



QUICK GUIDE –CURTAILMENTS IN PARK CALCULATIONS

Purpose:

The purpose of this quick guide is to help users use curtailments in time-varying and statistical PARK calculations, with primary focus on time-varying PARK.

Outline of Guide:

1. What is a curtailment?
2. Requirements for curtailments
3. Defining Curtailment rules
4. Prioritizing overlapping rules
5. Running time-varying PARK and quantifying losses
6. Running wind statistics-based PARK and quantifying losses
7. Miscellaneous

1. WHAT IS A CURTAILMENT?

A curtailment is a known and planned reduction of the wind turbine power output.

In PARK, turbines can be reduced (or increased) to any operation mode defined in the turbine catalogue. Users can manually define which climatic and/or temporal parameters will trigger a change in operation mode and define the hierarchy between overlapping rules.

Curtailment rules are defined on each individual WTG object and then used in the PARK calculation. Depending on the setup, this can increase or decrease the AEP and wake loss of each turbine.

In this quick guide we focus on curtailing a single WTG in a wind farm by defining two simple curtailment rules, Wind Sector Management (WSM) and Bat Curtailment.

2. REQUIREMENTS FOR CURTAILMENTS

The steps in this quick guide require windPRO 4.0 with a license for the PARK module, along with METEO or MODEL, and WAsP.

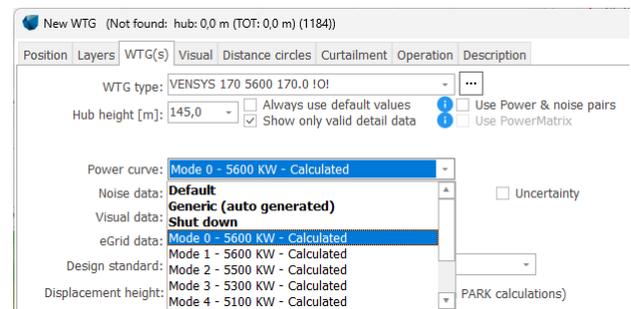
Depending on the type of PARK calculation and complexity of the intended curtailment strategy, up to three elements are required:

- WTG object(s) to apply curtailments to.
- Wind statistic or Meteo object with defined signals corresponding to those used as climate conditions in the curtailment setup for the WTG.
- Alternative power curves / operation modes defined in the turbine catalogue. Operation modes can be defined as *Power & noise pairs* or in a *PowerMatrix* file. See the BASIS manual for more information about operation modes.

In this quick guide we will be using the most common options.

3. DEFINING CURTAILMENT RULES

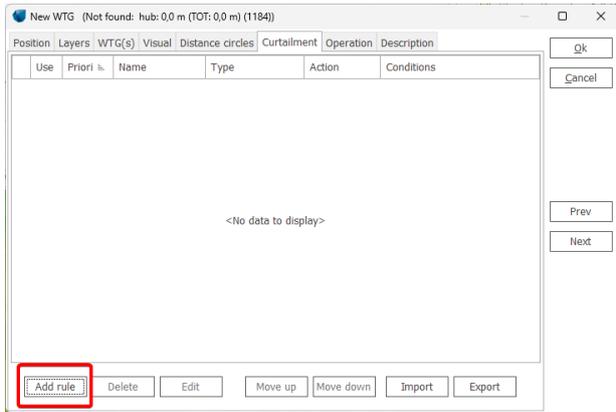
Open the “Properties” of the WTG object (⤴ or ⚙) to be curtailed:



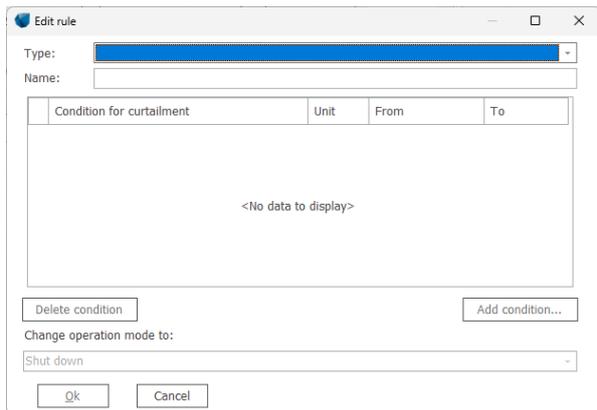
Select which power-curve dataset to use for the WTG. The selected power curve will later act as a reference when quantifying the losses/gains from the curtailments.

Next, jump to the Curtailment tab:

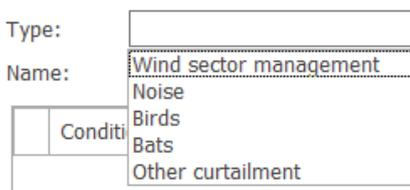
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Click “Add rule”, to add a new curtailment rule to the list. This opens a window defining the curtailment rule conditions and actions:



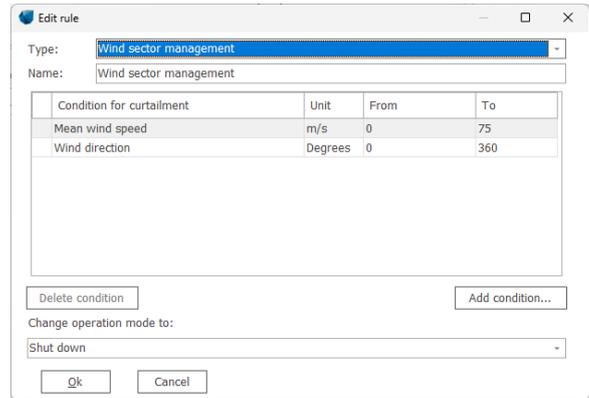
Select which type of curtailment rule to apply:



The selection of curtailment type determines which category the curtailment loss/gain will be attributed in Loss & Uncertainty. Each curtailment type (sector curtailment, noise curtailment, bat curtailment, bird curtailment) also has a different set of default signals

Then, give the curtailment rule a name. This name will be printed in turbine specific reports quantifying the loss caused by the triggering of this particular curtailment rule.

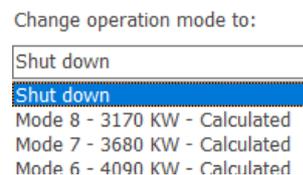
In this example we want to add Wind Sector Management (WSM). The default condition signals for this curtailment type are Mean wind speed and Wind direction:



We change the default values, and curtail the turbine at all wind speeds and the wind direction is the 30° sector around North:

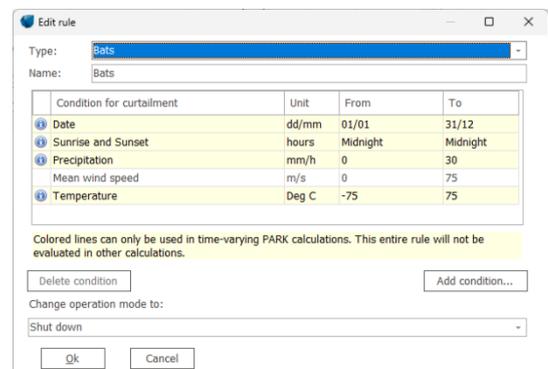
Condition for curtailment	Unit	From	To
Mean wind speed	m/s	0	75
Wind direction	Degrees	345	15

Next, choose what will happen when these conditions are met by setting the “Change operation mode to” to *Shut down*:



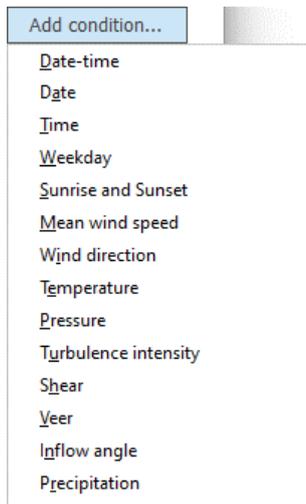
Click “OK” to save the curtailment rule. One curtailment rule has now been created.

To create another rule simply click the “Add rule” again. This time we want to create a curtailment rule to protect bats:



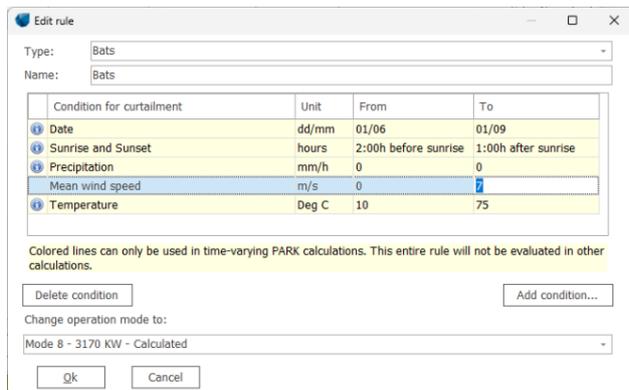
For all curtailment types, additional conditions can be added by clicking the “Add condition...” button:

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For Bat Curtailment, we already have all the necessary signals. In fact, we can remove the Temper

We define our rule saying if it is between June and August, 2 hours before sunrise and 1 hour after sunrise, no precipitation, wind speed between 0 and 7 m/s, then “Change operation mode” to e.g “Level 8” or “Shutdown”:



Click “Ok”.

4. PRIORITIZING OVERLAPPING RULES

We now have two curtailment rules:



Pay special attention to the “Priority” column. This number is used in the PARK calculation to determine which rule to execute in case of overlapping curtailment

definitions, and to ensure losses are attributed to the correct loss category in Loss & Uncertainty.

In this case the Bat curtailment rule is more important than the WSM rule, so we highlight the bat curtailment rule and click “Move up” to give it a higher priority:

Priority	Name
1	Bats
2	Wind sector management



Example of how rules are evaluated:

If it's a dry July morning and the wind direction is 5°, the conditions of both rules will be met.

In this case the PARK calculation will have to prioritize which rule should be executed first. **Notice that the default calculation method has changed in windPRO 4.0.** See the Miscellaneous section for more information.

Therefore, the rule with the highest priority will be considered first. The loss is then the difference in production between the default mode selected on the WTG(s) tab (Mode 0) and the first curtailment rule's mode (Mode 8).

Then, the next rule will be evaluated and if that rule is also valid PARK will calculate the difference in production between the operation of the first rule (Mode 8) and the operation mode of the second rule (Shutdown). Only if there is an additional loss will the second rule be executed.

In this example, the Bat rule has a higher priority than the WSM rule, and so the turbine will first change to mode 8 and attribute the loss to Bat Curtailment. Then it will turn off and attribute the remaining loss to the WSM rule.

The most important rules should be placed at the top of the list, to make sure the PARK calculation considers these rules before checking another rule.

windPRO does not know which operation mode will cause the greatest impact on AEP, Loads, Noise etc. and can therefore not offer guidance on priorities.

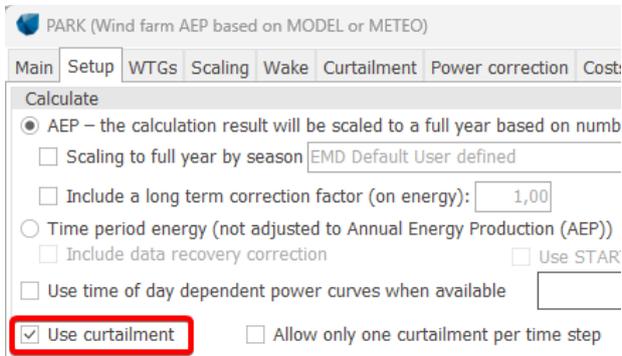
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5. RUNNING A TIMEVARYING PARK CALCULATION AND QUANTIFYING LOSSES

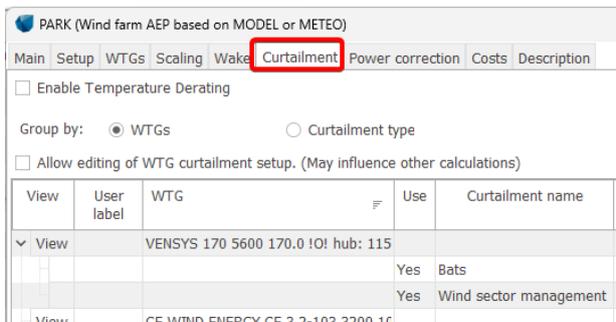
Enabling curtailments

Start by opening PARK from the calculation list and select one of the Time-series based calculations.

On the Setup page, enable “Use curtailment”:



This unveils a new Curtailment tab. Opening it shows any curtailment rules defined on each turbine selected on the WTG tab:



From this list it is possible to edit the curtailment rules of the individual WTGs by ticking the “Allow editing of WTG curtailment setup” checkbox, and then clicking the “Edit” button to open the WTG’s curtailment rules:

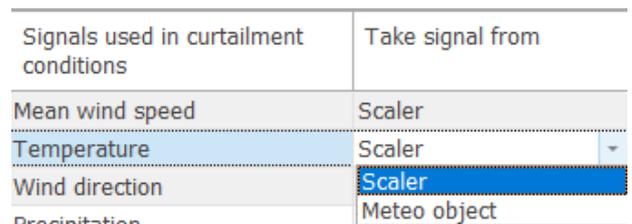


Defining climate data source(s)

Below the list of curtailments is a list of climate signals needed to evaluate the curtailments:



When PARK determines whether the climate conditions of this rule have been met, the wind speed and wind direction is always taken from the Scaler. Other signals can be taken from a Meteo object. If the Meteo object(s) selected in the Scaling tab also contains a temperature signal, you can choose to use this signal from the Scaler or pick the signal from an alternative Meteo object:



The selected data source purely determines when the conditions of a curtailment are met and is not used in any energy calculation. If the signal is taken from a Meteo object, the data are not corrected to hub height unlike when taking from the Scaler.

Ideally, select a data source which is concurrent to the wind speed and wind direction data. **If data is missing** for a signal which is used in a curtailment rule, this rule will be ignored for the missing time steps. This may lead to lower curtailment losses.

The number of times a curtailment rule has been applied or skipped due to missing data is documented in the “Curtailment Assumptions” report.

Reporting

Once the calculation is finished, a new column is added to the Main report showing the overall curtailment loss per turbine:

Annual Energy		
Result	Curtailment loss	Wake loss
[MWh/y]	[%]	[%]
6,726.8	1.1	2.8
6,843.8	0.0	0.1

Note, that a curtailment strategy can affect the wake losses as the change of operation mode of an upstream

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turbine will change the wind available to a downstream turbine. This wake loss is added to the downstream turbine before its own curtailment losses are added.

All the curtailments which have influenced the PARK calculation can be seen in the Curtailment assumptions report:

PARK - Curtailment assumptions

Curtailment signals

Signal	Signal source	Meteo object
Precipitation	Meteo object	EmdWrf_S28.779_W050.003 - H 2,00 m
Mean wind speed	Scaler	
Temperature	Meteo object	West mast - 90,00 m
Wind direction	Scaler	

WTG Curtailments

WTG Name	Index	Priority	Type	Action	Conditions
5 Bats	1	1	Bats	Mode 8 - 3170 KW - Calculated	Date [01/06/1
5 Wind sector management	2	2	Wind sector management	Shut down	WS [0;75], W

The Index column corresponds to the “Curtailment Index” column in Result to file, making it possible to track time-step by time-step which curtailment rule has been applied.

Notice the column “Times skipped”, which is the number of times a rule is not applied due to missing data. The “Times fully applied” is the number of times the rule has been exclusively activated. Meanwhile “Times partially applied” refers to the number of times another rule has simultaneously been executed in the same time step.

Times fully applied	Time partially applied	Times skipped
44	19	0
2253	19	0

In the Production Analysis report, the sector-wise curtailment losses for the whole park can be seen grouped by the curtailment type:

PARK - Production Analysis

WTG: All new WTGs, Air density varies with WTG position
Directional Analysis

Sector		0 N	1 NNE	2 ENE
Gross	[MWh]	2.861,9	1.000,6	1.755,6
-Decrease due to curtailments	[MWh]	911,0	0,1	0,1
Wind sector management	[MWh]	911,0	0,0	0,0
Bats	[MWh]	0,0	0,1	0,1
-Decrease due to wake losses	[MWh]	81,8	43,1	7,4
Resulting energy	[MWh]	1.869,1	957,4	1.748,1
Specific energy	[kWh/m ²]			
Specific energy	[kWh/kW]			
-Decrease due to curtailments	[%]	31,8	0,0	0,0
Wind sector management	[%]	31,8	0,0	0,0

Additionally, the losses of each individual curtailment rule can be seen for each WTG:

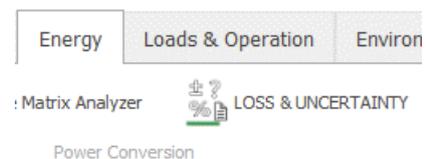
PARK - Production Analysis

WTG: 5 - VENSYS 170 5600 170.0 !O!, Hub height: 115,0 m
Directional Analysis

Sector		0 N	1 NNE	2 ENE
Gross	[MWh]	1.012,5	348,9	635,8
-Decrease due to curtailments	[MWh]	911,0	0,1	0,1
Bats	[MWh]	0,0	0,1	0,1
Wind sector management	[MWh]	911,0	0,0	0,0
-Decrease due to wake losses	[MWh]	0,0	0,0	0,0
Resulting energy	[MWh]	101,5	348,9	635,7

As multiple power curves can be used through out the calculation depending on the curtailment strategy, the Power Curve Analysis report shows all power curve datasets which have been used.

A PARK calculation can also be loaded into LOSS & UNCERTAINTY with the curtailment losses already included:



From Loss and Uncertainty, you can e.g. calculate flicker curtailment while other losses (electrical losses, degradation, availability etc.) can be inputted:

Group : 6. Curtailment (Loss = 1,71 %)	
Wind sector management	Included
Grid curtailment and ramp-rate	
Power purchase agreement curtailment	
Noise	
Flicker	
Birds	
Bats	Included

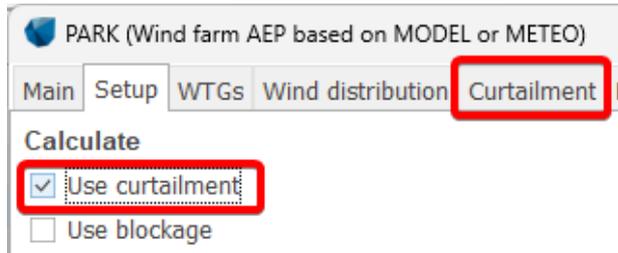
This makes it easy to quickly calculate e.g. a P₉₀

6. RUNNING A STATISTICAL PARK CALCULATION AND QUANTIFYING LOSSES

The curtailment setup for statistical PARK calculations is very similar to the time-varying calculations.

Start by opening PARK from the calculation list and select Standard PARK with WAsP. On the Setup page, enable Use curtailment:

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This unveils the Curtailmment tab, showing any curtailmment rules defined on each turbine selected on the WTG tab. The setup is similar to the time-varying calculations.

The key difference is that **the wind statistics-based PARK calculation can only utilize wind speed and wind direction**. Any other conditions, like temperature, will be completely disregarded in a statistical PARK calculation. In this case, the Bat curtailmment is disabled:

View	User label	WTG	Use	Curtailmment name
View		VENSYS 170 5600 170.0 !0! hub: 11!	<input type="checkbox"/>	Bats
			<input checked="" type="checkbox"/>	Wind sector management

As in the time-varying PARK calculations, the impact of the curtailmment can be found in the Main report and Production Analysis, while the list of curtailmments used in the calculation is found in the Curtailmment assumptions report and in Result to file.

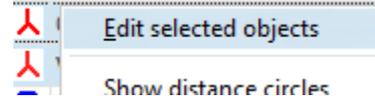
7. MISCELLANEOUS

How do curtailmments affect the wake losses?

The curtailmment of one turbine may affect another turbine, as reducing the thrust of an up-wind turbine will reduce the wake-loss of a downstream turbine. In turn, this change in wind-speed may affect which curtailmments are activated on a downwind turbine. Consequentially, one small change can potentially start a chain reaction propagating down the windfarm. This naturally holds true for both time-varying and statistics-based calculations.

Where do I get an overview of all curtailmments?

Select multiple turbines and then “Edit selected objects” to enter the multi-edit window:

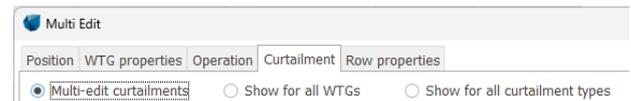


Opening the curtailmment tab and selecting “Show for all WTGs” will display a list of all curtailmments for all WTGs:

Position	WTG properties	Operation	Curtailmment	Row properties
<input type="radio"/> Multi-edit curtailmments <input checked="" type="radio"/> Show for all WTGs <input type="radio"/> Show for all curtailmment types				
View	User label	WTG	Use	Curtailmment name
View		VENSYS 170 5600 170.0 !0! hub: 11!	<input checked="" type="checkbox"/>	Bats
			<input checked="" type="checkbox"/>	Wind sector management
View		GE WIND ENERGY GE 3.2-103 3200 1	<input checked="" type="checkbox"/>	

How can I edit multiple curtailmments in one go?

Provided the turbine types and rules are *identical*, it is possible to insert and edit a rule for multiple WTGs. Select multiple turbines and then “Edit selected objects” to open the multi-edit window. Select the “Curtailmment” and choose “Multi-edit curtailmments”:



Creating a new curtailmment rule while in multi-edit will add the same curtailmment to all selected WTGs.

It is important to note that if a WTG already has a curtailmment rule defined which is not *completely* identical (use, priority, name, type, action, condition) with the other WTGs, all curtailmments will be grouped together as “Individual curtailmments”:

All WTG equal, but curtailmments are different. Curtailmments can be added an

Use	Priority	Name	Type	Action
<input checked="" type="checkbox"/>		Individual curtailm	Individual curtailm	

These cannot be multi-edited.

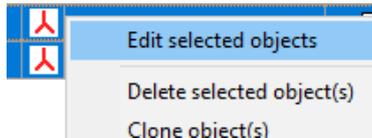
If a new common curtailmment rule is created, it will be prioritized above or below all “Individual curtailmments” as a group:

Use	Priority	Name	Type	Action
<input checked="" type="checkbox"/>	1	Other curtailmment	Other curtailmment	Shut down
<input checked="" type="checkbox"/>		Individual curtailm	Individual curtailm	

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How can I batch import curtailments from Excel?

Open the multi-edit window of the WTGs to import curtailments to:

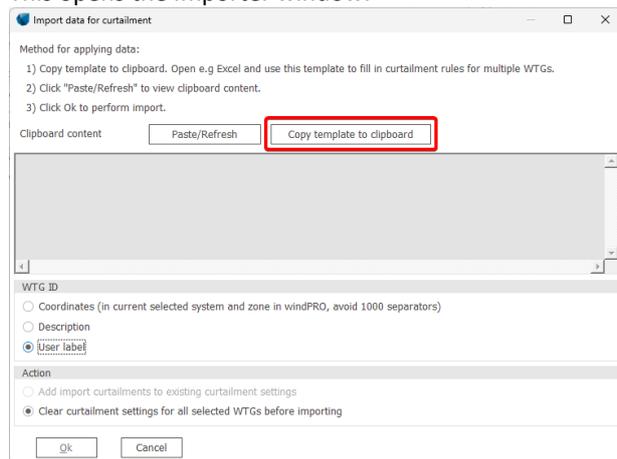


Go to the Curtailment tab and “Show for all WTGs” and select “Import”:

Multi-edit curtailments Show for all WTGs Show for all curtailment types



This opens the Importer window:



The curtailment rules can now be copied from e.g. Excel and pasted into windPRO, provided the curtailment rules are defined in the correct format. A template of the format can be copied from windPRO to the clipboard. When importing all existing curtailments are cleared.

What signals can be used as input for conditions?

For time-varying PARK calculations, the following signals can be used to trigger a change in operation mode:

Wind speed, Wind direction, Turbulence, Temperature, Pressure, Shear, Veer and Inflow angle, Date-time, Date, Time, Weekday, Sunrise & Sunset

For statistical PARK calculations, only wind speed and wind direction can be used.

How are curtailment losses handled in Loss & Uncertainty?

When you load a PARK calculation in Loss & Uncertainty, the curtailment losses from PARK will be automatically transferred to the corresponding loss categories.

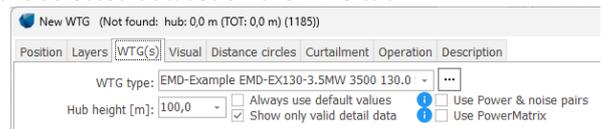
Why does the time stamps in result to file not match my temporal curtailment rules?

PARK takes time-zones and daylight savings time (DST) into account. If you create a rule to shutdown at 2 AM, the rule will be executed at 3PM due to DST.

Where do I control which operation modes / power curves are available to use in rules?

windPRO offers information about more than 1000 turbine models. Each turbine model comes with various amounts of data, but at least one power curve is usually included. Often, multiple power curves are included.

The list of available operation modes is determined by the selected dataset on the WTG tab:



“Always use default values”

If you select “Always use default values”, then the list of operation modes will usually contain all the available power curve datasets for the selected turbine model in the turbine catalogue.

“Use Power & noise pairs”

You can also create your own set of operation modes from the wind turbine catalogue, by creating a “Power & Noise Pair” list, which pairs together noise data and power data into a list of operation modes. These modes can then be used in curtailments or as input for the OPTIMIZE module’s noise optimization algorithm. More information on how to create Power and Noise pairs can be found in the BASIS manual.

“Use PowerMatrix”

PowerMatrix is a powerful data format capable of describing power at multiple operation modes, at multiple climate conditions (e.g. Wind Speed, TI, Air density) and at multiple noise levels.

Using a PowerMatrix dataset, PARK doesn’t have to apply any power corrections and can thus handle non-power optimal operation modes like Boost- and Load modes.

Ask your manufacturer to provide you with a PowerMatrix file. Multiple top-tier manufactures have already created PowerMatrix datasets.

What is the difference in the curtailment evaluation between windPRO 4.0 and earlier versions?

In earlier versions, only one rule could be executed at any given timestep. In windPRO 4.0, multiple rules can inflict losses at the same time. This influences both the

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attribution of losses into categories but may also impact the total curtailment loss and some rules would previously not have been evaluated but are so today. When opening an existing PARK calculation, the old methodology will be selected by default:

Use curtailment Allow only one curtailment per time step

Any new PARK calculation will not have this checkbox ticked, and therefore use the new 4.0 methodology.

Use curtailment Allow only one curtailment per time step

How does Temperature Derating play together with curtailments?

Temperature derating is available for time varying PARK calculations provided a temperature curve has been defined in the wind turbine catalogue. It can be activated together with regular curtailments:

Main Setup WTGs Scaling Wake Curtailment |
 Enable Temperature Derating

Once activated, temperate derating will always be executed as the first rule in any time step.