QUICK GUIDE – PARK WITH SCALER AND MESO SCALE WIND DATA CALIBRATED WITH TURBINE PRODUCTION

Purpose:

To calculate expected AEP (Annual Energy Production) as time step calculations based on EMD's Meso scale model data, where EMD's data is calibrated against local turbine production.

PARK calculates in time steps (hourly) based on meso modeled data, and it utilizes the terrain data that is held in the EMD meso data- therefore, at present, only MESO data downloaded from EMD server can be used with the described concept. Other Meso data can be used treating the meso data as "a mast" (see other quick guide:

PARK_Measurement_SCALER_Calculation).

This guide assumes the user is familiar with the basic use of windPRO, establishment of objects and the like, and import of measured data in Meteo objects.

Outline of Guide:

- 1. License and version requirements
- 2. Setup input data for PARK/MESO
- 3. Calibration of the SCALER
- 4. Calculation and results

1. LICENSE AND VERSION REQUIREMENTS

WindPRO 4.0 with license to the module PARK and a subscription to EMD-WRF Meso scale data OR purchase of WRF on demand cluster credits. Also, a WAsP 11 license must be installed.

2. SETUP INPUT DATA FOR PARK/MESO

Establish the Meso scale wind data in METEO objects.

- A) Based on EMD ERA5 EU+ or other pre-run (see list) Meso data sets: Create a METEO object, choose the "ON-Line" option, select the point to download, and choose period (recommended at least recent 20 years) – data will be downloaded.
- B) Based on WRF on demand: Run a WRF calculation on EMD cluster at any location in the world. Receive an email when it is ready, then reopen calculation and choose download. Meteo object(s) are automatically created.

If not already established in project:

- Create the turbines to be calculated (objects).
- Create micro terrain data (roughness and elevation) and make a site data object with link to these. The purpose for the site data object can be, e.g., STATGEN, so no wind statistics is needed in the site data object. Alternatively, WAsP CFD result files or FLOWRES files from other model providers can be used.

3. CALIBRATION OF THE SCALER

Having turbines with production data in the region makes it possible to calibrate the Meso scale data to reproduce this production correctly – by turbine, in time, by direction, etc. The more detailed the reproduction, the more trustworthy the calibration.

There are several approaches depending on how detailed the available turbine production data is, which, e.g., can be:

- 1. Annual production for an entire wind farm
- 2. Monthly production for each turbine
- 3. Monthly production and availability for each turbine
- 4. Detailed (10-min or hourly) production for each turbine

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Ad. 1: Set up a calculation with aggregation on annual level. Use the result-to-file to take calculation results to Excel and compare here to measured annual production. Adjust the Post calibration factor in SCALER until the PARK results match a ratio measured/calculated that reflects the expected loss (typically round 95%, but can vary much by project).

Ad. 2 & 3: Here, the PERFORMANCE CHECK module is used. A "step 1" can be to make a wind index correction within this module to establish a long term expected production for each turbine. Then, save these values in existing turbine objects on "statistic" tab. After, the calculation report will show the "Goodness" for each turbine in the PARK report. Adjust the Post calibration factor in SCALER until all turbines come up with goodness around 100% (assuming the long term expected production figures are at 100% availability and before grid loss deduction). If the goodness varies much turbine by turbine, there will be a need to look for reasons, e.g., the wake model settings, power curves etc. Another "next step" can be to compare calculated with measured in PERFORMANCE CHECK at different aggregation levels. Here, different filters can be applied.

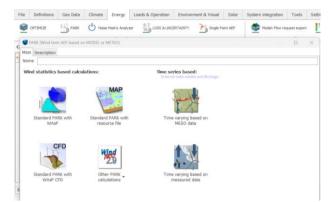
Ad 4: Here, the PERFORMANCE CHECK module is a must since it has all the features for comparing on a detailed time step basis. Aggregation by, e.g., direction, can explain a lot about wake model settings or inefficient roughness description. This is where it is possible to make a very accurate model calculation setup.

Here is illustrated the "simplest" approach (see PERFORMANCE CHECK manual for the more refined options).

In this example calculation, it is an existing wind farm "Black Hill" that is used. From the British REF, the actual production data can be found:

http://www.ref.org.uk/generators/index.php

The data is annual production (AEP) for the full wind farm with 22 Bonus (now Siemens) 1300 kW turbines with 60m rotor diameter and 47m hub height. The AEP periods are 1. April to 31.March with 8 full years (2007-15) available.



Click the upper right button to choose a time series based Meso data calculation.

PARK (Wind farm AEP based on MODEL or METEO)		\times
Main Setup WTGs Scaling Wake Power correction Costs Description	5	
Calculate		
AEP - the calculation result will be scaled to a full year based on numb	er of samples	
Scaling to full year by season EMD Default User defined	- Setup 🚺	
Include a long term correction factor (on energy): 1,00		
Time period energy (not adjusted to Annual Energy Production (AEP)) Include data recovery correction Use STAR	T – STOP time from WTG objects	
☑ Use time of day dependent power curves when available	Edit periods	
Use curtailment Allow only one curtailment per time step		
Use blockage		
Limit park output to grid capacity 0,00 MW		
Output to PERFORMANCE CHECK and/or Result to File/Wake Clear	ning/Hybrid/Cost functions	
Individual results for ALL (relevant) WTGs		
 Individual results for SELECTED WTGs 	Select WTGs to include	
Only SUM for turbines (NO data for PERF. CHECK/Wake cleaning)	Select WTGs to include Wind speeds inside wind farm	
Only SUM for turbines (NO data for PERF. CHECK/Wake cleaning)	Wind speeds inside wind farm ()	
Only SUM for turbines (NO data for PERF. CHECK/Wake cleaning) Sum column only for NEW WITGS (if any, else for all)	Wind speeds inside wind farm ()	
Only SUM for turbines (NO data for PERF. CHECK/Wake cleaning) Sum column only for NEW WTGs (if any, else for all) Aggregated time series values	Wind speeds inside wind farm ()	
Only SUM for turbines (NO data for PERF. CHECK/Wake deaning) Sum column only for NEW WITGs (if any, else for all) Aggregated time series values Month	Wind speeds inside wind farm ()	

In **Setup**, note especially the "Aggregate" level. This is, by default, Month, partly to save memory. But, if there is a need for the hour by hour values (for use in PERFORMANCE CHECK or for some detailed calculations in LOSS & UNCERTAINTY), this must be changed to "none". In this case, we use "Month", even though the data is available in years, but only from April to March. Therefore, aggregation on calendar year will not be useful to compare to informed production values.

tain Setup w/Gs Scaling V	Vake Power correction Costs Description	
Wake model		
N.O. Jensen (RISØ/EMD) Park	2 2018	
Wake decay constant		
Wake decay constant Use fixed hub height: Omnidirectional	100,0 DTU default onshore WDC: 0,090	•
Use fixed hub height:		•

In **Wake**, it is not as much the wake model that decides the accuracy of the wake loss calculation as the parameters that are used. For this model, the Wake Decay Constant (WDC) decides the results. The WDC shall, basically, be chosen based on the turbulence, if this is available. If not, different terrain types are described that, in combination with hub height, give reasonable choices. Here, with Hub height 47m, the logical choice will be "HH 50m, Very open farmland, WDC 0.062".

cts to scale from. Data type	Use in scaling	Sample rate [min]	Duration (enabled)	Recovery (enabled)	First	Shear heights	Last
			[years]	[%]			
urope+ (ER, Meso							
	4	60,0	23,0	100,0	01/01/2000 01.00		01/01/2023 00.0
	1	60,0	23,0	100,0	01/01/2000 01.00	1	01/01/2023 00.0
	4	60,0	23,0	100,0	01/01/2000 01.00	1	01/01/2023 00.
	~	60,0	23,0	100,0	01/01/2000 01.00	v	01/01/2023 00.
	1	60,0	23,0	100,0	01/01/2000 01.00	1	01/01/2023 00.
	1	60,0	23,0	100,0	01/01/2000 01.00	1	01/01/2023 00.
	1	60,0	23,0	100,0	01/01/2000 01.00	1	01/01/2023 00.
	4	60,0	23,0	100,0	01/01/2000 01.00	[*]	01/01/2023 00.
		60,0	23,0	100,0	01/01/2000 01.00		01/01/2023 00.
		9 9 9	マ 60,0 マ 60,0	● 69,0 23,0 ▷ 66,0 23,0 ▷ 66,0 23,0 ○ 66,0 23,0 ○ 66,0 23,0 ○ 66,0 23,0 ○ 66,0 23,0 ○ 66,0 23,0 ○ 66,0 23,0	✓ 60,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0 ✓ 66,0 23,0 100,0	✓ 66,0 23,0 160,0 01/02000 1.00 ✓ 66,0 23,0 160,0 01/02000 1.00 ✓ 66,0 23,0 160,0 01/02000 1.00 ✓ 66,0 23,0 160,0 01/01/2000 1.00 ✓ 66,0 23,0 100,0 01/01/2000 1.00 ✓ 66,0 23,0 100,0 01/01/2000 1.00 ✓ 66,0 23,0 100,0 01/01/2000 1.00 ✓ 66,0 23,0 100,0 01/01/2000 1.00	♥ 46,0 23,0 100,0 0.101/2000 0.1.0 ♥ ♥ 46,0 23,0 100,0 0.101/2000 0.1.0 ♥ ♥ 66,0 23,0 100,0 0.101/2000 10.0 ♥ ♥ 66,0 23,0 100,0 0.101/2000 0.1.00 ♥ ♥ 66,0 23,0 100,0 0.101/2000 0.1.00 ♥ ♥ 66,0 23,0 100,0 0.101/2000 0.1.00 ♥ ♥ 66,0 23,0 100,0 0.101/2000 0.1.00 ♥

In "Scaling", choose the "EMD Default Meso Scaler" and check the EMD/WRF Eupope- meso data set in the list below.

Choose to calculate from 1.4.2007, since this is where our first complete year with production data starts (see later).

Now, the SCALER will run a downscaling of the MESO data based on the Meso terrain in the Meteo object AND the Micro terrain + model selected in the SCALER setup.

This will transfer the Meso data to each turbine position for each hour.

lain Setup WTGs Scaling Wake	Power correction Costs Description	
Include air density correction		
	y/m³ ☑ Use standard (1.225 kg/m³)	
 Elevation dependent air density 	Data from setup will be used when no time varying correction or when no data available in a time series sample	Setup
	Station: ALBORG V3 2014, Temperature base height: 13,0 m, Temperature: 8,2 °C, Pressure base height: 0,0 m, Pressure: 1013,3 hPa	
✓ Use temperature in air de	nsity correction	
from scaler	- bject:	View
Use pressure in air densit	y correction	
● from scaler ○ from meteo	object:	View
Include turbulence correction	n	
from scaler () from meteo obie		Scaline
Edit correction setup	Used reference turbulence intensity for power curve: 0.12	
Include shear correction]	
from scaler	- ti	View
Include veer correction (incl	udes calculation for hub height +/- 0.5 rotor diameter)	
from scaler	ect: -	View
Power curve		
Power curve correction (EMD,	air density correction only)	
 Power curve correction accord 	ing to IEC 61400-12-1 ed. 2 (All selected corrections applied)	
PowerMatrix		
If correction is included, WTGs with	h PowerMatrix are corrected.	
	werMatrix' reference climate is used.	
	Matrix includes the correction in the data-matrices.	
For more infe on the DowerMatrix	format see: PowerMatrix format	
For more millio on the FowerMatrix		

Finally, the power curve correction is entered. The recommendation here is only to check the Temperature correction, since this gives a more precise month by month calculation. The other corrections are more for

"experimental use", these do not, in general, affect the AEP result significantly, although at "special sites" with, e.g. extreme shear, there might be some effect.

Now run the calculation.

Results to file		
Park result		
File name		
Save	Save as	Copy to clipboard
Park time variation		
File name		
Save	Save as	Copy to clipboard
Park time variation	- one file for each WTG	
File name		

Right click on calculation and choose "Result to file" and copy to clipboard.

Insert in Excel:

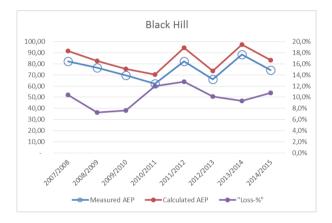
			SIMPLE Meso scal	Scaler:	EMD Def	Meteo dat	EmdConwx
			01-05-2016 13:56	Total		For referen	nce WTG: [1]
			Time stamp	Power	Time	Free wind	Reduced w
Period	Month. Pr	od.	Date-time	[kW]	[h]	[m/s]	[m/s]
1	5839128	1	01-04-2007 00:00	8109,9	720	7,1	6,9
1	6065609	5	01-05-2007.00:00	8152,7	744	7,2	7,1
1	2861784		01-06-2007 00:00	3974,7	720	5	4,8
1	5318335		01-07-2007 00:00	7148,3	744	6,7	6,6
1	6451298		01-08-2007 00:00	8671,1	744	7,3	7,2
1	8126352		01-09-2007 00:00	11286,6	720	8,3	8,2
1	5400473		01-10-2007 00:00	7258,7	744	7	7
1	9696384		01-11-2007 00:00	13467,2	720	9	8,9
1	9350071		01-12-2007 00:00	12567,3	744	8,9	8,8
1	10852133		01-01-2008 00:00	14586,2	744	10,3	10,1
1	10127009		01-02-2008 00:00	14550,3	696	10	10
1	11636904		01-03-2008 00:00	15641	744	10,1	10
2	5441328		01-04-2008 00:00	7557,4	720	6,8	6,5
2	2891779		01-05-2008 00:00	3886,8	744	5,6	5,2

The results will be average Power and the column next to date is the sum of all turbines. This must now be multiplied with time (hours) to get the calculated monthly production. Establish, in addition, a "Period" column, so each year from 1.4. – 31.3 can be summarized, either by a "SUMIF" function or by a pivot table.

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Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	91,73	9,57	10,4%
2008/2009	76,69	82,66	5,98	7,2%
2009/2010	69,57	75,29	5,72	7,6%
2010/2011	62,08	70,57	8,50	12,0%
2011/2012	82,33	94,37	12,04	12,8%
2012/2013	66,30	73,79	7,48	10,1%
2013/2014	88,24	97,35	9,11	9,4%
2014/2015	74,53	83,54	9,02	10,8%
Average:	75,24	83,66	8,43	10,1%

Now, we have the period productions as measured and calculated, and the differences are calculated, also, as "Loss-%".



A graphic presentation makes the picture clearer. It is obvious that Meso based calculations catch the annual variations well, but there seems to be an over prediction.

A 10% loss for the 8 year period seems high. Looking at individual years, it is a minimum of 7.2%. Is this realistic? It might be depending on which losses, how well the wind farm has been operated, etc. We are informed that, in the "better years", only a 5% loss should be observed. We, therefore, now calibrate our scaler to reach round 5% loss from 2008-10. We, thereby, have to get the AEP calculation down by around 2%.

From the export results of the Park calculation "first option from right click and result to file", we can see the "Sensitivity = ratio between windspeed and power" is calculated to 1.7. In order to bring down the AEP by 2.4% (to get the average 5% loss for 2008-10), we shall scale the wind speed by 2.4/1.7 = 1.4. We reopen the

calculation and enter a scaling factor of 0.986 (reduced 1.4%):

		to scaled wind dire	J I		
		to scaled wind dire	ection		
Wind speed		rs multiplied (offse	t added) on ter	rain scaled wind speeds	
Main scale:	0,986	Main offset:	0,0000	Insert from clipboard	

Then recalculate and paste the new results, and the table is updated:

Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	89,48	7,33	8,2%
2008/2009	76,69	80,39	3,70	4,6%
2009/2010	69,57	73,03	3,46	4,7%
2010/2011	62,08	68,44	6,37	9,3%
2011/2012	82,33	92,23	9,90	10,7%
2012/2013	66,30	71,64	5,34	7,4%
2013/2014	88,24	94,87	6,63	7,0%
2014/2015	74,53	81,54	7,02	8,6%
Average:	75,24	81,45	6,22	7,6%

We do not hit exact 5% in average for 2008-10 due to non-linearity, and might, therefore, change the factor 0.986 to 0.988 to get exact what is wanted. Here, we accept the results as okay – to make it better we must contact the wind farm management for more detailed information.

4. CALCULATIONS AND RESULTS

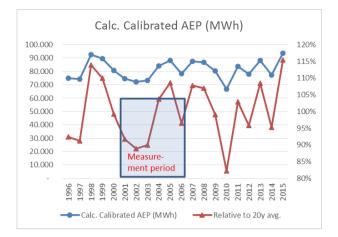
As the calculation setup is now ready, the only modification for a long term expectation would be to set the period to 20 years.

Take near	rest	 Distance weight 	ed at geostroph wind	 Distance wei 	ghted with selected meteo object
Interval) Use all) 🖲 Use period	• -	- 🗌 latest 🔿 U	Jse last years	offset time series 0 years
Qk	Cancel				

Here the calculation is setup for 1996-2015.

The aggregation is changed to Year under setup tab, and the results are:

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The time step based calculation offers, as seen, the benefit of illustrating the annual variations based on historical data - how much can be expected in variations year by year. It is also illustrated here how the wind conditions were during measurements on the site (clearly below long term average).

	MWh/y	
Calc. last 20y	81,32	
First 10	80,48	99,0%
Last 10	82,16	101,0%

And, as support for using 10 or 20 years as the long term reference period, the table above is informative. In this case, using only the last 10 years would give 1% higher calculated AEP.

To finalize the AEP study, a loss and uncertainty evaluation must be performed. Due to the coarse nature of the production data, the uncertainty will be higher than if more detailled data had been available.

It will be difficult to judge the uncertainty, but it is defenitely lower with this calculation concept than based on the traditional wind statistic concept - partly since weibull fit problems are handled better and partly since it gives much more confidence in being able to evaluate the model results against measurements in time instead of just having one average value to calculate with.

It should be noted that the calibration process illustrated here does not provide a refined model calibration – all is put into scaling the meso scaled wind speed. Other issues, like the wake loss model settings, are not possible to fine tune when only sum production for all turbines is available (see other PARK guides where the same project is recalculated using local measurements, which gives a better feedback for model calibration.

It is especially important to calibrate the right parts in the model of a new project when very different turbines and hub heights will be calculated.