QUICK GUIDE – LOAD RESPONSE

Purpose:

To check if the loads for a specific turbine or generic IEC turbine class are acceptable for the site and layout conditions.

LOAD RESPONSE calculates structural wind turbine loads based on a response surface approach according to the design load cases (DLC) in IEC 61400-1 ed. 3 (2010).

Outline of Guide:

- 1. Installation of LOAD RESPONSE
- 2. Setup input data for LOAD RESPONSE
- 3. Calculations in LOAD RESPONSE
- 4. Result in LOAD RESPONSE

1. INSTALLATION OF LOAD RESPONSE

Install windPRO 4.0 on your computer and check that you have license for LOAD RESPONSE indicated by the green circle.

М	odules	푸	\times
>	Basis	 	
>	Energy	 	
>	Environment		
>	Visual		
>	Economy		
>	Optimization		
>	Electricity		
Y	Loads		
	SITE COMPLIANCE (WTG suitability for site and layout)		
	 IOAD RESPONSE (WTG load and lifetime estimation) 		
>	Operation		
>	Cluster Services		
>	Other		

Check that one or several wind turbines are available for calculation. The response files for the individual wind turbines should be available in the folder "LoadResponse", which on a Windows PC normally is located at the path: "C:\Users\XX\Documents\WindPRO Data\LoadResponse". The wind turbines will be named "XX.loadresponse".



2. SETUP INPUT DATA FOR LOAD RESPONSE

Before using LOAD RESPONSE, a SITE COMPLIANCE analysis must be performed. The load calculation is included on the "Main" page.

	conn churc		ro suitability	TOT SILE OIT	u layout)							0	
/lain Ma	ast data 🛛 🕅	TGs	Mast-WTG	Long ter	m correctio	n 🗸 i	WAsP 🗸	WAsP-CFD	VEng	IEC checks	L	OAD RES	4
Name [Mast and fl	ow m	odel + Load	l response	9								
Site an	nd layout o	heck	k using:		Flow mo	dels:							
۲	Mast data	& flov	w model(s)		۰ 🗸 ۱	VEng							
	Mast data	only			۷ 🗸	VAsP	1	O Long-te	rm correcte	ed wind statistics			
	No mast da	ata			✓ \	VAsP-CI	FD }	Mast di	rectly				
	3rd party V	VTG	results (*.x	ml)	O Fla		D an auditor						
	Ambient si	te res	sult (*.siter	es)		wres cr	Diresults						
	Offshore si	te				viiscaliii	9						
oad ca	alculation	/ cui	rtailment:										
R	Include LO/	AD RE	SPONSE										
45	Apply secto	r cur	tailment										
esian	standard	TEO	C61400-1 e	d. 3 (2010	0	*							
0	Use design	class	from WTG	object	/								
	Overrule W	TG d	esign class	with			IA		*				
	Danie denie		-										
	Wind	enee	d class		T	п	ш						
	V	rof [n	n/el		50.0	42.5	37.5						
	v	mean	[m/s]		10.0	8.5	7.5						
	k	r.1	[[[]]]		2.0	2.0	2.0						
	K				2.0	2.0	2.0						
	Turbu	lence	dass		Α	в	С						
	In	ef [-]			0.16	0.14	0.12						
ortific	ntion hist		fett co			FEDON	er. Vari	on noter					
zer unic	adon nist	oryc	A 311E COI	ar LDARU	L / LUAD P	LOPUN	or, <u>108</u>						

To determine the wind climate parameters at each WTG, position a normal SITE COMPLIANCE analysis must be performed. In general, all the main checks in the page "IEC checks" should be calculated.

Quick Guide – LOAD RESPONSE

SITE COMPLIANCE (WTG suitabili	ty for site and layout)							×
lain Mast data WTGs Mast-WT	G Long term correction	on 🖌 W	AsP 🖌 WAsP-CF	D 🗸 WEng	IEC checks	LOA	D RES	4
Design standard: IEC61400-1 ed. 3	3 (2010)							
WTG design class: IA								
Result legend	No WTGs exc	eed TEC li	mits					
Caut	ion ≥1 WTG exce	ed IEC lin	nits - exceedance	not consider	ed critical			
Critic	al ≥1 WTG exce	ed IEC lin	nits - exceedance	potentially cr	itical			
		Includ	Sotup/Calculat					-
Checks and analyses		e /	Decupy concurat	Result	Comment			
A: Main IEC checks								
Terrain complexity		\checkmark	Edit	Caution				
Fatigue/Normal conditions								
Effective turbulence		~	Edit	Caution				
Wind distribution		\checkmark	Edit	Caution				
Flow inclination		~	Edit	OK				
Wind shear		~	Edit	Caution				
Air density		\checkmark	Edit	OK				
Ultimate/Extreme conditions								
Extreme wind		\checkmark	Edit	OK				
B: Other IEC checks & analysis								
Seismic hazard		~	Edit	OK				
Temperature range		\checkmark	Edit					
Lightning rate		~	Edit	OK				
Tropical cyclone analysis								
	ID fo	* objects						
(Re)calculate all	1010	robjects						
(,		scription	User iai	bei				
Note:								
 Red checks do not always 	exclude a WTG model	/class as :	suitable.					
 Final suitability depends or 	n fatigue trade-off betv	veen cheo	ks and manufactu	rers load ma	irgins.			
- SITE COMPLIANCE does n	ot fully model the trade	e-off and	loes not know the	load margin	s.			
- Consult the manufacturer	for final justification of	suitability	including trade-of	ffs and marg	ins.			
Qk Cancel								

3. CALCULATIONS IN LOAD RESPONSE

3.1 Select WTG response file

Select for all WTGs a specific or generic wind turbine from the dropdown menu.

If a layout contains several types of wind turbines, this can be selected by pressing the button "Select individually".

SITE COM	PLIANCE (WTG suitabil	ity for site and lay	out)				- 0	×
Main Mast d	ata WTGs Mast-W	rg Long term co	rrection 🗸 🗸	WASP 🗸 WASP-CFD	✔ WEng	J IEC checks	🖉 LOAD RES	$\langle \cdot \rangle$
Design star	idard: IEC61400-1	ed. 3 (2010)						
WTG design	class: IA							
Select WTG	i response file							
Show o	nly type/name:	Generic mod	lels nanufacturer	Carbon in bl	ades ('Car ('DD')	bon')		
Sele	ect for all WTGs	EMD Generic RI	0<90m		-			
🔿 Sele	ect individually	EMD Generic RI EMD Generic RI	D<=60m D>=90m	\	A			
Inclu WTC	ude 'DNVGL-ST-0262 S similarity with gene	EMD Generic RI EMD Generic RI EMD Generic RI EMD Generic RI	D>=90m Carbo D>=90m DD D>=90m DD Ci D<90m	arbon	•	D		
Result lege	nd 📕 Ok	EMD Generic RI EMD Specific II	0<90m Carbon ∙B		Ŧ			
	Crit	cal ≥1 WT	G exceed IEC	loads				
Load	Include / Clear	Setup/Calculat	Result	Load Index	WTG	Comment		
Fatigue loads	V	Edit						
	(Re)calculate all	s	how result as:	 Load Index 	⊖ Fatigu	ue Lifetime		
Note:								
- LOA - LOA - The - Fati - The - Con	D RESPONSE does n D RESPONSE approx estimated loads fror gue life does not incl accuracy of suitabili sult the manufacture	ot include the eff imates WTG load n the response s ude other degrad y analysis based r for final verifica	ect of special o Is using a resp urface are, thu lation processe on a generic \ ation of suitabil	operation modes. onse surface method l is, subject to a small n is like e.g. corrosion. VTG depends on the n ity.	oased on p nodel unce epresenta	ore-run aero-elas ertainty. tivity of the WTG	stic simulations. and load margi	ns.
<u>O</u> k	Cancel							

The wind turbines in the dropdown menu correspond each to an "XX.loadresponse" file. This file contains general information about the wind turbine and wind turbine loads for different wind climate conditions.

3.2 Include fatigue loads

Include the fatigue loads by pressing "include" marked by yellow and press the "Edit" button in order to setup the calculation.

😻 SI	TE COMP	LIANCE (W	TG suitabili	ity for site and la	iyout)						×
Main	Mast da	ta WTGs	Mast-WT	G Long term	correction 🖌 V	VASP 🖌 WASP-CFD	✔ WEng	g 📕 IEC check	s 📀	LOAD RES	-
Desi WTG	gn stan design	iard: IEC class: IA	61400-1	ed. 3 (2010)							
Sele	ct WTG	response	e file								
	Show or	ly type/na	ime:	Generic m	odels manufacturer	Carbon in bla	ades ('Car ('DD')	'bon')			
	Selection	t for all W	TGs	EMD Generic	RD<90m		w				
	Selection	t individua	ally	Select		Define load marg	jins				
Resu	WTG	similarity d	With gener	ric turbine desi No V cal ≥1 V	gn: High simil /TGs exceed IEC /TG exceed IEC I	larity (low uncertainty) loads oads) ~ (D			
Load		Include ;	/ Clear	Setup/Calcula	t Result	Load Index	WTG	Comment			_
		(Re)calc	ulate all		Show result as:	Load Index	🔿 Fatigu	ue Lifetime			
Not	e: - LOAD - LOAD - The - Fatig - The a - Cons	RESPONS RESPONS estimated ue life doe accuracy o ult the ma	SE does no SE approxi loads fron es not inclu of suitabilit nufacturer	ot include the e imates WTG lo n the response ude other degr y analysis base r for final verifi	ffect of special o ads using a respo surface are, thu adation processe ed on a generic V cation of suitabili	peration modes. onse surface method b s, subject to a small n is like e.g. corrosion. VTG depends on the re tty.	oased on p nodel unce epresenta	pre-run aero-ela ertainty. tivity of the WTC	istic si Gand I	mulations. oad margir	ns.

3.3 Setup fatigue load calculation

The "Setup" tab shows first the included design load cases from IEC 61400-1 ed. 3 (2010). The wind climate parameters which influence this design load case(s) are listed. The names refer to the IEC-checks in SITE COMPLIANCE. General WTG information is shown in the middle and the WTG components included in the fatigue load calculations are listed to the right.

Setup		
lame		
IEC design load case (DLC)		
DLC 1.2: Power production		
DLC other: E.g. Start-up (3.1), Shut-down (4.3 Directional tower loads () Edit), Parked (6.4)	
Wind climate parameters	WTG information	WTG components
- Effective turbulence	Manufacturer: EMD	- Blade
- Wind distribution	Type: Generic RD>=90m	- Tower
- Flow inclination	Version: 3.0.605	- Nacelle
- Wind shear	Design lifetime: 20 year(s)	- Shaft
- Air density	Response model: Central composite approximation	
Directional resolution	Effective Turbulence	Normalization loads (specific models)
Construction of the state of th	Variable Wöhler exponent (IEC61400-1 ed. 3, ed.	 From response file
 Omnidirectional (IEC61400-1 ed. 3, ed. 4) 		 Una response model
 Omnidirectional (IEC61400-1 ed. 3, ed. 4) Sectorwise 	 Fixed Wöhler exponent (m=10 from SITE COMPL) 	 Obe response model

3.4 Advanced calculation settings

When wind turbines are implemented in LOAD RESPONSE pre-defined values for the advanced settings are selected. It will therefore normally not be necessary to change these. However, in the following a short description is given.

directional resolution The "Omnidirectional" or "Sectorwise" describes whether omnidirectional or sectorwise wind climate parameters should be used for the load calculation. According to IEC 61400-1 ed. 3 (2010) omnidirectional wind climate parameters should be used. However, more accurate results can be obtained by using sectorwise wind climate parameters. The sectorwise wind climate parameters are only available in WindPRO if a WAsP or WEng calculation has been performed. In addition, the option "Full resolution (no effective TI integration) can be used to account for variation in wind climate parameter at each single directional degree.

Directional resolution
Omnidirectional (IEC61400-1 ed. 3, ed. 4)
○ Sectorwise
 Full resolution (no effective TI integration)

The effective turbulence is obtained by combining the ambient turbulence and the wake added turbulence using the Wöhler exponent. In SITE COMPLIANCE this is often done using a Wöhler exponent on m=10. In LOAD RESPONSE the effective turbulence can either be calculated using the component specific Wöhler exponent (denoted "variable Wöhler exponent") or the Wöhler exponent used in SITE COMPLIANCE (denoted "fixed Wöhler exponent"). The first approach is recommended in IEC 61400-1 ed. 3 (2010).

Effective Turbulence
Variable Wöhler exponent (IEC61400-1 ed. 3, ed.
Fixed Wöhler exponent (m=10 from SITE COMPL)

3.5 Calculate fatigue loads

By pressing the "Calculate" button the calculation is started. The calculation time should normally only take few seconds.

Ok Cancel	Calculate
-----------	-----------

4. RESULTS IN LOAD RESPONSE

4.1 Results (Map)

The results are shown on a map. Green circles indicate turbines with acceptable load level, whereas red circles indicate turbines with load level higher than normally accepted. The accepted load level is for a generic turbine the load level corresponding to the IEC-class wind climate. For a specific turbine the acceptable load level will normally correspond to the certification loads.

Using the dropdown menus marked by red individual components and sensors in the wind turbine can be selected. By default, the results for the worst component and worst sensor for each turbine is shown.

The radio button marked by yellow shows the results by a color legend. This gives a better indication of which turbines in the layout are subjected to the highest loads.



4.2 Results (Graphics)

The results are shown in a graph, where the load index is shown for each turbine. A load index ≤100% correspond to an acceptable load level (green), whereas a load index >100% corresponds to a load level higher than normally acceptable (red).

Similarly, using the dropdown menus each individual components and sensors in the wind turbine can be selected.



4.3 Results (Table)

The results are shown in a table, where the load index is given for each turbine. By expanding the table, the load index is shown for each component (e.g., blade, tower, nacelle, shaft). By expanding the table further, the load index is shown for each sensor along with the respective Wöhler exponent.

The fatigue life in years is also shown for each component. Note that the fatigue life is relative to the design lifetime for the turbine and does not include other degradation processes like e.g., corrosion.

Name	Design Class	Component	Sensor	Sensor description	Wohler	Load Index [%]	Fatigue lifetime [y]	Visualize damage ma
✓ T24	Class IA	Blade	BirMx1	Root in-plane bending		96.4	28.8	
>		Blade	BirMx1	Root in-plane bending		96.4	28.8	
>		Tower	TwbMy	Bottom for-aft bending		80.1	48.6	
>		Nacelle	YawMz	Yaw bearing yaw bending		83.7	40.7	
>		Shaft	LSSMx-LDD	Low speed shaft torque load duration		95.5	26.4	
> T26	Class IA	Blade	BirMx1	Root in-plane bending		96.6	28.3	
> T27	Class IA	Blade	BirMx1	Root in-plane bending		96.8	27.8	
> T28	Class IA	Blade	BirMx1	Root in-plane bending		96.5	28.6	
> T29	Class IA	Blade	BirMx1	Root in-plane bending		97.0	27.2	
> T30	Class IA	Blade	BirMx1	Root in-plane bending		97.6	25.6	
> T32	Class IA	Blade	BirMx1	Root in-plane bending		97.1	26.7	
► T34	Class IA	Blade	BirMx1	Root in-plane bending		97.3	26.4	
T35	Class IA	Blade	BirMx1	Root in-plane bending		97.3	26.7	
T37	Class IA	Blade	BirMx1	Root in-plane bending		96.8	27.6	
> T38	Class IA	Blade	BirMx1	Root in-plane bending		96.7	28.0	
T39	Class IA	Blade	BirMx1	Root in-plane bending		97.1	26.7	
> T40	Class IA	Blade	BirMx1	Root in-plane bending		96.3	29.2	