QUICK GUIDE – PERFORMANCE CHECK WITH POST CONSTRUCTION FOCUS

Purpose:

To evaluate future production and losses by calculating expected production in each time step based on individual turbines' nacelle wind speed.

To use the new error code-based loss evaluation features.

It is worth noting that this guide creates a simple calculation, based on each turbines' historic measured power curve. No model (flow or wake model) is involved.

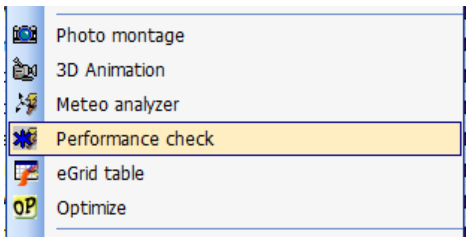
Outline of Guide:

1. **Workflow**
2. **Initial data import and check**
3. **Error code setup & Park calculation**
4. **Performance check & loss evaluation**
5. **Long term corrected potential production with future losses**

1. WORKFLOW

The process explained in this quick guide requires windPRO 3.3 with licensed modules METEO, MODEL, PARK & PERFORMANCE CHECK.

Start Performance Check from the Tools menu or use the shortcut in the toolbar:



The workflow of this quick guide is as follows:

- Import measurement data with production, wind data and error codes into Existing WTG objects.
- Import and merge error codes from turbine log files to 10min production data, if not already part of original SCADA data.
- Run loss calculation from historic individual turbines power curves.
- Evaluate losses caused by error codes based on the *calculated-measured* production for the time stamps with error codes.
- Generate 100% availability, potential production & export to Gross monthly production.
- Long-term correct potential production & predict future production, reporting.

2. INITIAL DATA IMPORT AND CHECK

To run this Performance Check, you need to import Scada data, through the following process:

- Prepare the SCADA data as text files
- Create Existing WTG objects (including ID)
- Add the Scada data files to Performance Check
- Setup the import filter (Auto detect)
- Pair and load
- Merge event log from time step turbine error lists

Prepare the Scada data as text files

Scada data must be in a text file, typically as 10-minute values. If your data is in Excel or some other format, the file(s) must be saved as .TXT (TAB separated preferable) or .CSV. The Performance Check data importer is quite flexible, and can handle data in single or multiple files, e.g. one turbine per file; all turbines in one file; one turbine per day, per month etc in one file.

It is important to have an identifier (ID) of the turbine in the file headers or in a column or in the file names (if one file per turbine). Later this ID will be used to automatically pair the Scada data with an Existing WTG object. This is convenient when working with multiple turbines. If multiple files are loaded, they should have a consistent format.

In the import setup, you can extract a part of a text string from file names or column headers.

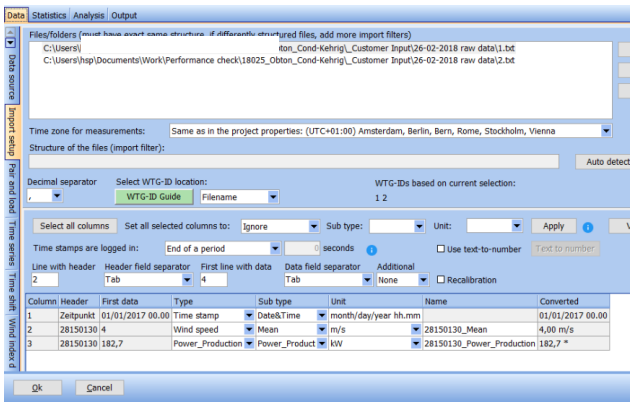
Create Existing WTG objects (including ID)

Either manually insert an Existing WTG object or download turbine positions directly through the Online WTG Data tool from the Data menu. Alternatively, convert New WTGs into Existing WTGs by using the paste option "Edit object(s) before pasting".

Remember to assign an ID to the WTG object as either Description or User label.

Import from data files:

Open Performance Check and choose "Import from data files". This opens an importer which is similar to the importer in the Meteo object.



In the example shown above, two files each with one turbine are added to the import set up with following data fields:

1. Date/Time (mandatory)
2. Wind speed (mandatory)
3. Production (mandatory)

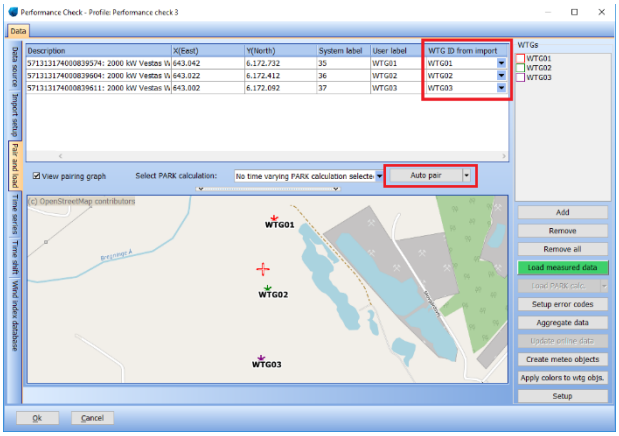
More signals can be added for more detailed analyses.

Wind direction, Temperature, Error code, RPM, Pitch Angle.

NB It is important to setup whether the SCADA data is time stamped at the end or beginning of a 10min period, in order to correctly merge the production data with the error events, and other data signals in windPRO. The WTG-id Guide will assist with identifying how the turbines are listed in the loaded .txt files.

Next step is **"Pair and load":**

Now that the data are imported, they must be paired to the corresponding Existing WTG objects:

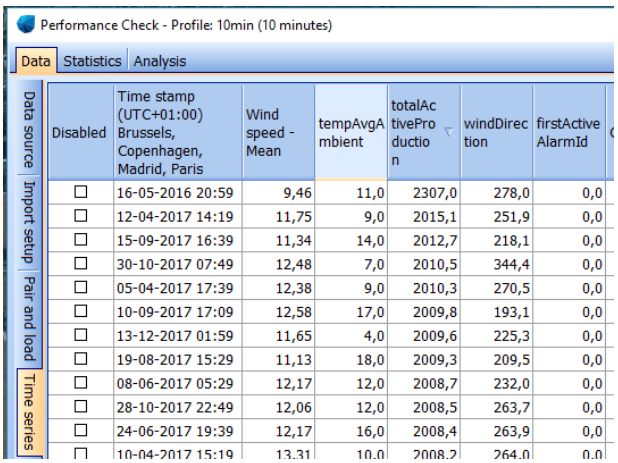


In the image above, the turbines as "Existing WTGs" are selected and automatically matched to the turbines in the import filter, using the "Auto Pair" function. In case the automatic pairing does not work properly, use the drop down in upper right corner to match the ID in the import filter to the objects.

Once correctly paired, click Load measured data and the data will be imported into the WTG objects.

Initial data screening:

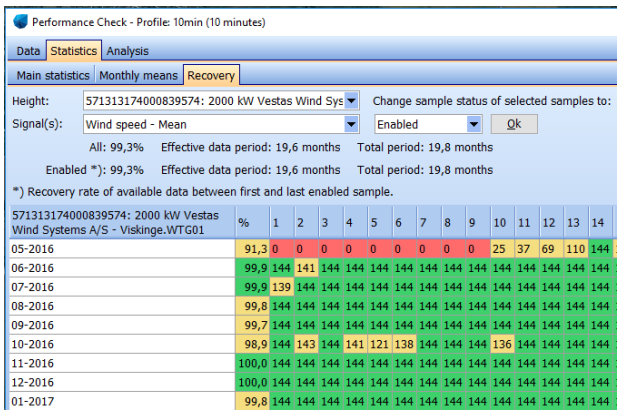
In the "Time series" tab, check if the import seems ok.



Disabled	Time stamp (UTC+01:00) Brussels, Copenhagen, Madrid, Paris	Wind speed - Mean	tempAvgAmbient	totalActiveProduction	windDirection	firstActiveAlarmId
☐	16-05-2016 20:59	9,46	11,0	2307,0	278,0	0,0
☐	12-04-2017 14:19	11,75	9,0	2015,1	251,9	0,0
☐	15-09-2017 16:39	11,34	14,0	2012,7	218,1	0,0
☐	30-10-2017 07:49	12,48	7,0	2010,5	344,4	0,0
☐	05-04-2017 17:39	12,38	9,0	2010,3	270,5	0,0
☐	10-09-2017 17:09	12,58	17,0	2009,8	193,1	0,0
☐	13-12-2017 01:59	11,65	4,0	2009,6	225,3	0,0
☐	19-08-2017 15:29	11,13	18,0	2009,3	209,5	0,0
☐	08-06-2017 05:29	12,17	12,0	2008,7	232,0	0,0
☐	28-10-2017 22:49	12,06	12,0	2008,5	263,7	0,0
☐	24-06-2017 19:39	12,17	16,0	2008,4	263,9	0,0
☐	10-04-2017 15:19	13,31	10,0	2008,2	264,0	0,0

Sort, for example, by power and check the maximum power (kW) is as expected. If it is a factor of 6 wrong, the reason could be the choice of units in the import filter: kWh or kW, or if a factor 1000, Wh or kWh. Simply change the unit in the import filter and reload the data. Spikes in the data can come from a reset of the turbine computer resulting in an offset in the production counter. Such data should be deleted.

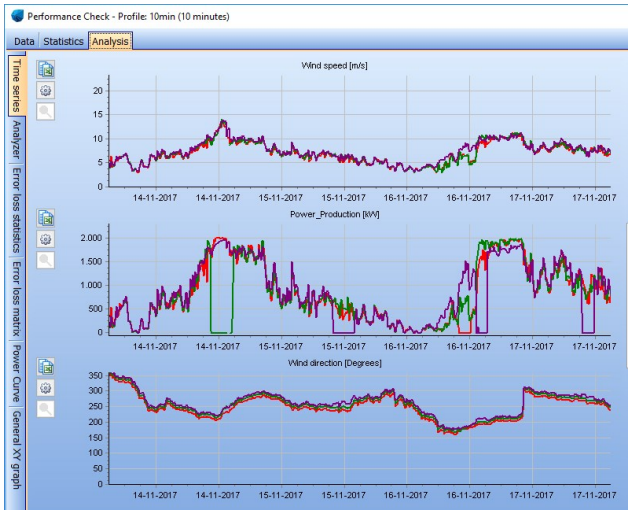
Now check the data on the Statistic tab:



571313174000839574: 2000 kW Vestas Wind Systems A/S - Viskinge.WTG01	%	1	2	3	4	5	6	7	8	9	10	11	12	13	14
05-2016	91,3	0	0	0	0	0	0	0	0	0	25	37	69	110	144
06-2016	99,9	144	141	144	144	144	144	144	144	144	144	144	144	144	144
07-2016	99,9	139	144	144	144	144	144	144	144	144	144	144	144	144	144
08-2016	99,8	144	144	144	144	144	144	144	144	144	144	144	144	144	144
09-2016	99,7	144	144	144	144	144	144	144	144	144	144	144	144	144	144
10-2016	98,9	144	143	144	141	121	138	144	144	144	136	144	144	144	144
11-2016	100,0	144	144	144	144	144	144	144	144	144	144	144	144	144	144
12-2016	100,0	144	144	144	144	144	144	144	144	144	144	144	144	144	144
01-2017	99,8	144	144	144	144	144	144	144	144	144	144	144	144	144	144

Here a clear overview of data period and recovery is provided. This will tell if elements of data are missing, which might be due to some data which were not included, or some data not loaded correctly, e.g. a change in date format over time.

On the "Analysis | Time series" tab further checks of data can be performed:

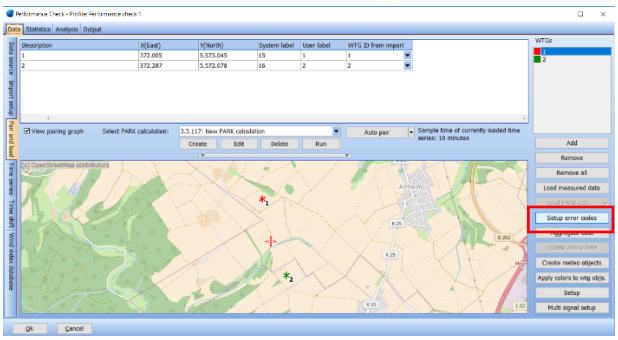


It may be necessary to clean the data, by disabling erroneous windspeeds.

NB the methodology assumes consistent nacelle wind speeds, thus jumps occurring from anemometer exchange or scale changes from the turbine controller should be corrected in the Scada data and re-loaded. The same applies to Icing if the windspeed is locked at zero or at an offset value, this should be corrected or deleted prior to merging with error codes and calculating losses.

Import of turbine error log.

Under the Pair and Load tab, enter "Setup error codes"

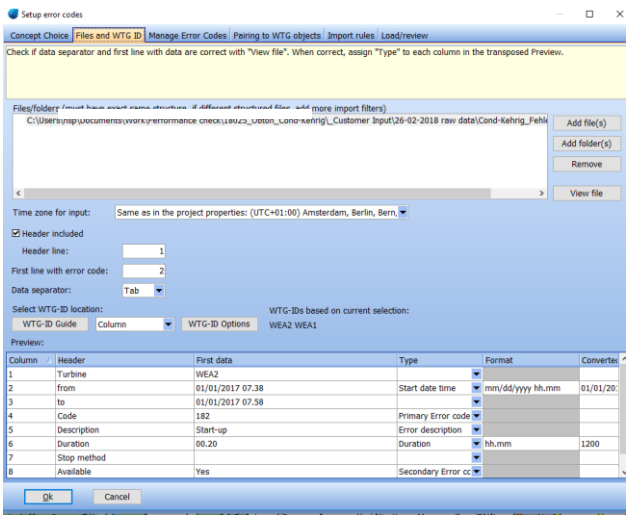


Here you will see two concept choices:
If error codes are already part of the 10-min SCADA data loaded, follow this path: ○ Error codes in time series

If error logs come in a different file format, following time duration event lists, choose this path:
⦿ Seperate error codes

This guide follows the second option, subsequently merging time domain error logs with production data.

Files and WTG ID



Different manufacturers have unique output of their turbine error code log, so here you first need to convert

it to a .txt or .csv file format. Build the translator for how to read the loaded files, making sure windPRO can find the ID of the individual turbines and the format of the data.
You can load two columns of error signals. Note, currently error codes have to be numbers, as "text" error codes are not currently supported.

The Manage Error Codes tab, is where the loaded data are assigned categories, related to the error description given by the OEM.
Multipliers can be assigned to the first error code. So when the first error code is merged with the second error code each merged error code will get a unique status signal for the individual alarm code. It is recommended that you assign a multiplier which exceeds the highest value of the secondary error code to ensure unique status codes.

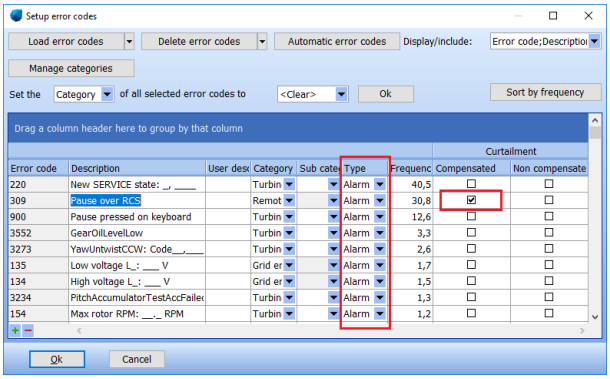
The info columns, including some that are optional are as follows:

- **Error code:** A number that corresponds to the Error code number loaded to WTG objects with the Scada importer. Mandatory.
- **Description:** Typically, the manufacturer fault naming.
- **User description:** Can be additional text.
- **Category:** This is mandatory, while the Loss matrix groups losses by categories, which can be "Turbine error", "Environment", "Grid error" etc. Categories can be user defined.
- **Sub-category:** Could for turbine error be like "Hydraulics", "Electric" etc.
- **Type:** Alarm, Warning, Event, State

Frequency is auto-filled and shows how many events of the specific error code are found in all data as a percentage. This helps identifying the important ones, that might require more information than others.

Curtailment: This is a special added value to the analysis. If a turbine is curtailed, for example for Flicker stop or Bat stop, this is an upfront known loss included in the AEP expectations. Therefore, this would often be given a special treatment, which is possible by marking this.

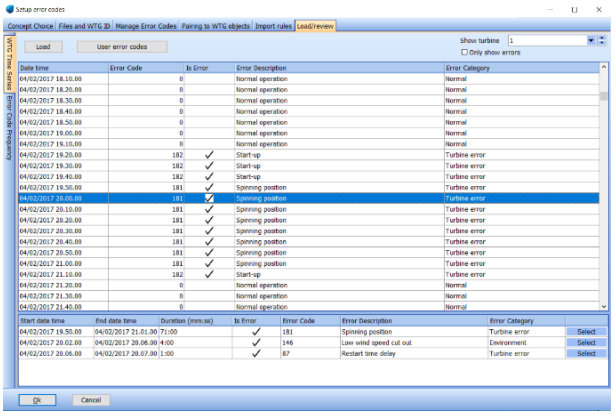
Compensated curtailment is typically when the turbine owner is paid during stop due to the electricity market or if the utility cannot take the power due to grid constraint problems. This is treated as a special event, as this is not a "real" loss. It should be added to measured production for a fair evaluation of the project performance.



Above is shown how the loaded error codes now include a description and category. In this case the "Pause over RCS" is also checked with "Compensated curtailment". This is the code used by turbine stop due to market regulation in this example.

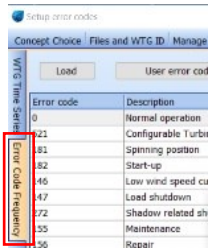
In the "Pairing to WTG objects" tab, ensure that the individual turbine IDs are known and that windPRO has read the IDs from the error log, to merge the error logs onto the production time series for the correct turbines.

Load/review

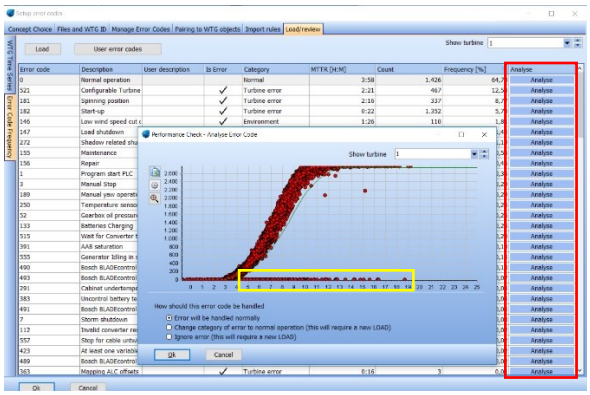


Hit the "Load" button to see the merged time series table. If the button is green, it means changes have been applied to the data setup, error code translator or import settings, and you can re-load the data with the new settings.
You can now go through the time series and check if multiple alarms are present in each single 10min time step.

Advanced import settings of the error log can be managed under the “Error Code Frequency” sub-tab:



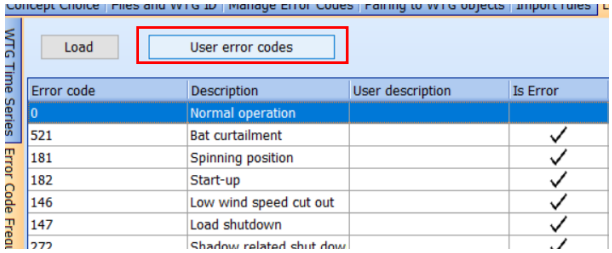
Pressing the “Analyse” button you are presented with a scatter plot of the merged production and error events, for all time steps of this unique error code:



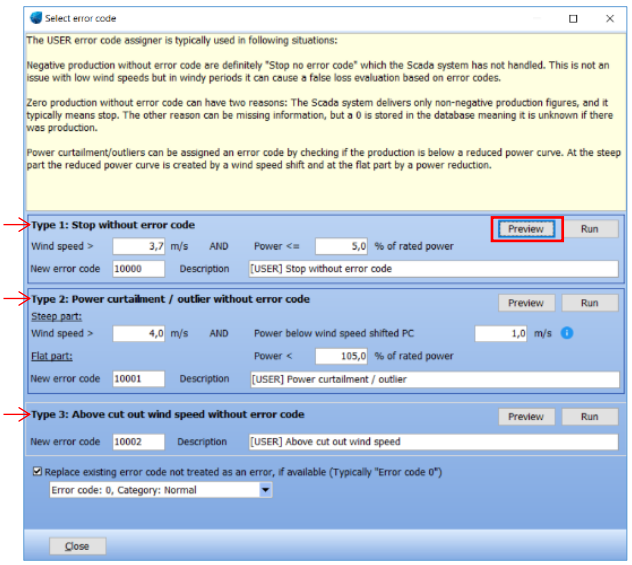
In this example, all 10-min time steps with a “0” error code represent normal operation.
Unfortunately, not all turbine stops are caught by the manufactures error logs. In the Analyse Error code window, these erroneous error logs can be handled.

You can choose to ignore certain alarm signals which may not be relevant for the turbines’ operational status. Here it is possible to select “Ignore error” and then reload all error signals excluding this individual code. For instance, if an error code clearly represents good normal operation, this error code may camouflage other genuine turbine stops e.g. the alarm occurred before the turbine stopped and had a long duration in where the real problem was logged. By ignoring such alarms, the real reasons for turbine stops may be revealed.

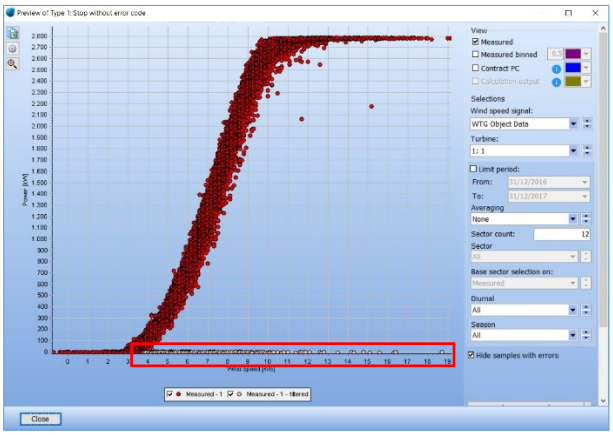
Note: The above example (outlined in yellow) showed normal operation, but clearly multiple periods of zero production at high wind speeds were observed, which did not have an error code. This can be handled by clicking the “User error code” button:



Here, these turbine stops and sub-optimal performances can be given a new error code in order to be able to quantify the potential production considering 100% availability. Currently three filters can be applied to the loaded production data:



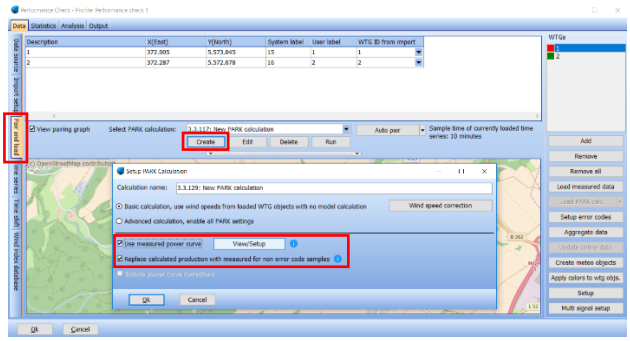
To catch poor performance and give it an error code, you can re-name the signal and change the code given, and the threshold for the auto filter.
Under “Preview” you will be presented with what data will be given a new user error code based on your filter setting:



All 10-min data with the pink marked color will be given a new error code, here for stops without error code. When done with error code setup click "Ok" to save and exit the settings.

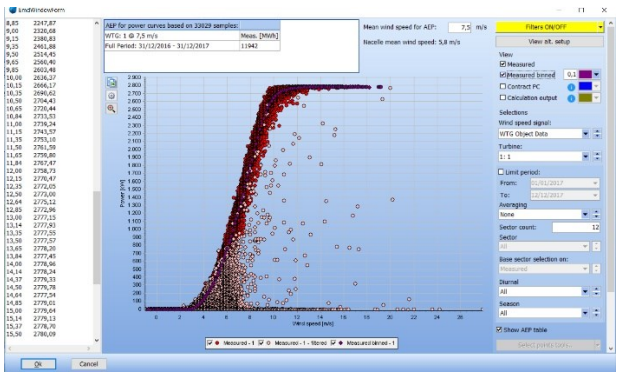
3. ERROR CODE ANALYSIS & PARK CALCUALTION

After initial screening and merging of production data with error codes, the data are ready for loss calculation. To accomplish this, return to the "Data | Pair and Load" tab:



Here click "Create" to establish a new simple PARK calculation. To follow the industry recommendation for post-construction analysis, enable "Use measured power curve" and "Replace calculated production with measured for time stamps without error codes"

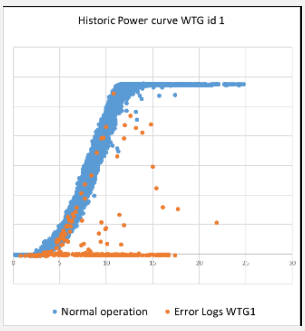
Each loaded, individual turbine will now use its historic measured production for when the turbine is in normal operation only. The binned normal operation power curve will be used as a lookup table to find what the turbine could have been producing at a given time step where an error is present. "View/setup" will let you see the result of your error codes imported and what data is left as "normal operation" with no errors.



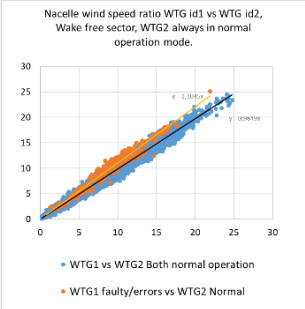
The example above illustrates the binned measured power curve for turbine 1, based on the Measured SCADA power curve, for all time steps where the turbine has no error codes "including user error codes"

Press "Ok", and press run calculation. This will now calculate power as if the turbine was 100% of the time in normal operation, all data sets, without errors are kept intact and untouched, thus the real power are maintained for typically 95% to 99% of the entire time series and only time stamps with an error event present will be calculated using the historic power curve.

NB: EMD has observed multiple turbines to have a different wind speed response recorded by the nacelle anemometer once the turbine stops, as compared to when it is in normal operation. For the basic calculation it is possible to correct this bias on the wind speed. This will, prior to calculating the losses, scale the individual WTG's 10-min wind speeds concurrent with a turbine error and use this corrected wind speed for looking up the potential production.



Currently, this scaling factor correcting the biased nacelle wind speed for the turbines' operational status, needs to be investigated outside windPRO. Future windPRO releases will include tools to find and apply this scaling factor.



Knowing the factor, it can be applied when creating the simple PARK calculation, by selecting the "Wind Speed Correction" button.

The changes applied can be visualized under the "Analysis | Time series" tab, where the thin line at below image now represents the calculated wind speeds, and while all other data where the turbine is in normal operation is untouched.

4. PERFORMANCE CHECK & LOSS EVALUATION

From the simple PARK calculation, it is now possible to investigate the performance and losses of wind farms or individual turbines.

Now there is a calculated production for ALL error time steps, where those with normal operation match

measured production. The losses are then the difference between *calculated "Potential Production"* and *measured "Actual Production"* for each time step with sub-optimal performance or turbine stop.

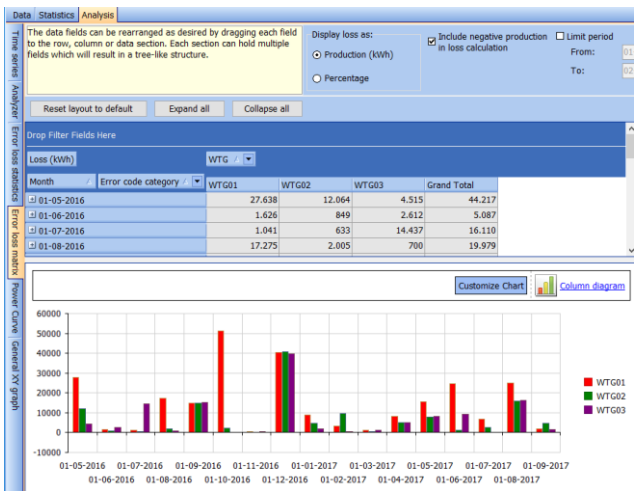
NB: The nacelle anemometer is not a precision instrument and the flow around the nacelle affects the measured wind speed significantly, but the power produced is with a very low uncertainty the real power, since the losses are typically in the order of 1% - 5% its acceptable that there are uncertainties related to calculating the losses.

The sum of the measured power from the loaded SCADA system, and the calculated potential production which now represents the power which the turbine could potentially produce had it been operating at 100% availability.

NB: A problematic part is the "Missing/faulty data". If for instance, we have 6% data we don't know about if icing was an issue causing faulty wind speed readings. The only way to improve this is to run substitutions on the wind speed data in Meteo analyzer, either taking wind from other turbine objects or from meso-scale wind data, and then re-load the data and re-run the simple PARK calculation. All loaded SCADA data can be exported to a meteo object under the pair & load tab, if significant data repair is required. By excluding it out we assume the turbine was in normal operation or stopped, both can be handled later when we generate monthly potential production.

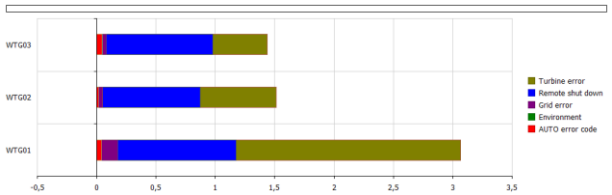
Loss evaluation

Next view is the "Error loss matrix", which is a flexible data viewer:

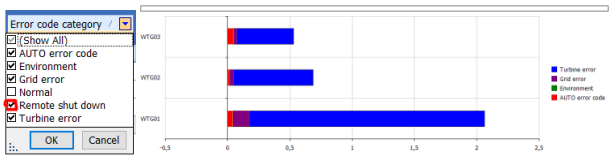


The layout of the graphs can be decided by month, turbine and category. Any combination view can be made by dragging around the filter buttons. Units can be kWh or %.

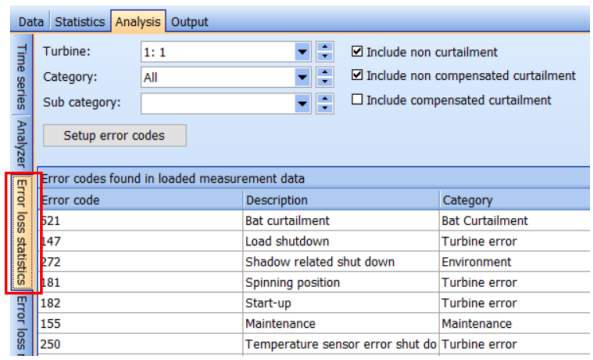
Below, a typical graph with loss percentage by turbine and category for a specific period:



In this example the "Remote shut down" is a compensated curtailment and thus not a real loss. This can be unchecked, and the real losses shown:



Also, it is worth mentioning that a longer data period will help achieve more accurate results for assessing the potential production, where it may be visible that in the run-in phase the losses were large in the first months of operation, and then for the later years have settled down to a realistic value which can be expected for the future.



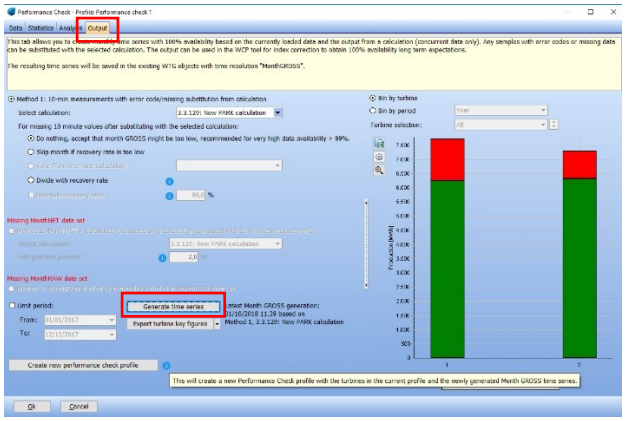
Under the "Error loss statistic" sub-tab you can dig into the individual error codes, and see the kWh lost production, the mean time between failure and the average time for repair, plus the frequency of occurrences for the selected period of time under investigation. In the above example a faulty Bat curtailment strategy resulted in severe losses.

This table can be copied to create in-house "pareto" charts or other visualizations of the observed turbine specific performance, and gain insight into which turbine faults are the costliest and should have the highest priority for rectifying.

Monthly Gross production

The next step is to generate the Monthly Gross production figures required for long term correction of the wind turbines' potential production.

This is managed under the Output Tab:

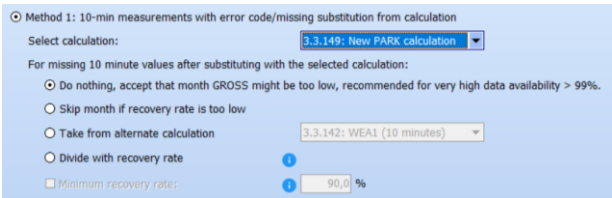


Click "Generate time series", which will make monthly 100% availability production time series.

Then click "Create new performance check profile"

This will make a new performance check session, in where you will work with long-term wind data like EMD WRF mesoscale datasets, for long-term correction of the measured and potential production so its representative as a long-term mean to be expected in the future.

Before exporting you need to evaluate if your 10-min data sets of provided SCADA time series have sufficiently high availability and expect the same availability in the future.



For option 1 "*do nothing, accept that month Gross might be too low, recommended for very high data availability > 99%*" this will maintain the measured monthly production and calculated values of potential production. Use this if you believe that the less than 1% of SCADA data represents turbine stops, and you assume similar values in the future.

Option 2, "*skip months if recovery rate is too low*", provides an alternative to substitution of faulty wind speed readings in the SCADA system. NB this may increase uncertainty for long-term correction due to seasonal bias.

Option 3, "*take from alternate calculation*", use a previous calculated PARK calculation.

Option 4, "*divide with recovery rate*": this assumes that the turbines were in average operation during the period where you have no information, and will increase the measured monthly production for each month, with the missing % of time in each month where you have no data recovery.

To extract the losses and key data from the 10min performance session, this can be copied to file or clipboard for documentation/in-house tools for later reporting. This is under the "Export turbine key figures button"

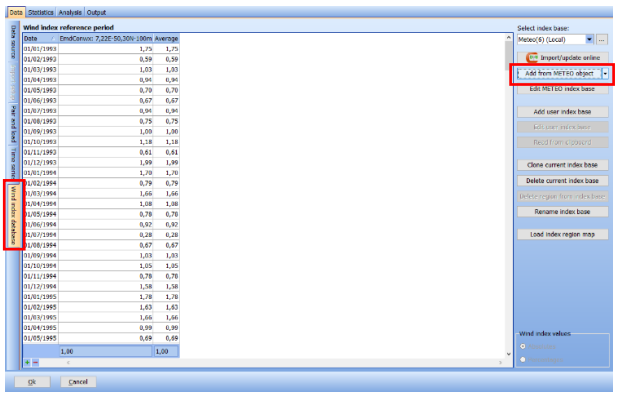
Press "Ok" in the lower left corner inside performance check to save your current filters and settings and exit this performance check session.

5. LONG TERM CORRECTED POTENTIAL PRODUCTION WITH FUTURE LOSSES

Now open the new generated performance check session, named extension "1 month Gross (auto)"

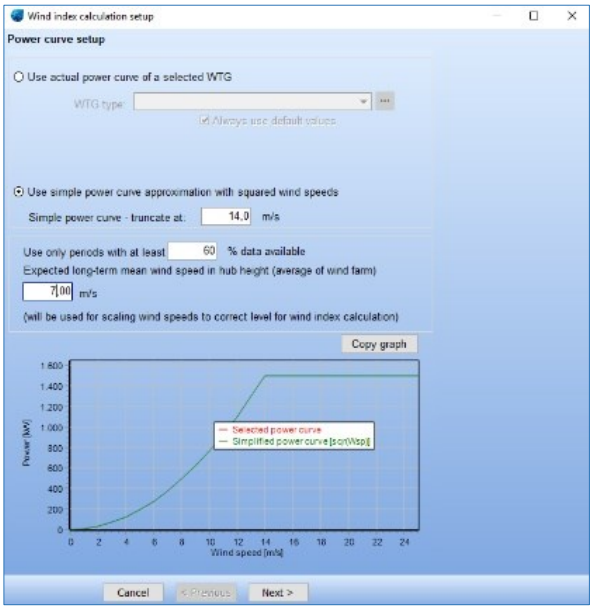
This is a clone of the 10min SCADA, containing all the existing turbines under investigation but preloaded with the monthly potential production values.

First step here is to go to "Wind index database" under the starting Data tab. Here you can add a long-term wind time series from a meteo object:

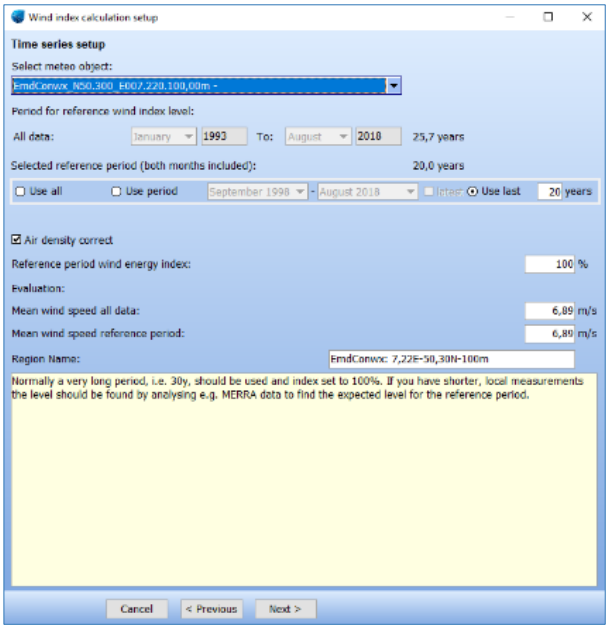


First, we need to convert the long-term wind speed time series into a monthly wind energy index.

Choose the specific turbine model of your project or a simple generic power curve, scale it to an average mean wind speed representative of the site and press Next:

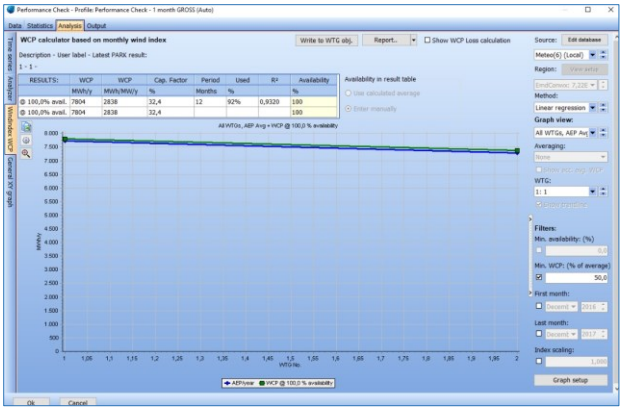


The long-term time series should be trimmed to whole years. This is easily done by selecting "Use last" and set the number of years, to avoid a small seasonal bias:



Several long-term data sets can be tested for trends etc.

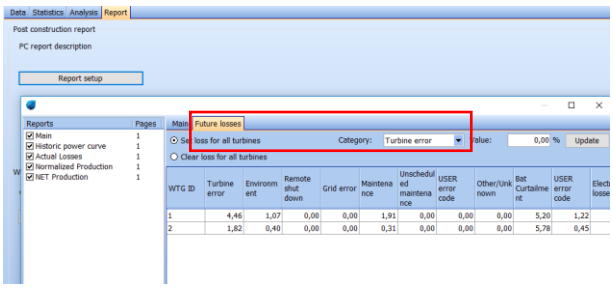
Once loaded and tested and the best reference long-term data set has been selected, go to the Analysis tab, and then Wind index WCP. Here the potential production has been calculated for being representative as a 20-year average future normalized production:



You can choose different sources of the energy index from the data sets loaded earlier.

Reporting & future losses

The results can be exported as a simple report, showing the index correlations with assumptions for the future losses. These future losses are pre-read using the historic losses observed in the 10-min SCADA analysis. These can be changed by selecting the drop-down menu under Category and inserting a common estimate of future losses for the relevant groups:



NB. windPRO has two additional losses to be considered for future losses: as electrical losses are managed outside the scope of performance check a recommended 1% standard value is listed, and 0.5% for future degradation to be expected over the life time of the turbine. These values can also be changed by the user with a different value in the "value" field. Clicking "Update" will change the % of future lost production for the selected category. The labels and background maps can be changed under the normal report settings in windPRO.

The report closes the loop of the calculated losses to the potential productions, and having the assessed future losses the NET production is calculated, which represents the expected future yield of the turbine(s).