NOISE CURTAILMENT OPTIMIZATION

Purpose:

This quick guide shows how to generate optimal noise curtailment strategies for a wind farm. The turbine positions and noise receptors are fixed, but their operation modes can be changed in various dimensions (time, wind speed, wind direction, temperature etc.).

The goal is to maximize AEP, while respecting noise constraints.

Outline of Guide:

- 1. Requirements
- 2. Preparing data
- 3. Setting up the optimization
- 4. Combining optimized strategy with other curtailments
- 5. FAQ

1. REQUIREMENTS

The noise optimization procedure requires an activated license to OPTIMIZE and either DECIBEL or NORD2000.

The WTGs to be optimized must contain information about available operation modes, including noise and power curves. Some turbine models in windPRO Wind Turbine Catalogue already include this information, while others don't. You can always add your own list of operation modes by creating a "Power & Noise pair" or "PowerMatrix" (see BASIS manual 2.6.4.4 and 2.6.4.5)

If no "Power & Noise pairs" or "PowerMatrix" is defined for all WTGs, then no curtailment optimization is possible.

2. PREPARING DATA

Turbine information

In this quick guide we assume you already have a fixed layout of WTG objects:



Every WTG object must have noise data and power curve defined as "Power & noise pairs" or "PowerMatrix":

(钉 New 1	NTG (T2	:7)	•					-
	Position	Layers	WTG(s)	Visual	Distance circles	Curtailment	Operation	Description	
		W	G type:	NORDEX	N149/5.X 5700 1	49.0 !0!	-		
		Hub heig	3 (T27) yers WTG(s) Visual Distance circles Curtailment Operation Description WTG type: NORDEX N149/5.X 5700 149.0 10! • • • • • • • • • • • • • • • • • • •						

This makes it possible for the Curtailment Optimizer to know which operation modes are available for optimization for each WTG.

The curtailment strategy will be applied to all turbines in a layer, so make sure to group the turbines in appropriate layers.

🗸 🔳 🗁 WTG
WTG area
WTG area for
resource
VTG layout 1

Wind data

To quantify the production loss the Curtailment Optimizer needs information on wind speed either through a resource map or a λ Meteo Object.

Noise sensitive areas

In this quick guide it is assumed that the noise receptors (
NSA objects) have already been defined:

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The noise demands defined on each receptor will be used and respected in the curtailment optimization.

3. SETTING UP THE OPTIMIZATION

Open the Optimizer module from the Energy tab:

(-	*	🧼 windPRO	4.0	
File	Definitio	ons	Geo Data	Climate	Energy L
K	OPTIMIZE	-		🕛 Curta	ilment analyzer

Click New and select "Curtailment - Noise":

•	Delete	Clone				
Layout - Irregular pattern						
<u>C</u> urtailment - Noise						
	≠ - Ir me	Delete Irregular pattern ment - Noise				

The Curtailment Optimizer is organized in a tree structure:

Site	1. 2. 3.	Define noise calculation model Select noise sensitive areas to respect Define energy calculation model
Layout	4.	Select which fixed layout to optimize
Strategy	5. 6.	Define which dimensions the optimization is allowed to use to generate a curtailment strategy. Evaluate results and apply strategy to WTG objects.

Defining the Site

Select calculation model (DECIBEL or NORD2000):

Calculation model:	DECIBEL	Ŧ
	DECIBEL	
Basis	N2000	

Next, select noise standard (ISO, German, Dutch, Danish, Swedish etc.):

Noise Model:	· · · · · · · · · · · · · · · · · · ·
	Danish 2007
	Danish 2011 and 2015
	Danish 2019
	Danish Codes
	Danish Low frequency 2011 and 2015
	Danish low frequency 2019
	Dutch, 1999
	Finland Low frequency
	German Codes VDI 2714 (outdated)
	IL-HR-13-01 (Netherlands)
	TCO 0612-2 Einland

Depending on the flexibility of the noise model you can choose to edit some or all noise model parameters:



For instance, if the you wish to optimize the curtailment strategy by wind speed, then you need to define the which range of wind speeds to include:



And/or how wind direction will be considered:

A Wind direction		
R		
 All receptors downwind of all wind turbines (Cmet = 0) 		
\bigcirc Fixed value for Cmet. Recommended maximum: 2 dB	0,0	
$\textcircled{\bullet}$ Directional correction based on ISO 9613-2 / TÅ Lärm	Fixed wind direction [°]	0
\bigcirc Directional correction based on Institute of Acoustics Good Practice Guide, 2013	 Number of sectors 	12
	Calculate entire curtailme	nt matrix

Click Ok in the Edit model parameters window.

Next, select the **Mathebasic** NSA objects to be included in the optimization:



Use all objects from selected layers

✓ Noise Sensitive Area (1)

The last step in the Site setup is to go to the "Energy" tab, and select a time series and Scaler for evaluating the production loss due to changes in operation modes:

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Noise Energy					
Concept: Time series	O Resour	rce file			
Wake Model: N.O. Jensen ((RISØ/EMD) Pa	ark 2 2018 ,	- Wake	Decay: DT	U default
Scaler: Calibrated scaler			*	Setup	
Select meteo objects to scale fro	om.				
Name	Data type	Use in scaling	Sample rate [min]	Duration (enabled) [years]	Recov (enab [%
> West mast, incomplete	Other/unkno				
✓ ✓ West mast	Other/unkno				
> 80,00m -		\checkmark	10,0	1,0)
5 CO 00			10.0		

(Alternatively, select Resource map if you already have one)

Selecting the turbines to optimize

Click "Add Layout", in the left side of the window:

Add Site	Add Layout	Add Strategy
Delete Site		

Select the layer with WTGs to be included in the curtailment optimization:

👻 🔳 🗁 WT	G
	WTG area
	WTG area for resource
	WTG's

All WTG objects located in this layer will then be included in the optimization.

Defining the optimization strategy

Next, click Add Strategy:



Here, you get an overview of the dimensions the Curtailment Optimizer will use to generate a curtailment strategy:

	ilment bins						×
Time bin	Tim	e binning setup			Reset	to default	
Enabled	Name	Bin start	Unit	Bin size	B	in count	
 ✓ 	Wind speed	5	m/s	2			3
✓	Wind direction	-15	deg	30			12
	Temperature		deg C				
	Relative humidi		%				
	Turbulence inte		%				
	7,0)		9,0			_
•		•					

In case you wish to reduce the complexity of the optimation, it is possible to disable dimensions and to reduce the number of bins, the start value and size of each.:

Enabled	Name	Bin start	Unit	Bin size	Bin count
\checkmark	Wind speed	5	m/s	2	3
\checkmark	Wind direction	-15	deg	30	12
	Temperature		deg C		

The bottom graphic shows the wind speed ranges which the selected noise calculation will be evaluated against:

	7,0	9	,0
•	•		

To start the calculation, click Create & queue strategy:



Now the Optimizer will run for seconds, minutes or hours depending on the number of turbines, receptors, dimensions and bins.

Analyzing the results

The results of the curtailment optimization will appear for all turbines:

Status: Done			
WTG	AEP Loss [MWh]	Loss [%]	Curtailed AEP [M\
Siemens Gamesa SG 6.6-170 6600	-137.5	-0.7	20,249.8
Siemens Gamesa SG 6.6-170 6600	-62.4	-0.3	21,108.2
Siemens Gamesa SG 6.6-170 6600	5,115.4	27.6	13,419.0
Siemens Gamesa SG 6.6-170 6600	-103.8	-0.5	20,120.9
Siemens Gamesa SG 6.6-170 6600	-219.9	-1.1	19,654.9
TOTAL	4,591.8	4.6	94,552.8

You can dive into the results of the individual turbines using the tree in the left side of the window:

¥.	Site: 2
~	Layout: 1
	 D Strategy: 1
	T24
	T26
	T27

For each turbine you will see a matrix showing which operation mode the turbine will operate in for the selected dimensions:

: Siemens Ga	amesa SG 6.6-1	170 6600 170.) !O! hub: 115	.0 m (TOT: 20	00.0 m) (3)			
(Win Win Win	d direction [de d speed [m/s]	g] -	Reset to) default	Wind speeds are at hub heigh			
0	30	60	90	120	150	180	210	
(AM 0,								
Shut down								
(AM 0,								
	Siemens Ga Win Win O (AM 0, Shut down (AM 0,	E Siemens Gamesa SC 6.6-3 Wind direction [de Wind speed [m/s] 0 30 (AM 0, Shut down (AM 0,	Siemens Gamess SG 6.6-170 6600 170.0 Image: Second Seco	Siemens Gamesa SG 6.6-170 6600 170.0 101 hub: 115 Image: second secon	Siemens Gamesa SG 6.6-170 6600 170.0 101 hub: 115.0 m (TOT: 20 Wind direction [deg] - Wind speed [m/s] - 0 30 60 90 120 (AM 0, - - - - Shut down - - - -	Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SG 6.6-170 6600 170.0 IOI hub: 115.0 m (TOT: 200.0 m) (3) Image: Simens Gamesa SIM (TOT: 200.0 m) (3) <t< td=""><td>Simens Gamesa SG 6.6-170 6600 170.0 101 hub: 115.0 m (TOT: 200.0 m) (3) Wind direction [deg] Reset to default Wind speed (m/s) Wind speed [m/s] Reset to default Wind speed are at hub 0 30 60 90 120 150 180 (AM 0, Comparison <thcomparison< th=""> Comparison</thcomparison<></td></t<>	Simens Gamesa SG 6.6-170 6600 170.0 101 hub: 115.0 m (TOT: 200.0 m) (3) Wind direction [deg] Reset to default Wind speed (m/s) Wind speed [m/s] Reset to default Wind speed are at hub 0 30 60 90 120 150 180 (AM 0, Comparison Comparison <thcomparison< th=""> Comparison</thcomparison<>	

Above, the turbine shuts down in all directions at 8 m/s, while operating in mode AM 0 for all other directions and wind speeds.

You can always repeat the calculation with different dimensions by adding an additional strategy:

Add Site	Add Layout	Add Strategy
Delete Layo	out	

You can also repeat the calculation with a different set of turbines by adding a different Layout:

Add Site	Add Layout	Add Strategy
Delete Site		

Realizing the results

Once you are satisfied with the optimization results go to the Strategy layer:

~	Site: 2
~	Layout: 1
	↓ D Strategy: 1
	T24
	т 76

And click the "Write curtailment strategy to all WTGs"

	0,0	0,0	124.545,2
Create noise calculation based on strategy	Write	curtailment strategy	to all WTGs

You will be asked to confirm the overwriting of any existing curtailment strategies:

Confirm	
?	13 WTGs already have an existing noise curtailment strategy. Do you want to continue and overwrite the existing noise curtailment strategy? This cannot be undone.
Do not sho	ow again
<u>Y</u> es	No

In this case, say yes.

Close the Curtailment Optimizer and open one of the \bigvee WTG objects which was included in the optimization.

You will see that the selection for normal operation remains the same as before the optimization:

🍯 New WTG 🛛 (Siemens Ga	mesa SG	6.6-170 6600 170.0 !	!O! hub: 115.0 r	m (TOT: 200.0) m) (3))
Position Layers WTG(s	Visual	Distance circles	Curtailment	Operation	Description
WTG type: Hub height [m]:	Siemens 115.0	s Gamesa SG 6.6- Always u	170 6600 170 se default val ly valid detail).0 !O! - ues i data i	✓ Use Power & noi Use PowerMatrix
Power & noise pairs:	Power 8	k noise pairs (58)		*	
Selection:	(AM 0,	6.6MW) - 1		-	den

But a curtailment rule called "Noise Matrix" has now been added to the list of curtailments:

Position Layers WTG(s) Visual Distance circles Curtailment Operation Oc Oc Use Priori ⊨ Name Type Action Conditions Cancel V 1 Noise Matrix Noise Matrix Noise Matrix Noise Matrix Noise Matrix	() N	lew V	/TG (Siem	nens	Gamesa	a SG 6.	.6-170 6600 1	70.0	O! hub: 115.0 r	m (TOT: 20	0.0	m) (3))			×
Use Priori La Name Type Action Conditions	Posi	tion	Layers \	NTO	G(s) Vis	sual	Distance cir	cles	Curtailment	Operatio	n	Description		<u>0</u>	k
V 1 Noise Matrix Noise Matrix		Use	Priori	<u>.</u>	Name			T)	pe	Actio	m	Conditions		Can	cel
	0	\checkmark		1	Noise M	latrix		No	se Matrix					2011	

If you double click this line, you can see the noise curtailment matrix for different dimensions:



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If you delete or change this rule, then the entire optimized strategy for the other WTGs will no longer be valid. Their Noise Curtailment Matrices will therefore also be cleared!

4. REVIEW THE CURTAILMENTS IN THE CURTAILMENT ANALYZER

It is possible to review, turbine by turbine, all the curtailments applied to a layer. Simply open the Energy Tab and select "Curtailment analyser":

Image: Second							
File	Definitions	Geo Data	Climate	Energy	Loads & Oj		
			Curtailment analyzer				
				Power Co	nversion		

5. FAQ

Can I combine an optimized noise strategy with other curtailments?

Yes, it is possible to combine the optimized noise curtailments with any other (existing or new) curtailments, such as wind sector management, bat/ bird curtailments etc.

The losses will be subsequently attributed depending on the priority.

Can I use the curtailment strategy in other calculations?

Yes, the operation strategies created by the optimizer can be used directly in PARK, DECIBEL and NORD2000.

In Time Varying PARK, simply check the Use curtailments checkbox:

Use curtailment

What about proving that the noise curtailment strategy actually works, protecting the neighbours from excessive noise?

An easy way to ensure that the resulting noise calculation uses the same assumptions and input as the optimizer is to let the Curtailment Optimizer output a DECIBEL or NORD2000 report:

Open the Curtailment Optimizer again and go to the desired strategy. There, click the button *Create noise calculation based on strategy*:

	Status:	Done			
	WTG		AEP Loss [MWh]	Loss [%]	Curtailed AEP [M
	Siemens Gar	nesa SG 6.6-170 6600 170.0 !O! hub	-137.5	-0.7	20,249.8
	Siemens Gan	nesa SG 6.6-170 6600 170.0 !O! hub	-62.4	-0.3	21,108.2
	Siemens Gar	nesa SG 6.6-170 6600 170.0 !O! hub	5,115.4	27.6	13,419.0
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	Siemens Gan	nesa SG 6.6-170 6600 170.0 !O! hub	-219.9	-1.1	19,654.9
	TOTAL		4,591.8	4.6	94,552.8
trategy					
trategy 0 0 3 0					
0 0 0 3 0 3 2		Create noise calculation based on str	ategy Wri	te curtailment strat	regy to all WTGs

This will create a noise calculation (DECIBEL or NORD2000) in the calculation list:

Calculations (65)						
*	Name					
	V DE DE	CIBEL: Site: 2 - Strategy: 1				
Þ		Main Result				
		Detailed results				
		Detailed results, graphic				
		Assumptions for noise calculation				
		Man				

This calculation will use the exact same model parameters as the Curtailment Optimizer.

Now, run the generated DECIBEL/NORD2000 calculation from the calculation list (we're assuming you have already saved the curtailment strategy in the WTG Objects as shown before).

The result on the map shows the case of the loudest period, indicating that the NSA in the North is unaffected (well, the optimizer also had to fully shut down the nearby WTG...):

