



## 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. Previously, in windPRO 3.2 PARK calculations, turbines could only be reduced by 100% and the reduction could only be triggered by defined wind speed and wind direction intervals.

In windPRO 3.3 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 Heat Protection.

#### 2. REQUIREMENTS FOR CURTAILMENTS

The steps in this quick guide require windPRO 3.3 with a license for the PARK module, along with METEO or MODEL, and WAsP (preferably version 11 or higher).

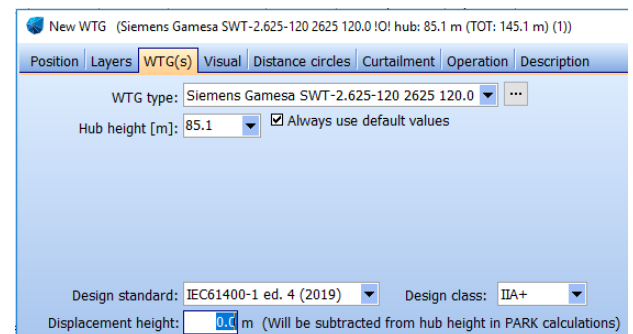
Depending on the type of PARK calculation and complexity of the intended curtailment strategy, up to three elements are required:

- 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.

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

#### 3. DEFINING CURTAILMENT RULES

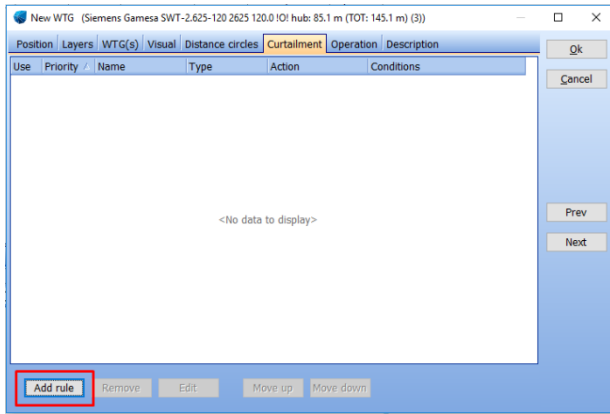
Open the “Properties” of the WTG object (👤 or ✨) to be curtailed:



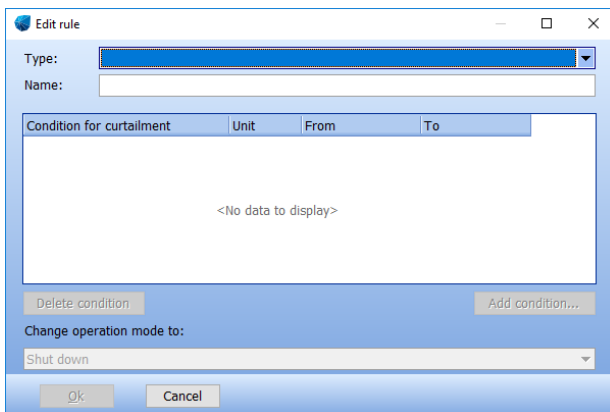
Select which power-curve dataset to use for the WTG. The selected power curve will later act as a reference when quantifying the losses/gains from the curtailments.

Next, jump to the Curtailment tab:

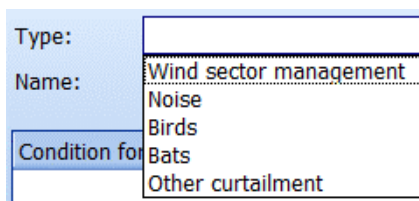
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Click “Add rule”, to add a new curtailment rule to the list. This opens a window defining the curtailment rule conditions and actions:



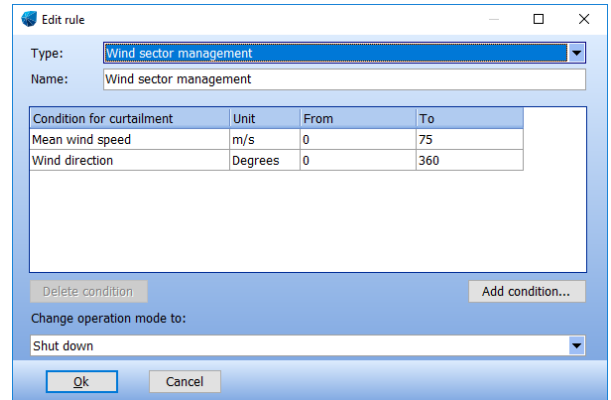
Select which type of curtailment rule to apply:



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.

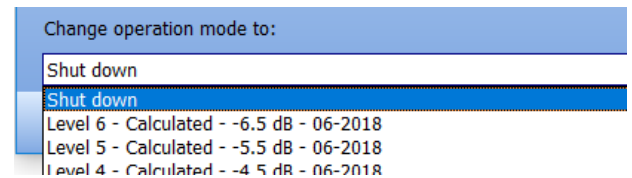
In this example we want to add Wind Sector Management. The default condition signals for this curtailment type are Mean wind speed and Wind direction:



We change the default values, and curtail the turbine when mean wind speeds surpass 10 m/s and the wind direction is the 30° sector around North:

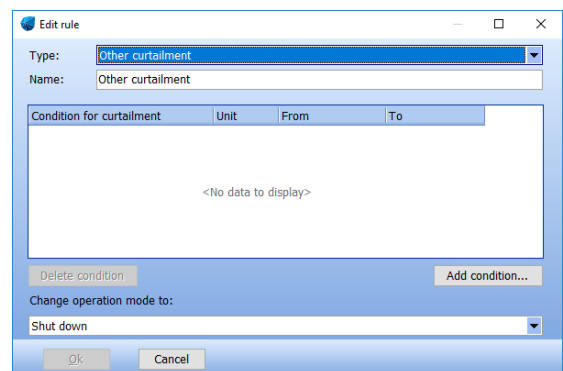
Condition for curtailment	Unit	From	To
Mean wind speed	m/s	10	75
Wind direction	Degrees	345	15

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



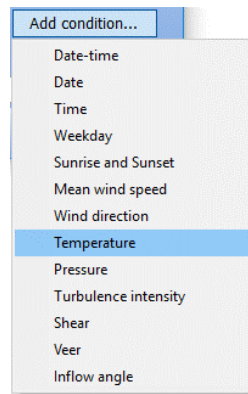
Click “OK” to save the curtailment rule. One curtailment rule has now been created.

To create another rule simply click the “Add rule” again. This time we want to create a curtailment rule to protect the turbine from over-heating by using the ambient temperature. As this is not a pre-defined curtailment type, we select “Other curtailment”:



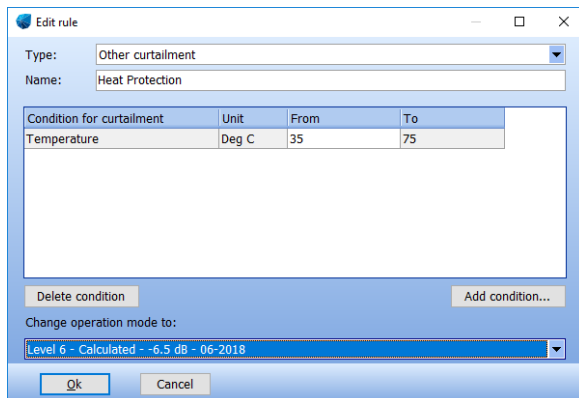
For all curtailment types, additional conditions can be added by clicking the “Add condition...” button:

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This time, we add a “Temperature” condition.

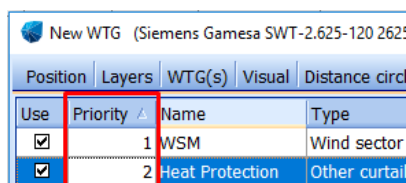
We define our rule saying if the ambient temperature is above 35° C, then “change operation mode” to “Level 6”:



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.

For example, if the mean wind speed is above 10 m/s, the temperature is above 35°C and the wind direction is 5°, the conditions of both rules will be met. However, **only one curtailment rule can be active at a time**. Therefore, the rule with the highest priority will be considered first.

If the conditions of the first rule are not met, the next rule will be considered. **As soon as the conditions of a curtailment rule is met, no lower-priority rule will be considered.** This is key!

In this example, the WSM rule has a higher priority than the Heat Protection rule, and so the turbine will shut down, instead of changing to mode Level 6.

The priorities can always be changed afterwards using the “Move up” and “Move down” buttons.

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 offers a little help in suggesting the priority order. If the action of a new curtailment rule is set to Shutdown, then that rule will be placed with highest priority by default. If any another operation mode is selected, the rule will be placed with lowest priority by default. 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 (yet).

### 5. RUNNING A TIMEVARYING PARK CALCULATION AND QUANTIFYING LOSSES

#### Enabling curtailments

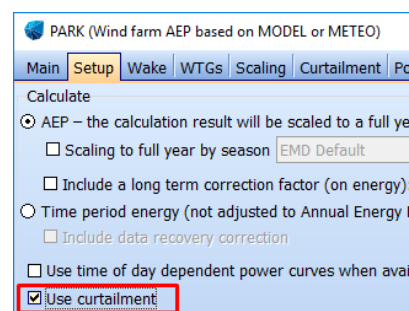
Start by opening PARK from the calculation list and select one of the Time-series based calculations. Depending on your setup, more help on PARK calculations can be found in these quick guides:

[PARK with Scaler, Mesoscale Data & Turbine production](#)

[PARK with Scaler & measured wind data](#)

[PARK with Scaler, Mesoscale Data & wind data](#)

On the Setup page, enable “Use curtailment”:



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

View	User label	WTG	Use	Curtailment name	Priority	Curtailment type	Action
<input type="checkbox"/> View	T1	Siemens G	Yes	WSM	1	Wind sector m	Shut down
<input type="checkbox"/> View	T2	Siemens G	Yes	Heat Protection	2	Other curtailme	Level 6 -

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:

Edit	User label	WTG	Use	Curtailment name	Priority	Curtailment type
<input checked="" type="checkbox"/> Allow editing of WTG curtailment setup. (May influence other calculations)	<input type="checkbox"/> Edit	T1	Siemens G			

### Defining climate data source(s)

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

Signals used in curtailment conditions	Take signal from	Meteo object height	View
Mean wind speed	Scaler		
Wind direction	Scaler		
Temperature	Scaler		

In [step 3](#) we created the Heat Protection curtailment rule which was defined by wind speed and temperature.

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. 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:

Signals used in curtailment conditions	Take signal from
Mean wind speed	Scaler
Wind direction	Scaler
Temperature	Scaler
	Meteo object
	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.

In this example, temperature data is missing in a few time steps. In these time steps PARK will then only evaluate the conditions for wind speed and wind direction. The WSM rule is evaluated first (it has higher priority), but the Heat Protection curtailment rule will be ignored where temperature data is missing.

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	Wake
	[MWh/y]	loss [%]	loss [%]
	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 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.

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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
Mean wind speed	Scaler
Wind direction	Scaler
Temperature	Scaler

#### WTG Curtailments

WTG Name	Index	Priority	Type	Action
1 WSM	1	1	Wind sector management	Shut down
* 1 Heat Protection	2	2	Other curtailment	Level 6 - Calculate

Curtailment has been applied using fewer conditions than specified due to missing data.

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. In this case the Heat Protection rule was ignored 42 times because of missing temperature data:

	Times applied	Times skipped
1	969	0
2	9	42

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 1.133 kg/m<sup>3</sup>

#### Directional Analysis

Sector		0 N	1 NNE	2 ENE
Gross	[MWh]	1,247.8	2,219.9	2,488.4
-Decrease due to curtailments	[MWh]	4.8	7.5	6.2
Wind sector management	[MWh]	4.0	0.0	0.0
Other curtailment	[MWh]	0.8	7.5	6.2
-Decrease due to wake losses	[MWh]	86.4	0.0	0.0
<b>Resulting energy</b>	<b>[MWh]</b>	<b>1,156.6</b>	<b>2,212.4</b>	<b>2,482.2</b>
-Decrease due to curtailments	[%]	0.4	0.3	0.2
Wind sector management	[%]	0.3	0.0	0.0

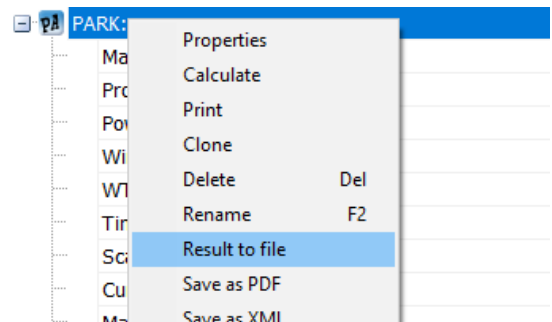
Additionally, the losses of each individual curtailment rule can be seen for each WTG:

### PARK - Production Analysis

**WTG:** 1 - Siemens Gamesa SWT-2.625-120 2625 120.0 !  
**Directional Analysis**

Sector		0 N	1 NNE	2 ENE
Gross	[MWh]	626.6	1,114.2	1,256.8
-Decrease due to curtailments	[MWh]	4.8	7.5	6.2
WSM	[MWh]	4.0	0.0	0.0
Heat Protection	[MWh]	0.8	7.5	6.2
-Decrease due to wake losses	[MWh]	86.4	0.0	0.0
<b>Resulting energy</b>	<b>[MWh]</b>	<b>535.4</b>	<b>1,106.6</b>	<b>1,250.6</b>
-Decrease due to curtailments	[%]	0.8	0.7	0.5
WSM	[%]	0.6	0.0	0.0

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. For more detailed information about *when* a particular power curve has been used, one must export Park time-variation data using Result to file:



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

- PARK (Wind farm AEP based on MODEL or METEO)
- LOSS&UNCERTAINTY (Loss and uncertainty analysis in a bankable format)

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

High and low temperature	
Site access and other force majeure events	
Tree growth or felling	
<b>Group : 6. Curtailment (Loss = 0.55 %)</b>	
Wind sector management	Included
Grid curtailment and ramp-rate	
Power purchase agreement curtailment	
Noise	
Flicker	
Birds	
Bats	
Other curtailment	Included
<b>Group : 7. Other (Loss = 0.00 %)</b>	

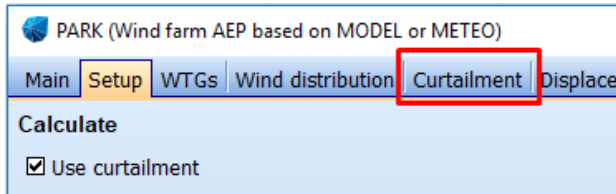
This makes it easy to quickly calculate e.g. a P<sub>90</sub>

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### 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:



This unveils the Curtailment tab, showing any curtailment 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.

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

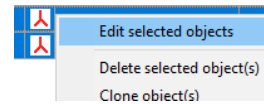
### 7. MISCELLANEOUS

#### How do curtailments affect the wake losses?

The curtailment 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 curtailments 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 curtailments?

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

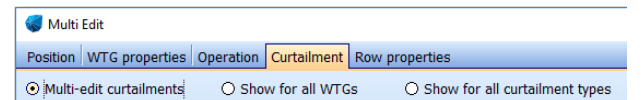


Opening the curtailment tab and selecting “Show for all WTGs” will display a list of all curtailments for all WTGs:

View	User label	WTG	Use	Curtailment name	Priority	Curtailment type	Action	Condition
View	T1	Siemens G	Yes	WSM	1	Wind sector m	Shut down	WS [1
View	T2	Siemens G	Yes	Heat Protection	2	Other curtailment	Level 6 - T	[35;

#### How can I edit multiple curtailments 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 “Curtailment” and choose “Multi-edit curtailments”:



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

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

All WTG equal, but curtailments are different.

Use	Priority	Name	Type
<input checked="" type="checkbox"/>	1	Individual curtailments	Ind

These cannot be multi-edited.

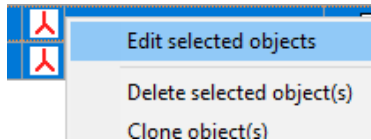
If a new common curtailment rule is created, it will be prioritized above or below all “Individual curtailments” as a group:

Use	Priority	Name	Type	Action	Conditions
<input checked="" type="checkbox"/>	1	Bats	Bats	Shut down	SunRiseSet [1h before sunset
<input checked="" type="checkbox"/>	2	Individual curtailments	Individual curtailment		

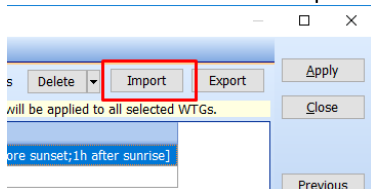
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### How can I batch import curtailments from Excel?

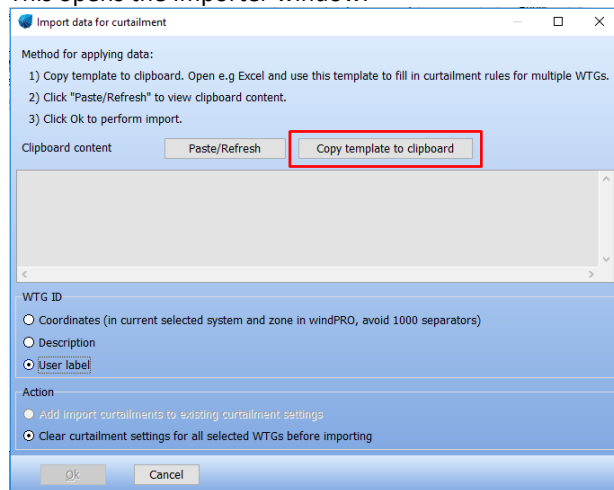
Open the multi-edit window of the WTGs to import curtailments to:



Go to the Curtailment tab and select Import:



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.

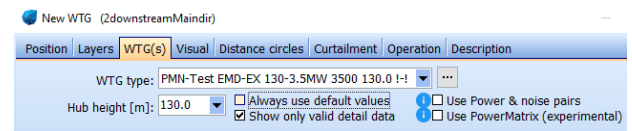
### Why does the time stamps in result to file not match my temporal curtailment rules?

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 section 2.6.3.3](#)

### “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.