 wind farm came in production in 2019, so for the period from 2004-2019 (~15 years), the wind farm has operated without the additional loads from Hitra 2.

Wind farm	Mean lifetime Worst comp	Lifetime range individual turbines Worst comp	Mean lifetime Tower	Lifetime range individual turbines Tower
Hitra 1 without Hitra 2	32.1 years	27.2 – 33.8 years	49.5 years	40.2 – 50 years
Hitra 1 with Hitra 2	31.0 years	21.7 – 33.7 years	47.2 years	34.9 – 50 years
Smøla 2 with Smøla 1	32.3 years	30.1 – 35.2 years	50 years	50 years

Table 2: *Calculated lifetime range and mean values for Hitra 1 and Smøla 2 (with IEC IA turbines).*

Table 2 shows that the mean lifetime of the Hitra 1 turbines is at a similar level as Smøla, but slightly more exposed. Individual turbine lifetime calculations are visualized in Figure 1-Figure 4. It is particularly turbine 12 that has a significantly reduction of the lifetime resulting for the additional wake loads from Hitra 2, going from 27.5 years to 21.7 years. This is for the component “Shaft;LSSMx; Low speed shaft torque”, which differs from the most common worst component which is the “Blade;BlrMx1; Root in-plane bending”. The blade component is only reduced from 29.3 years to 28.8 years for turbine 12 as a result of Hitra 2 turbines. We expect the wear of the shaft to be less critical than the blade in a safety perspective.

Since it is typically the tower that is the most critical component if overloaded, we have shown the tower results isolated. For the tower, it is seen to be a large margin for all three alternatives. 50 years is the maximum level shown, which means 50 years in this context typically means more than 50 years.

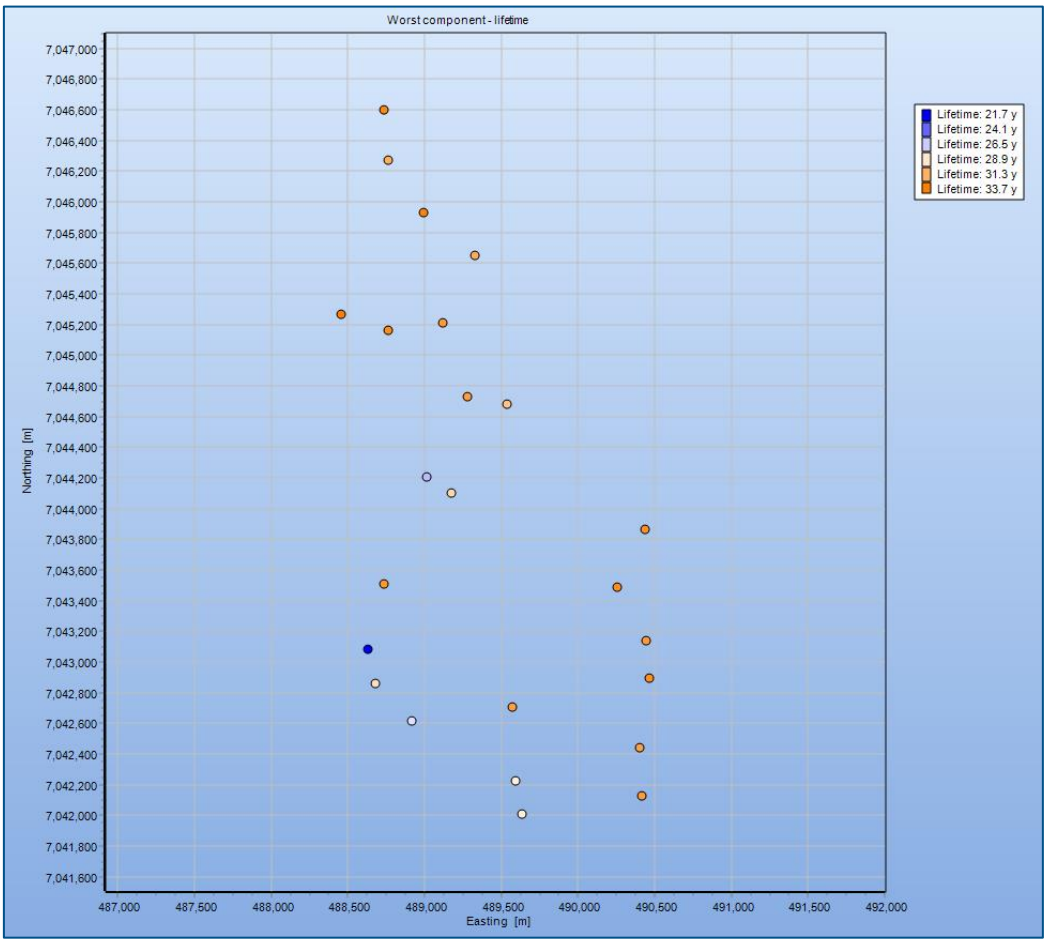

Figure 1: *Graphically view of the lifetime of the worst component for Hitra 1. The figure shows the lifetime with the impact from neighboring Hitra 2 turbines.*

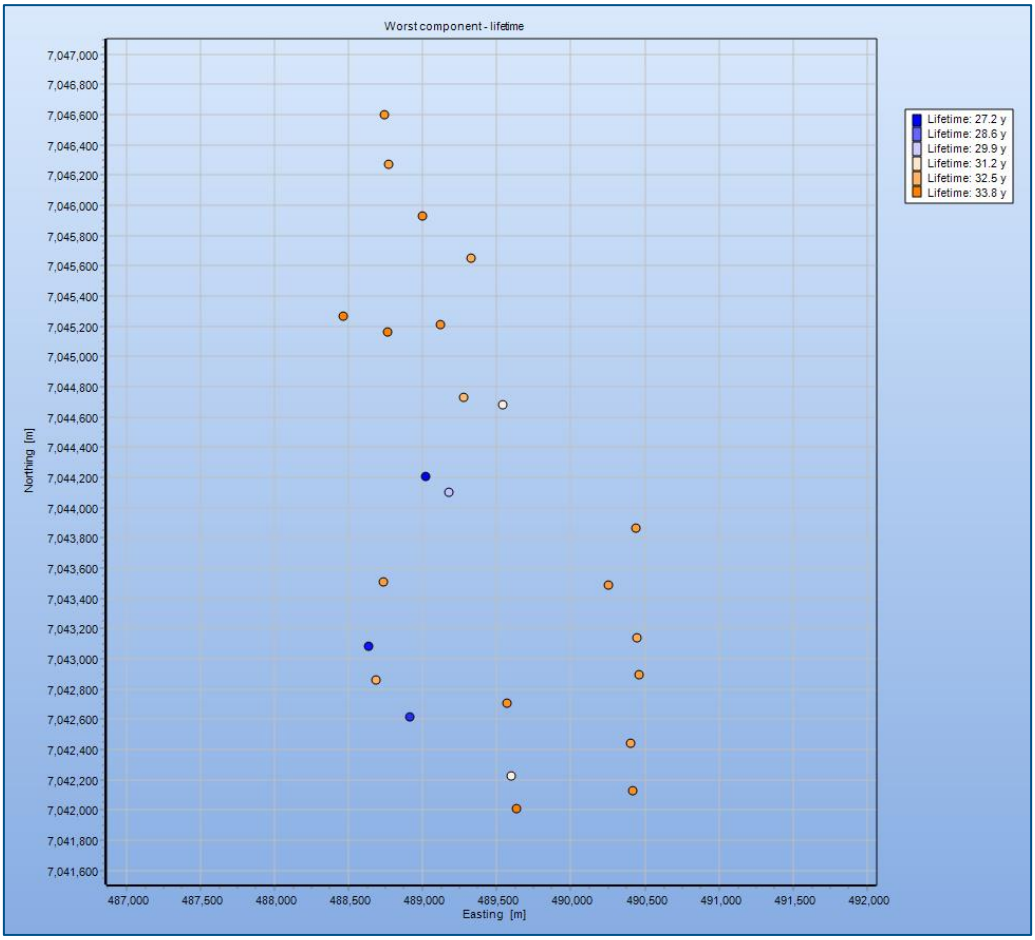

Figure 2: *Graphically view of the lifetime of the worst component for Hitra 1. The figure shows the lifetime without the impact from neighboring Hitra 2 turbines.*

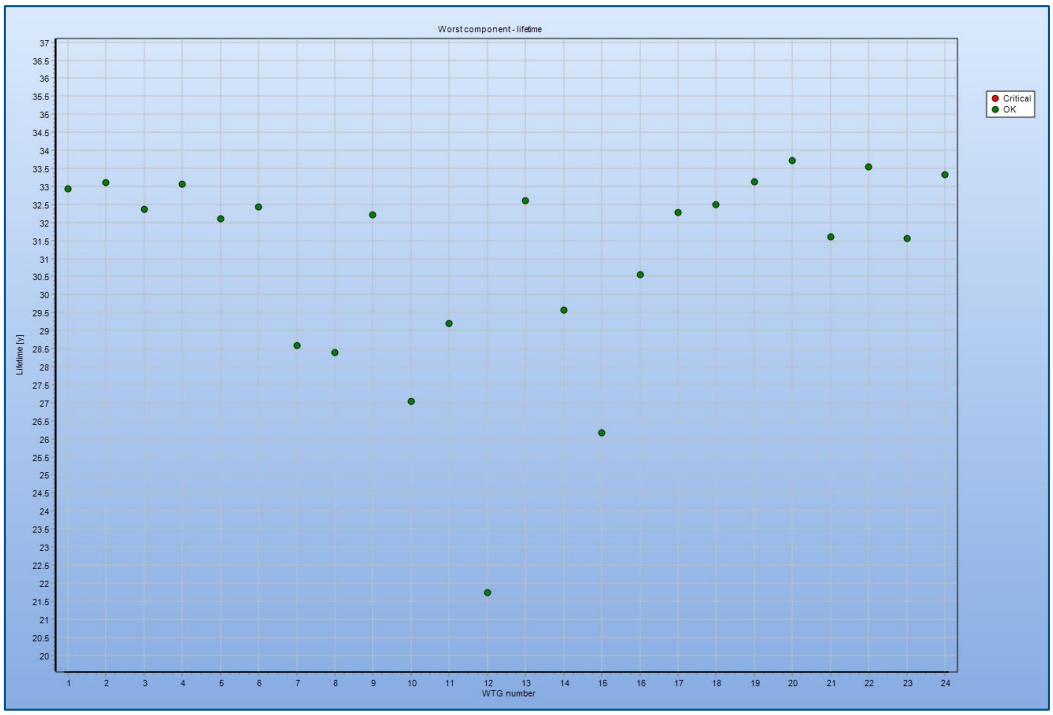

***Figure 3**: Single turbine life worst component for Hitra 1 with neighbouring Hitra 2 turbines.*

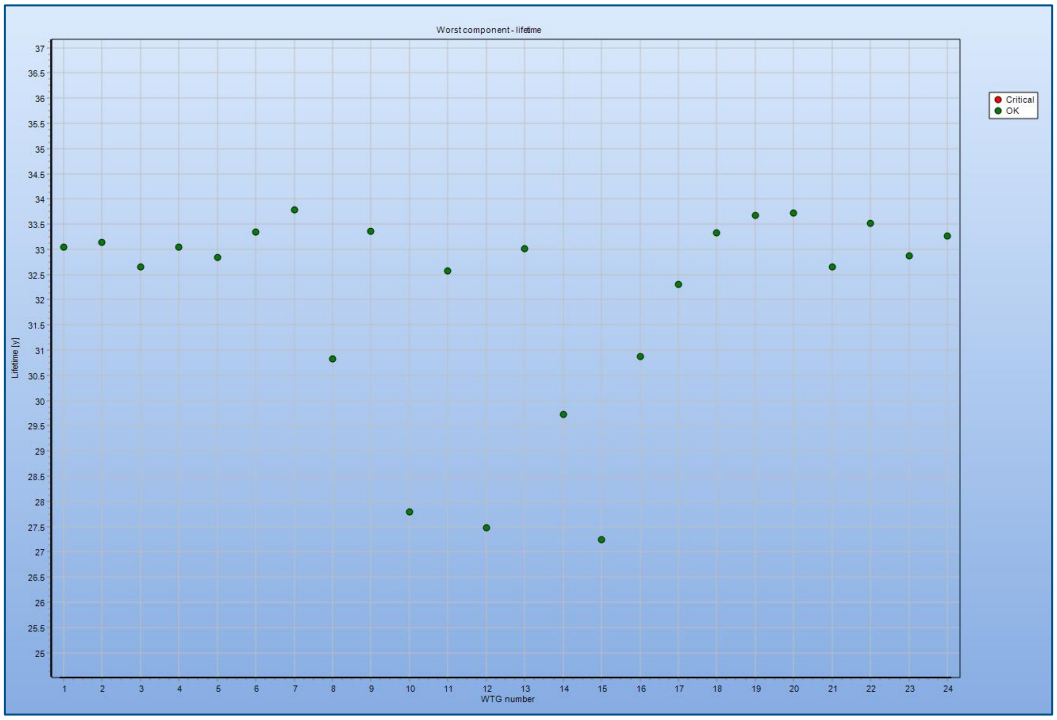

***Figure 4**: Single turbine life worst component for Hitra 1 without neighbouring Hitra 2 turbines*

3.1 Wind speed and effective TI for the different alternatives

The mean wind speed level of Hitra 1 is 7.8 m/s and the mean wind speed level of Smøla 2 is 7.5 m/s. The corresponding average effective TI of the different alternative configurations of the two areas is generally similar as seen in Figure 5. The reason for significantly longer life than 20 years is primarily the margin up to the mean wind speed level of 10 m/s for class I, but also on average below class A turbulence level.

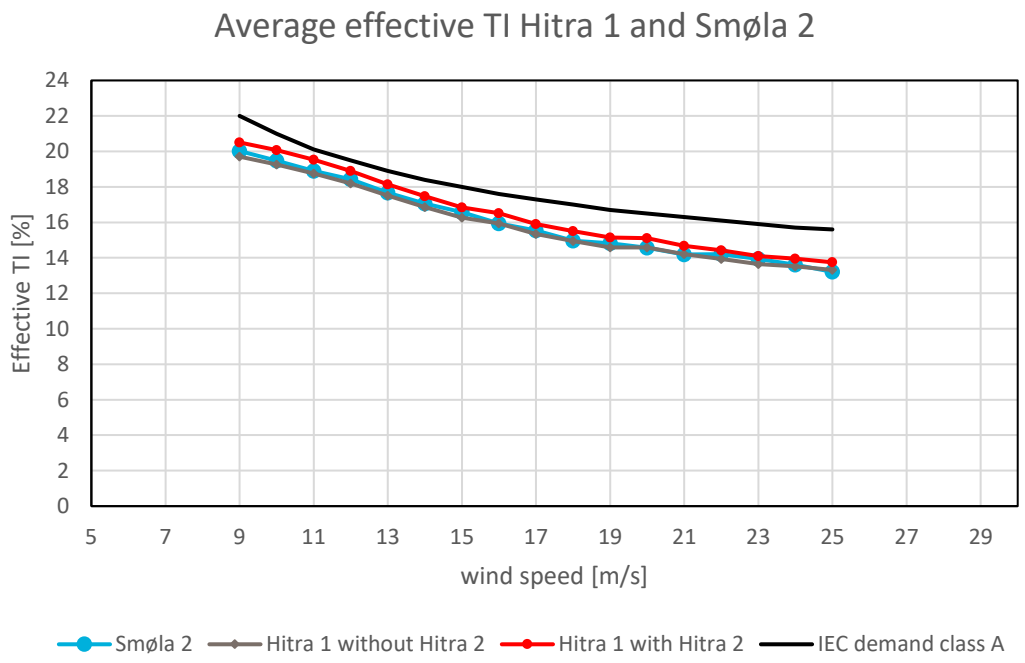

Figure 5: *Average effective TI as function of wind speed for the three alternative set-ups compared to the IEC class A limit.*

4 Conclusions

This document supports the application for concession extension at Hitra 1 from 01.04.2028 to 19.12.2030. Hitra 1 was commissioned in 2004, which means a total operational time of 26-27 years if the extension is approved. We regard the presented results to be an indication of this extension for the Hitra 1 turbines to be within the expected true life of the turbines.

5 References

[1] Det Norske Veritas, "Type Certificate; Bonus 2.3 MW B40 IEC I A," 2004.

[2] Det Norske Veritas, "Statement of Compliance; Bonus 2.3 MW Hitra," 2005.

[3] Det Norske Veritas, "Statement of Compliance; Bonus 2.3 MW Smöla II," 2005.

[4] EMD WindPRO, "https://help.emd.dk/knowledgebase/," [Online].

[5] IEC 61400-1 Ed.4., "Wind Turbines Part 1: Design requirements," 2019.