KENT HILLS 3: KENT HILLS WIND FARM EXPANSION PHASE 3

Appendix K Shadow Flicker Modeling Analysis

Appendix K SHADOW FLICKER MODELING ANALYSIS



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Shadow Flicker Analysis – Kent Hills 3 Wind Project

Date: September 5, 2017

Re: Shadow Flicker Analysis for the Proposed Kent Hills 3 Wind Project

1. Introduction and Project Background

The modeling results presented in this report are based on the cumulative impact of the potential shadow flicker to occur at the Kent Hills 3 Wind Project (the Project) considering nine additional turbine locations (5 preferred, 4 alternate) and the existing 50 turbines already in operation from the previous two phases – Kent Hills 1 (KH1) and Kent Hills 2 (KH2). Once constructed, the proposed Kent Hills 3 Project will consist of five Vestas V126-3.45 megawatt (MW) turbines with a 117 m hub-height, in addition to the existing 50 Vestas V90-3 MW wind turbines with 80 m hub height.

The Project area can be described as a mix of hills and flat terrain covered by hardwood and conifer forest in varying stages of regrowth with a history of logging in the area. There is very little residential development in the Project area as the Project is situated on Crown land.

Results from the previous shadow flicker impact assessments completed for the Kent Hills 1 and Kent Hills 2 wind farm phases suggest that maximum number of shadow hours were predicted below 30 hr/yr and 30 min/day at all adjacent known receptors (residences) within 1.5 km of the nearest wind turbine. Incorporating variables such as turbine location, receptor location, topography, rotor diameter, hub height and time zone information the model assumes a "worst case" scenario including the following conditions: the sun is fully shining all year (no clouds or fog), the rotor plane is perpendicular to the sun (biggest shadows), and the rotor is always turning (causing shadow movements) and no visual obstructions (trees, buildings). To date no shadow flicker complaints have been received by TransAlta in relation to the Kent Hills Wind Farm 1-2 (T. Kwas, pers. comm.)

In this report, we will discuss considerations and results to our cumulative shadow flicker modeling of the Kent Hills 3 Project.

2. Shadow Flicker Modeling

Shadow flicker caused by wind turbines is defined as alternating changes in light intensity due to

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the moving blade shadows cast on the ground and objects (including windows at residences).

Shadow flicker is more prevalent when the sun is low in the sky at either sunrise or sunset and is less apt to occur during the spring and fall equinoxes (March 21 and September 21), and more likely during the summer and winter solstices (June 21 and December 21) when the sun is low in the sky.

The shadow-flicker frequency is related to the rotor speed and number of blades on the rotor. The modeling results presented in this report are based on the respective wind turbine model parameters of each project phase which include blade length, hub height and nominal rotor speed (of less than 1 alternation per second).

The modeling software used for this analysis is produced by EMD of Denmark and is part of the WindPro Version 3.1.617 modeling software package. The following inputs are used for the simulation:

- Turbine locations
- Receptor locations (Adjacent residences within 1.5 km)
- Area topography map
- Area height contours
- Time zone and daylight saving time information
- Rotor diameter
- Hub height
- Receptor window 1 m x 1 m with the bottom edge 1.5 m above grade regardless of direction.

To determine daylight hours at this specific site the software holds information about the earth's orbit and rotation relative to the sun and in relation to the Project area.

It should be noted that the model intentionally overpredicts shadow flicker effects. Its calculations represent "worst case" scenarios regardless of typical real case conditions minimizing effects such as:

- The reduction of shadow flicker on calm or overcast days where there is insufficient sunlight to cast a shadow. The model presumes sun always shining from sunrise to sunset.
- The rotor orientation not always casting in direction of the dwellings. The model presumes the rotor is always oriented perpendicular to the dwellings (same direction as the sun)
- If there is a non-transparent obstacle between the receptor that would block the



sunlight and any shadow impacts (e.g. trees, buildings)

• Statistics regarding wind conditions and number of hours with clear sky are not considered. The model presumes the turbines always running

3. Modeling Results

Wind turbine names (T1 to T9 for the proposed KH3 project and A1 to I2 for the operating turbines at the KH1 and KH2 phases) and shadow-flicker receptors (A to O) have been named according to the attached Project layout maps (Appendix A). Only shadow-flicker receptors in the immediate vicinity of turbines have been included in the model, as those more distant buildings will not be affected. Shadow-flicker receptors to the north or south of wind turbines are not likely to receive shadow-flicker, because the cast shadow is very short in the north and south directions, as can be seen in the shape of the contour lines on the accompanying analysis.

The model accounts for all of the adjacent dwellings (regardless of their status) within a 1.5 km range of a wind turbine. These dwellings were selected as they represent the potential worst case scenarios based on their locations relative to the proposed turbines.

Presently best industry practices tend to consider the guideline for a maximum of 30 hours per year and 30 min par day as an acceptable threshold of shadow flicker impact using "worst case" scenarios (WEA-Schattenwurf-Hinweise, 2002).

As a result of the cumulative shadow flicker impact from the addition of the 9 proposed turbine locations (5 preferred, 4 alternate) to the existing KH1 and KH2 wind farm;

- the maximum number of shadow hours cast per year at any receptor within the Kent Hills Wind Farm is at 22 hours (22 hours, 06 minutes) spread over 82 days during the year at Receptor M. Shadow hours is the sum of the durations of all daily occurrences of shadows being cast on the receptor during over the year. A shadow day is any day in which a shadow occurrence is cast on the receptor;
- the maximum number of shadow minutes per day are at Receptors I & L with 23 minutes. Shadow minutes is the maximum number of minutes for the day of the year a shadow occurrence is the longest of the year (May 6th at receptor I, February 12th & October 30th at Receptor L)

The table below summarizes the results of the shadow flicker report calculations. The shadow flicker map can be found in Appendix A. The detailed results from the WindPro© analysis are in Appendix B.



Receptor	PID	Max Shadow Hrs/Yr	Max Shadow Days/Yr	Max Shadow Mins/day
А	00601708	0:00	0	0:00
В	05073549	4:05	20	0:16
С	05026844	0:00	0	0:00
D	05026836	0:00	0	0:00
E	05026836	0:00	0	0:00
F	00607259	0:00	0	0:00
G	00618371	0:00	0	0:00
Н	05043476	0:00	0	0:00
I	00623934	11:11	39	0:23
J	01104942	7:19	30	0:20
К	05017249	0:00	0	0:00
L	00606160	18:13	64	0:23
М	00746610	22:06	82	0:20
N	05043955	9:10	34	0:21
0	05028907	0:00	0	0:00

Table 1. Cumulative Shadow Flicker Results for Nearby Dwellings at the Kent Hills Wind Farm

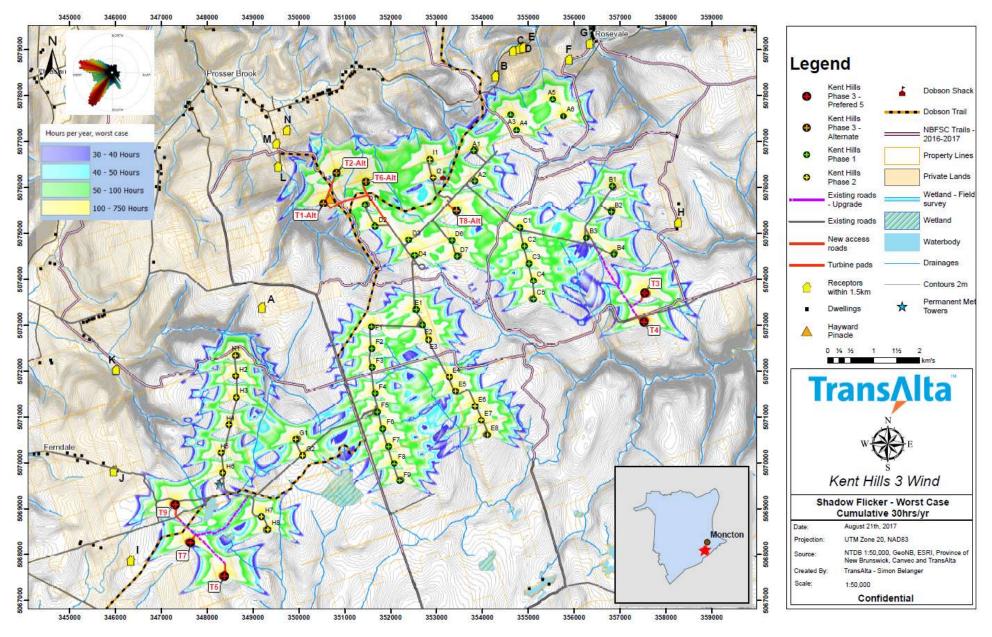
4. Conclusion

Shadow flicker impact at all dwellings modeled within 1.5 km of all existing and proposed wind turbines are well below generally accepted levels of 30 hours/year and 30 min/day based on a worst-case calculation. Therefore, cumulative shadow flicker from the proposed Kent Hills 3 wind farm, is not expected to cause any significant impact on adjacent receptors nor imply any expected mitigation measure to be required.

5. References

WEA-Schattenwurf-Hinweise. 2002. Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergianlagen (Notes on the identification and assessment of the optical pollutions of Wind Turbines)

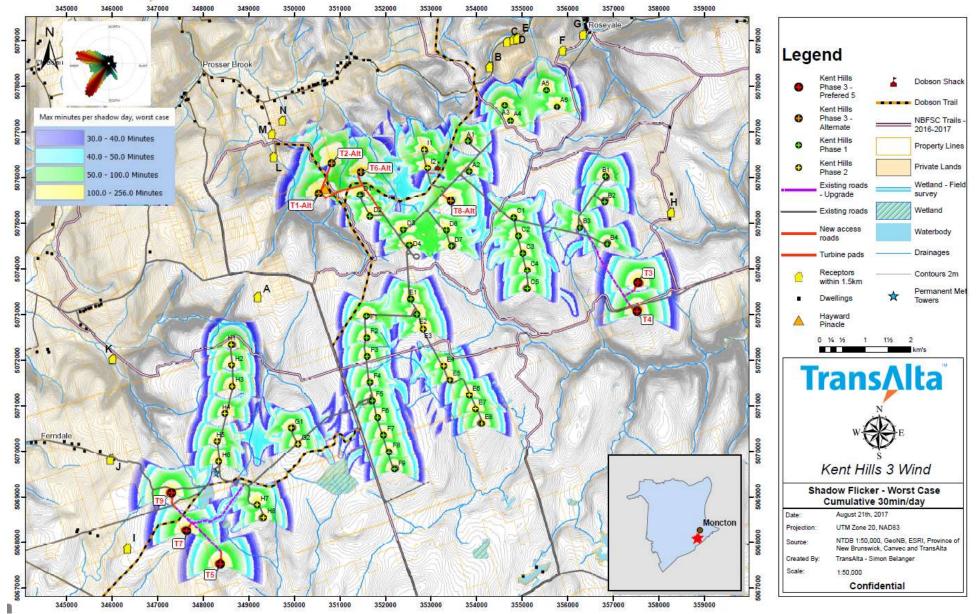




Appendix A – Shadow Flicker maps



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Appendix B – Model results (WindPro)

Kent_Hills_3

Simon Belanger P.Eng., Design Renewables TransAlta Box 1900, Station "M"

SHADOW - Main Result

Calculation: KH3 (9WTG) Cumulative with KH1-2 Assumptions for shadow calculations

Maximum distance for influence Calculate only when more than 20 % of sun is covered by the blade Please look in WTG table

Minimum sun height over horizon for influence 3 ° Day step for calculation 1 days Time step for calculation 1 minutes The calculated times are "worst case" given by the following essumptions:

The sun is shining all the day, from survise to sunset. The rotor plane is always perpendicular to the line from the WTG to the sun The WTG is always operating.

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions: Height contours used: Height Contours: ZmContours_KentHills_CDEM_20160503.ma

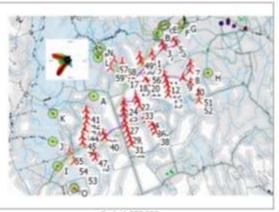
Height contours used: Height Contours: 2mContours_KentHills_CDEM_20160503.me Obstacles used in calculation

Eye height: 1.5 m Grid resolution: 10.0 m

All coordinates are in UTM WGS84 Zone: 20

A New WTG

Itanian TransAlta Corporation Station M 110 - 12th Avenue SW PO Box 1900 CA-7292911 Calgary, Alberta +1 (403) 267-2000 Simon Belanger / simon, belanger@transalta.com Isaasta 2017/08/22 7:42 PM/3.1.617



Scale 1:250,000 Shadow receptor

low receptor

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www.transalta.com



Kent_Hills_3

Simon Belanger P.Eng., Design Renewables TransAlta Box 1900, Station "M"

SHADOW - Main Result

Calculation: KH3 (9WTG) Cumulative with KH1-2

...continued from previous page

www.transalta.com

Lternal use: TransAlta Corporation Station M 110 - 12th Avenue SW PO Box 1900 CA-T2P2M1 Calgary, Alberta +1 (403) 267-2000 Simon Belanger / simon_belanger@transalta.com 2017/08/22 7:42 PM/3.1.617

		- and the second			WTG	i type					Shadow da	ata
	X(East)	Y(North)	Z	Row data/Description	Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
38	354,109	5,070,605	360.1	VESTAS V90_1.21 3000 90.0 10! hub: 1	J Yes	VESTAS	V90_1.21-3,000	3,000	90,0	80.08	1,425	16.1
39	349,938	5,070,506	398,7	VESTAS V90_1.21 3000 90.0 IO! hub: 1	3Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80,0	1,425	16.1
40	350,087	5,070,150	398.5	5 VESTAS V90_1.21 3000 90.0 101 hub: 1	3Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
41	348,618	5,072,336	352.6	VESTAS V90_1.21 3000 90.0 101 hub: 1	Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
42	348,626	5,071,885	363.8	VESTAS V90_1.21 3000 90.0 IO! hub: 1	3Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
43	348,637	5,071,418	378.6	VESTAS V90_1.21 3000 90.0 10! hub: 1	IYes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
44	348,514	5,070,822	382.0	VESTAS V90_1.21 3000 90.0 10! hub: 1	3Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
45	348,307	5,070,209	390.0	VESTAS V90_1.21 3000 90.0 IO! hub: (IYes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
46	348,343	5,069,777	384.9	VESTAS V90_1.21 3000 90.0 !O! hub: 1	3Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
47	349,185	5,068,894	396.3	VESTAS V90_1.21 3000 90.0 !O! hub: !	Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
48	349,332	5,068,537	397.0	VESTAS V90_1.21 3000 90.0 IOI hub: 1	3Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
49	352,846	5,076,610	375.7	VESTAS V90_1.21 3000 90.0 O! hub: 1	Yes	VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
				VESTAS V90_1.21 3000 90.0 10! hub: 1		VESTAS	V90_1.21-3,000	3,000	90.0	80.0	1,425	16.1
				VESTAS V126-3.45_HighTor_TA 3450 1		VESTAS	V126-3.45_HighTor_1	FA-3,450 3,450	126.0	117.0	1,716	
				VESTAS V126-3.45_HighTor_TA 3450 1		VESTAS	V126-3.45_HighTor_1		126.0	117.0	1,716	
				VESTAS V126-3.45_HighTor_TA 3450		VESTAS	V126-3.45_HighTor_1		126.0	117.0	1,716	
				VESTAS V126-3.45_HighTor_TA 3450		VESTAS	V126-3.45_HighTor_1	FA-3,450 3,450	126.0	117.0	1,716	12.8
				VESTAS V126-3.45_HighTor_TA 3450 1		VESTAS	V126-3.45_HighTor_1	FA-3,450 3,450	126.0	117.0	1,716	12.8
				VESTAS V126-3.45_HighTor_TA 3450		VESTAS	V126-3.45_HighTor_		126.0	117.0	1,716	
				VESTAS V126-3.45_HighTor_TA 3450		VESTAS	V126-3.45_HighTor_1		126.0	117.0	1,716	
				VESTAS V126-3.45_HighTor_TA 3450 1		VESTAS	V126-3.45_HighTor_1		126.0	117.0	1,716	
59	350,539	5,075,645	370.6	VESTAS V126-3.45_HighTor_TA 3450 1	2.Yes	VESTAS	V126-3.45_HighTor_1	FA-3,450 3,450	126.0	117.0	1,716	12.8

Shadow receptor-Input

No.	Name	X(East)	Y(North)	z	Width	Height	Height a.g.l.	Degrees from south cw	Slope of window	Direction mode
				[m]	[m]	[m]	[m]	["]	[*]	
	A	349,201	5,073,382	361.8	1.0	1.0	1.5	0.0	90.0	"Green house mode"
E	B	354,278	5,078,419	234.8	1.0	1.0	1.5	0.0	90.0	"Green house mode"
0	C	354,661	5,078,971	208.9	1.0	1.0	1.5	0.0	90.0	"Green house mode"
C	D	354,804	5,079,023	197.3	1.0	1.0	1.5	0.0	90.0	"Green house mode"
E	E	354,883	5,079,043	192.5	1.0	1.0	1.5	0.0	90.0	"Green house mode"
F	F	355,883	5,078,781	247.1	1.0	1.0	1.5	0.0	90.0	"Green house mode"
	G	356,334	5,079,133	167.8	1.0	1.0	1.5	0.0	90.0	"Green house mode"
H	H	358,266	5,075,232	333.4	1.0	1.0	1.5	0.0	90.0	"Green house mode"
1	1	346,339	5,067,869	361.0	1.0	1.0	1.5	0.0	90.0	"Green house mode"
	1	345,965	5,069,817	326.3	1.0	1.0	1.5	0.0	90.0	"Green house mode"
K	K	346,017	5,072,016	167.2	1.0	1.0	1.5	0.0	90.0	"Green house mode"
- 1	L	349,552	5,076,449	157.0	1.0	1.0	1.5	0.0	90.0	"Green house mode"
M	M	349,512	5,076,949	145.4	1.0	1.0	1.5	0.0	90.0	"Green house mode"
N	N	349,743	5,077,245	155.9	1.0	1.0	1.5	0.0	90.0	"Green house mode"
C	0	347,674	5,066,138	364.4	1.0	1.0	1.5	0.0	90.0	"Green house mode"

Calculation Results

		Shadow, wor	st case	
No.	Name	Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
A	A	0:00	0	0:00
в	В	4:05	20	0:16
C	C	0:00	0	0:00
D	D	0:00	0	0:00
E	E	0:00	0	0:00
F	F	0:00	0	0:00
G	G	0:00	0	0:00
н	н	0:00	0	0:00
I	I	11:11	39	0:23
1	1	7:19	30	0:20
K	ĸ	0:00	0	0:00

To be continued on next page ...

wendPRO 3.1.617 by EMD International A/S, Tel. +45 96 35 44 44, www.emd.dk, windpro@emd.dk



TransAlta

Kent_Hills_3

Simon Belanger P.Eng., Design Renewables TransAlta Box 1900, Station "M"

SHADOW - Main Result

Calculation: KH3 (9WTG) Cumulative with KH1-2

... continued from previous page

	Shadow, wor	st case	
No. Name	Shadow hours per year	Shadow days per year	Max shadow hours per day
	[h/year]	[days/year]	[h/day]
LL	18:13	64	0:23
MM	22:06	82	0:20
NN	9:10	34	0:21
00	0:00	0	0:00

Total amount of flickering on the shadow receptors caused by each WTG No. Name

IVESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2705) 0:00 2 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2720) 0:00 4 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2721) 0:00 5 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2721) 0:00 5 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2721) 0:00 7 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2723) 0:00 9 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2725) 0:00 9 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2725) 0:00 10 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2728) 0:00 11 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2728) 0:00 12 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2731) 0:00 13 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2731) 0:00 14 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2731) 0:00 15 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2731) 0:00 17 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2731) 0:00 18 VESTAS V90_1.21 3000 90.0 101 hub: 80.0 m (TOT: 125.0 m) (2731) 0:00 19 VESTAS V90_1.21 3000 90.0 101	Total amount of flickering on the shadow receptors caused by each WTG. No. Name W	orst case
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TransAlta Corporation Station M 110 - 12th Avenue SW PO Box 1900 CA-T2P2M1 Calgary, Alberta +1 (403) 267-2000 Simon Belanger / simon_belanger@transalta.com 2017/08/22 7:42 PM/3.1.617

2017/08/24 9:57 AM / 3 WindPRO



Kent_Hills_3

Simon Belanger P.Eng., Design Renewables TransAlta Box 1900, Station "M"

www.transalta.com

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2017/08/22 7:42 PM/3.1.617

SHADOW - Main Result

Calculation: KH3 (9WTG) Cumulative with KH1-2

...continued from previous page No. Name

Worst case [h/year] 55 VESTAS V126-3.45_HighTor_TA 3450 126.0 10l hub: 117.0 m (TOT: 180.0 m) (2979) 56 VESTAS V126-3.45_HighTor_TA 3450 126.0 10l hub: 117.0 m (TOT: 180.0 m) (2980) 57 VESTAS V126-3.45_HighTor_TA 3450 126.0 10l hub: 117.0 m (TOT: 180.0 m) (2981) 58 VESTAS V126-3.45_HighTor_TA 3450 126.0 10l hub: 117.0 m (TOT: 180.0 m) (2982) 7:19 0:00 24:07 0:00 59 VESTAS V126-3.45_HighTor_TA 3450 126.0 IOI hub: 117.0 m (TOT: 180.0 m) (2983) 25:22

Total times in Receptor visio and WTG visio tables can differ, an a WTG can bad to Bolen at 2 or more receptors simultaneously and/or receptors may receive ficher tram 2 or more WTGs annultaneously.

