## QUICK GUIDE – PERFORMANCE CHECK WITH POST CONSTRUCTION FOCUS

## Purpose:

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

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

**This guide creates a simple calculation, based on each turbines' historic measured power curve.**

## 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 4.0 with licensed modules METEO, PARK & PERFORMANCE CHECK.

Start Performance Check from the Main tab "Loads&Operation" Then select Performance Check, make a new session and open this.
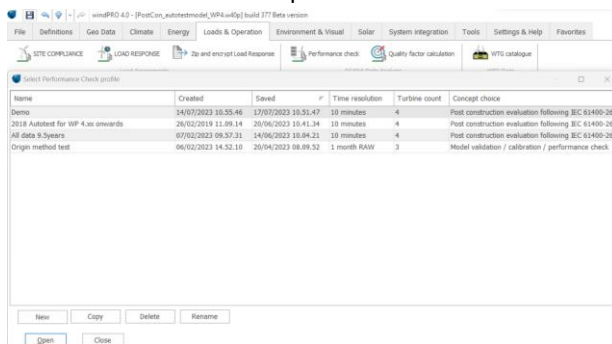


The workflow of this quick guide is as follows:

- Import WTG production data & wind data 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.

- Substitute faulty or missing nacelle wind speeds using TR10 methodology.

- Run loss calculation from historic seasonal and Day & Night individual turbines power curves.

- Evaluate losses caused by individual wtg error codes

- Generate 100% availability, potential production monthly production.

- Long-term correction & 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.

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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 Geo Data Tab. 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 under the Loads & Operation main Tab and choose "Post construction evaluation following IEC 61400-26-1". Then, select your data source as "Import from data files". Here it is 10min SCADA data. Clicking the green Ok button opens an importer which is similar to the importer in the Meteo object.
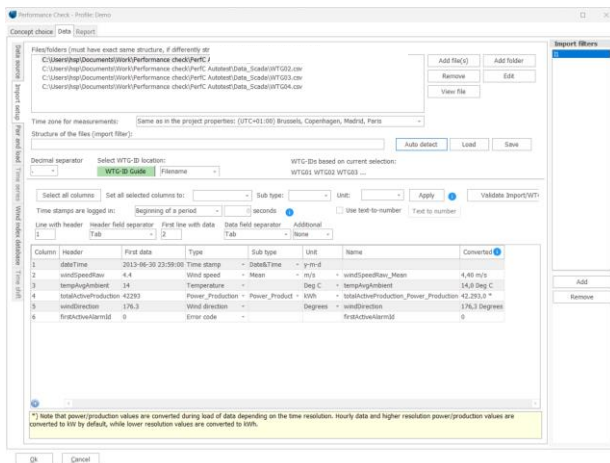


In the example shown above, two files each with one turbine are added to the import set up with following data fields:

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.

Note: It is important to define 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:
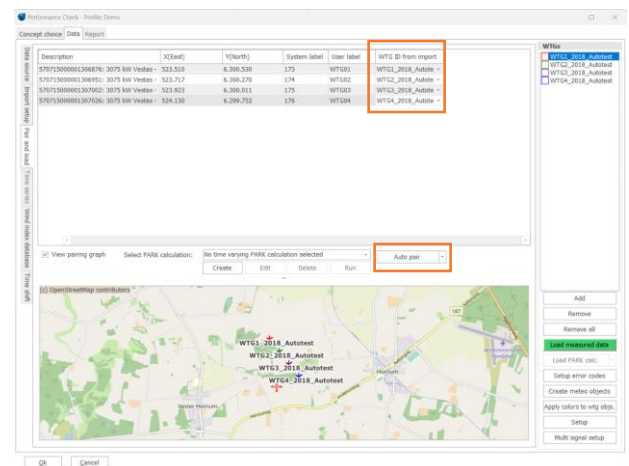


In the image above, the turbines added as "Existing WTGs" are selected and automatically matched to the turbines in the import filter, using the "Auto Pair" function. In case the automatic pairing does not work properly, use the drop down in upper right corner to match the ID in the import filter to 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.
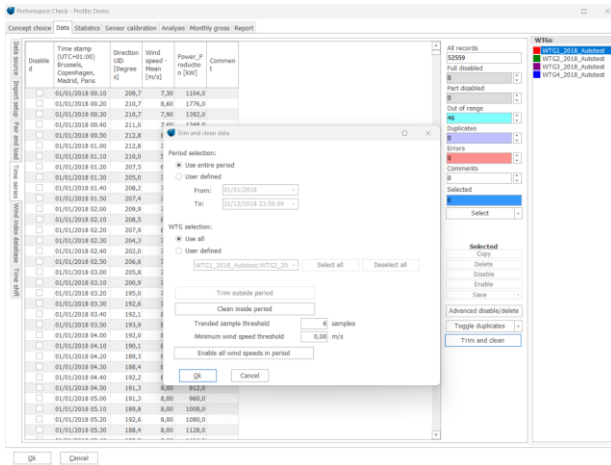
Sort, for example, by power and check the maximum power (kW) is as expected. If it wrong by a factor of 6, the reason could be the choice of units in the import filter: kWh or kW, or if a factor 1000, Wh or kWh. Simply change the unit in the import filter and reload the data. Spikes in the data can come from a reset of the turbine computer resulting in an offset in the production counter. Such data should be deleted.

By selecting the Trim and Clean button a window opens that allows to trim and part disable trended windspeed signals automatically for all loaded turbines signals, significantly easing the manual process of data cleaning.

Now check the data on the Statistic tab:



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. "NB if the TR10 methodology is used later the original availability will be changed to the resulting values post the windspeed substitution"

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

It may be necessary to further 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 before undertaking loss evaluations.

**IMPORTANT** to delete or disable erroneous wind speed measurements, as this is used for the loss calculation and cascades through to wrong Potential Energy, Normalized Energy and future Net production result.

**Import of turbine error log.**

With consistent wind speed signals ready, next step is to "Setup error codes"
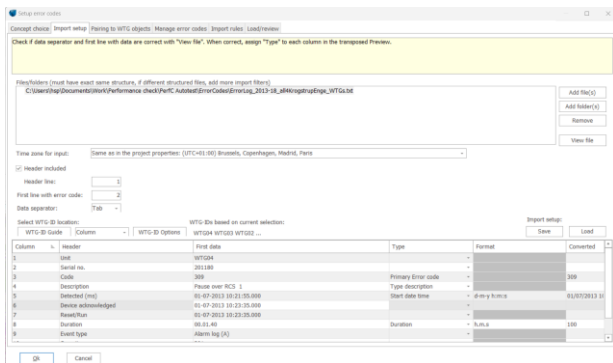


Here you will see three concept choices:

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If error codes are already part of the 10-min SCADA data loaded, follow this path:



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

**Import setup**



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.

**NB** just like SCADA import and as in METEO, its required to sometimes manually set if date format is D/M/Y h:m:s or M/D/Y h.m.s here under the Format column. You can load two columns of error signals in order to ensure a unique error code for each possible event type and category.

The Manage Error Codes tab, is where the loaded data are assigned categories, related to the error description given by the OEM if the Category is not part of the provided event log.

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.

- **Error code:** A number that corresponds to the Error code number loaded to WTG objects with the Scada importer. Mandatory "numerical number".
- **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.
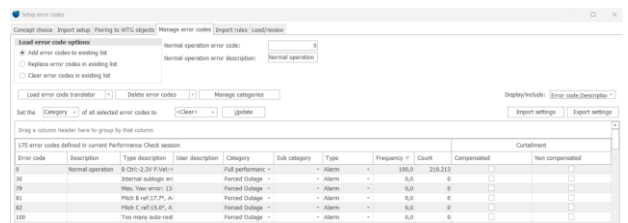


New since windPRO 3.4 is the ability to catch error codes which have different "text descriptions" if this is detected a new feature is enabled "Separate error Codes"
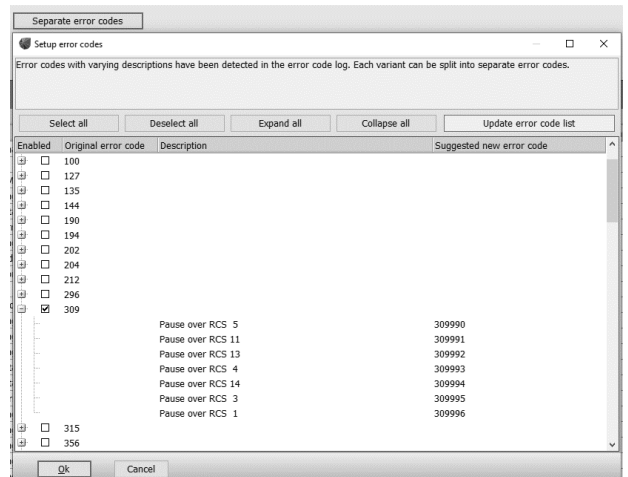
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By clicking the "separate error codes" which is only visible if the error codes loaded contain varying text descriptions. In the example error codes 307, remote shut down is actually representing different stop reasons, where it's the Pause over RCS 5 only which is compensated, the rest represent different stops which do not get compensated and shall be included in the future loss evaluation.

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.

Import rules, allow to eliminate alarms which may only be one second and not affect the turbines true operational performance, and to select a hierarchy for selecting an error code, when multiple events inside a given 10min period is present.

**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 "Preview" button you are presented with a scatter plot of the merged production and error events, for all time steps of this unique error code for a given selected WTG:
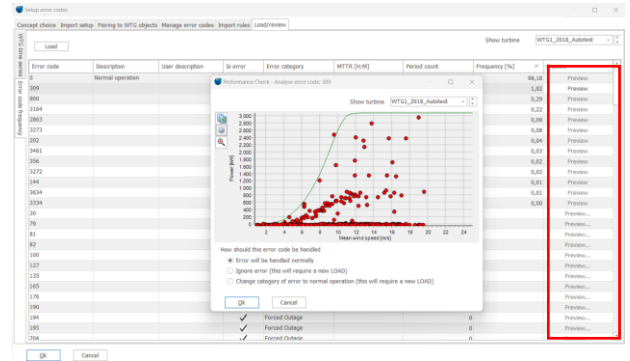


You can choose to ignore certain alarm signals which may not be relevant for the turbines' operational status. Here it is possible to select "Ignore error" and then reload all error signals excluding this individual code. For instance, if an error code clearly represents good normal operation, this error 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: Not all events may be described by the event logs. 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 four filters can be applied to the loaded production data:

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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:
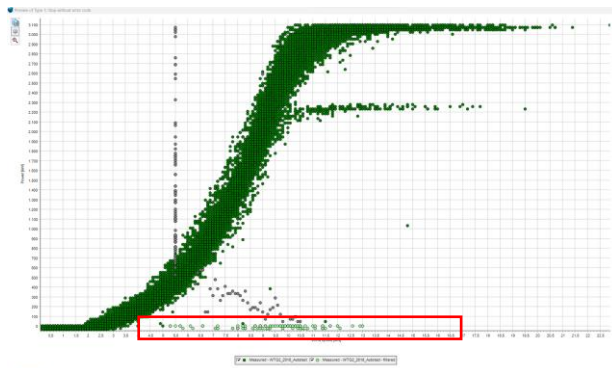


All 10-min data with the light marked color will be given a new error code, here for stops without error code. When done with error code setup click "Ok" to save and exit the settings. User error codes can be deleted again.

**Sensor calibration.**

Wind speed measurements must be consistent for the period of investigation, this can be evaluated and if needed corrected under the Sensor Calibration Tab

This opens a new window for Sensor calibration:
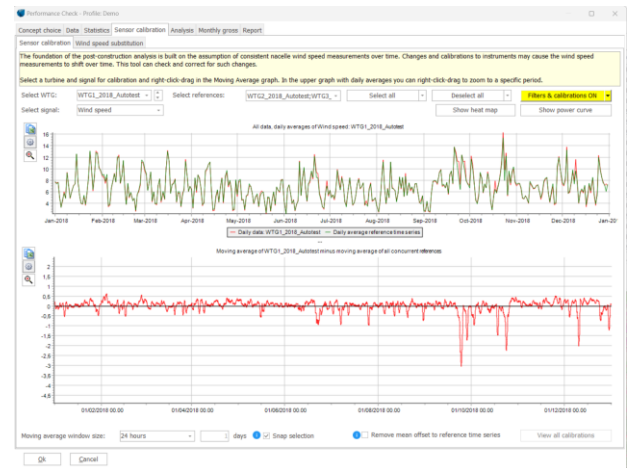


Here one turbine signal is pre-loaded, and a set of reference data pre-selected. The image above shows a daily time series of the selected WTG under investigation, and for this setup 3 neighboring wind turbines has been selected as reference data. This tool will combine the selected reference data sets into an average hourly reference data set. The lower graph, then shows the selected time series minus the reference time series with a set averaging time: annual, monthly or daily.

In case a large offset is found. **To calibrate this** "possible anemometer exchange, changed NTF of the nacelle anemometer" mouse-over the start of the trend in the bottom view, right click and hold & Drag the mouse over the desired time period where an offset is required to correct the wind speed signal. Let go of mouse right button and a pop-up window ask if the found offset shall be corrected.
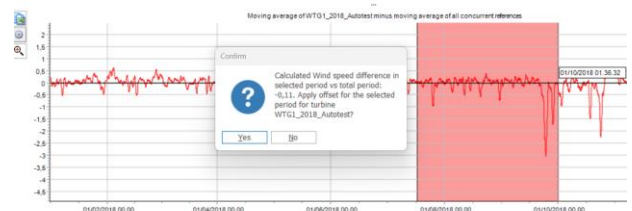


If filters are on the graph they will update and show the new generated and corrected time series. It is recommended to visually check the power curve plots to ensure, the right period is adjusted, and that the right WTG was selected. For instance, if only one reference turbine is selected, changing to this turbine as selected and the other now as reference, it will appear to also have a trend, however when evaluating the heatmap or

the power curve view should help ensure that the wind speed signal which truly has a trend is the one corrected.

**Wind Speed Substitution**

Requires wind direction data "often this will come from Mesoscale data" but Nacelle direction or other reference data can be used.

Its recommended to import Meso-scale data and use its wind direction as a master for all turbines, unless thorough evaluations of individual WTGs direction data has been validated. Then simply press calculate, which will pending on duration of loaded data and amount of turbines take a while to calculate a best fit correlation, Scale and offset between every single loaded data set pr 12 sectors, and pr month. Once complete it becomes possible to push the Substitute disabled/missing windspeed signal button, where the most suitable reference data is found for each disabled on missing 10min windspeed signal pr loaded turbine.
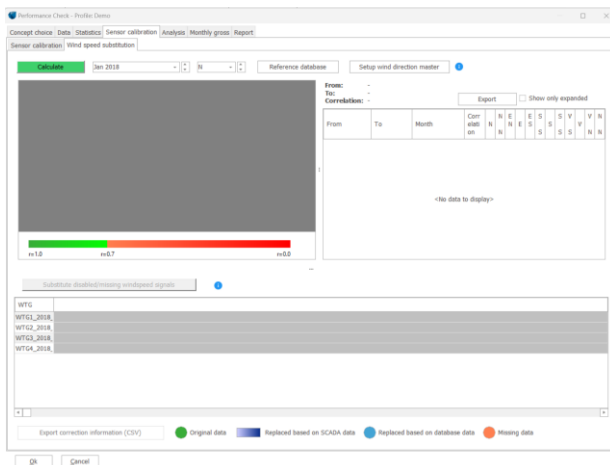


## 3. LOSS CALCUALTION SETUP

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:
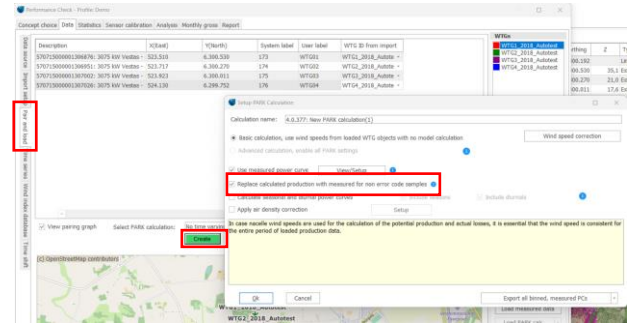


Here click "Create" to establish a new simple PARK calculation. To follow the industry recommendation for post-construction analysis, enable "Use measured power curve" and "Replace calculated production with measured for time stamps without error codes" And if desired use 4 seasonal historic power curves and or day and night historic power curves to lower the bias for calculation losses as given average site conditions.

Each loaded, individual turbine will now use its historic measured production for when the turbine is in normal operation only. The binned normal operation "or Seasonal binned and or Day / Night time binned" 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.
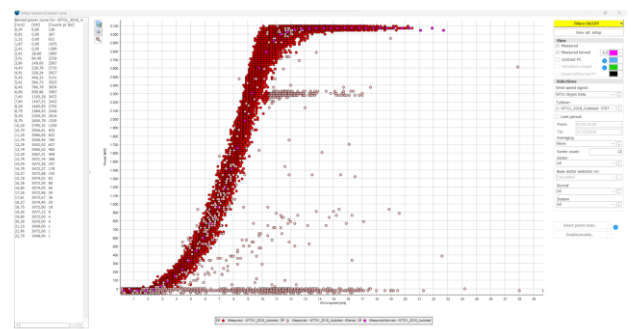


The example above illustrates the binned measured power curve for turbine 1, based on the Measured SCADA power curve, for all time steps where the turbine has no error codes "including user error codes"



Some turbines, have a simple Nacelle transfer function applied to the nacelle anemometer, where a very clear change in anemometer response can be observed, when the wind speed signal is compared to a

neighboring turbine, when the selected turbine is in normal operation or its stopped. This can now be corrected for by selecting the Wind speed correction button.
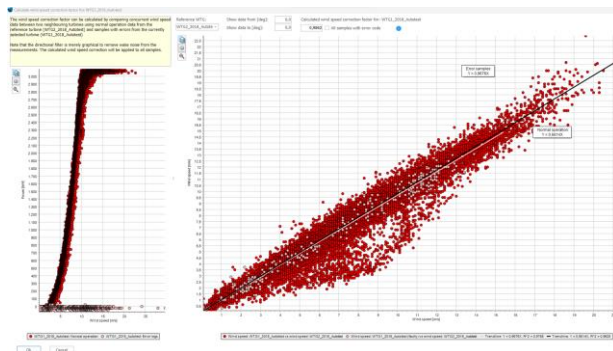


By pressing Calculate next to each wtg, open up the menu to evaluate individual turbines nacelle anemometer, if it indicates a clear correlation to its wind speed response vs the turbines operation mode.



windPRO automatically evaluate the loaded data and suggest a scale factor which can be applied to all wind speeds containing an error event, in order to correct for the potential missing NTF for when the turbine is stopped or in suboptimal performance mode.

Note small changes of 1-3% are very difficult to know if its method uncertainty or a true variation in wind speed response, here its recommended to not apply a scale factor.

Press "Ok" to exit wind speed correction and again to exit the calculation setup, and then 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.

## 4. PERFORMANCE CHECK & LOSS EVALUATION

From the simple 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.

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.

**Loss evaluation**

Under the analysis tap. Error loss statistic, you have a pareto investigation into the entire fleet of loaded turbines on you can select a different mix, of turbine numbers, time period to see the most severe individual error code with the largest combined lost production and their mean time between failure "MTBF" and mean time to repair "MTTR".

Next view is the "Error loss matrix", which is a flexible data viewer:
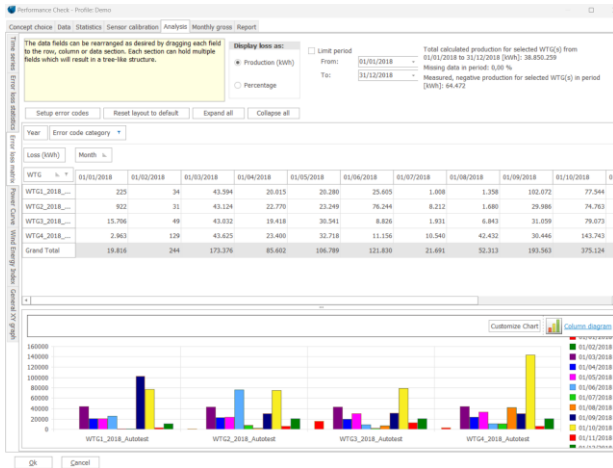
The layout of the graphs can be decided by month, turbine and category. Any combination view can be made by dragging around the filter buttons. Units can be kWh or %.

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.

**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 Monthly Gross Tab:
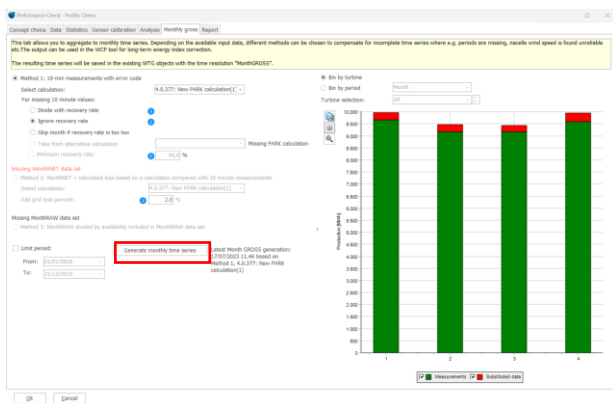


Click "Generate monthly time series", which will make monthly 100% availability production time series.

Before 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.

Option 1, "*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.

For option 2 "*do nothing, accept that month Gross might be too low, recommended for very high data availability > 99% and if the TR10 methodology has been applied*" 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 3, "*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 4, "*take from alternate calculation*", use a previous calculated PARK calculation.

Once the monthly Gross data has been generated, a pop up window ask if you want to continue to the long term correction set-up, under analysis tap.

## 5. LONG TERM CORRECTED POTENTIAL PRODUCTION WITH FUTURE LOSSES

If no wind index data set has previously been made in this windPRO project, its now possible to hit

 top right corner of the WCP tap window.

This opens up a traditional wind index menu know from meteo/MCP. Its recommended to use highest quality Meso-scale time series or similar high quality long term data sets, and select the height closes to hub height of the turbines under investigation.

Alternative the setup of the energy index time series:

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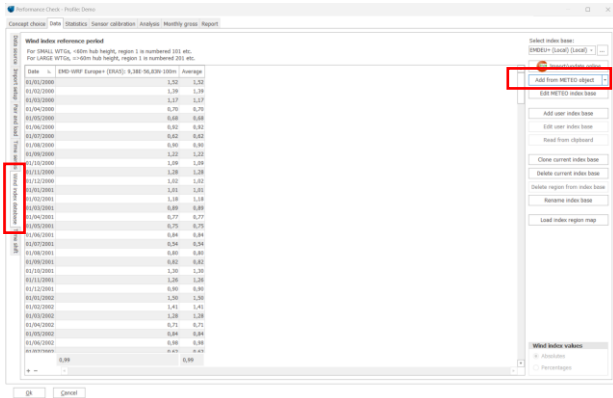


First, we need to convert the long-term wind speed time series into a monthly wind energy index.

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:
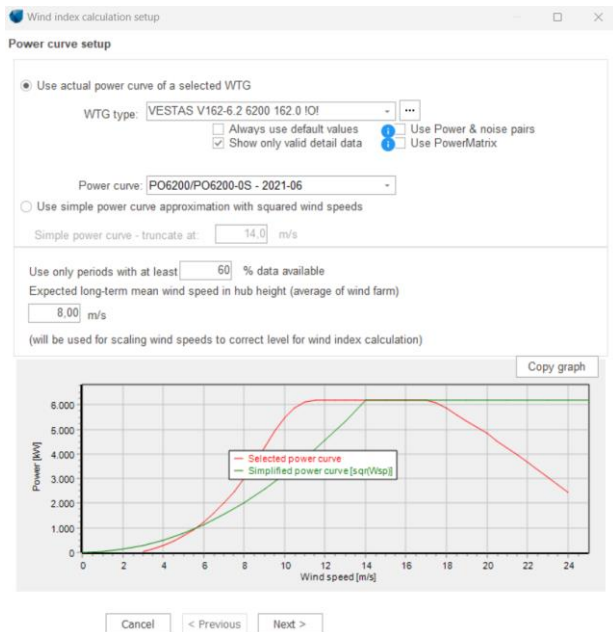


The long-term time series should be trimmed to full years. This is easily done by selecting "Use last" and set the number of years, to avoid a small seasonal bias:
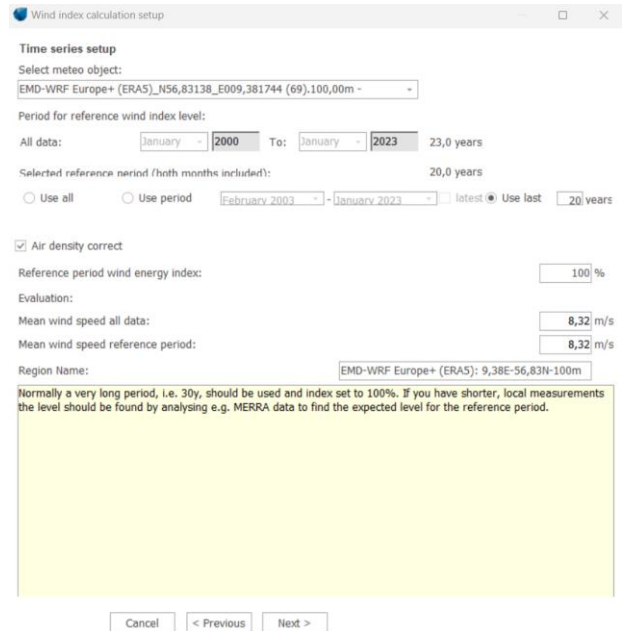


Several long-term data sets can be tested for trends etc.

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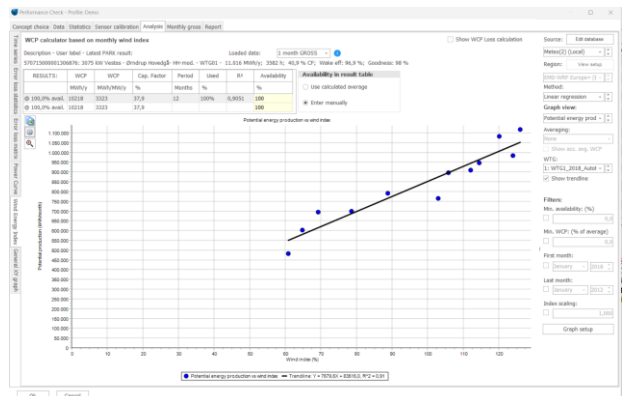


You can choose different sources of the energy index from the data sets loaded earlier.

**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:
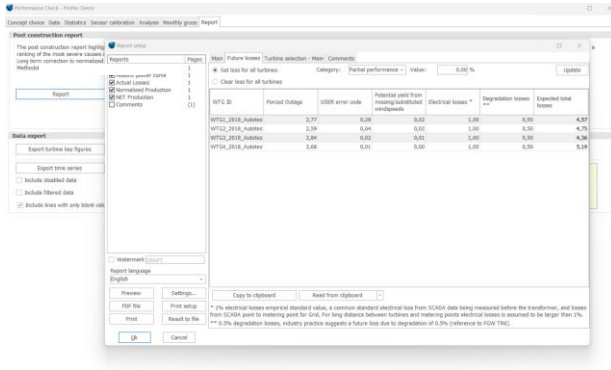
*NB. windPRO has two additional losses to be considered for future losses: as electrical losses are managed outside the scope of performance check a recommended 1% standard value is listed, and 0.5% for future degradation to be expected over the life time of the turbine. These values can also be changed 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).

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" found under the report tap.

Here its now also possible to export Measured and calculated data, from the session for detailed custom investigations.