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Air density normalisation using remote weather data for SCADA based performance analysis

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Abstract

It is undisputable that **air density has an influence on** wind turbine (WTG) **performance**. This needs to be accounted for when conducting performance analysis following the industry best practices.

Unfortunately, **in most SCADA analysis**, this normalisation is either partially performed, using only temperature, or **completely excluded**. It is typically due to the absence of one or more of the required signals, namely pressure, temperature, and humidity (PTH) in the studied dataset.

Interconnection of databases (DB) using Application Programming Interfaces (**API**) is now easier than it ever was, and a multitude of **web services** have emerged enabling direct and automated access to various **historical weather datasets**.

In this study, we explored the validity of using such weather data in the context of air density normalisation of WTG SCADA data.

Fundamentals: Air Density Normalisation

Following the recommendations from IEC 61400-12-1 [1], "the wind speed signal shall be normalized to a reference air density", generally being 1.225 kg/m³. "The air density shall be determined from measured air temperature, air pressure and relative humidity" according to:

$$\rho_{10min} = \frac{1}{T_{10min}}\left(\frac{B_{10min}}{R_0} - \Phi P_w\left(\frac{1}{R_0} - \frac{1}{R_w}\right)\right)$$

For modern WTGs, the normalisation is applied to the wind speed following:

$$V_n = V_{10min}\left(\frac{\rho_{10min}}{\rho_0}\right)^{1/3}$$

Where:
- ρ_{10min} is the derived 10 min air density
- T_{10min} is the 10 min air temperature
- B_{10min} is the corrected 10 min pressure
- Φ is the relative humidity
- V_n is the normalised wind speed
- V_{10min} is the 10 min wind speed
- ρ_0 is the reference air density
- R_0, R_w, P_w are constants [1]

However, **pressure and humidity are** commonly **missing** from the OEM SCADA 10min database. Furthermore, the available **air temperature**, **can be affected by** the sensor's **position on the nacelle**, sometimes over-estimating the outside temperature. These limitations often inhibit the full application of the normalisation method using SCADA data.

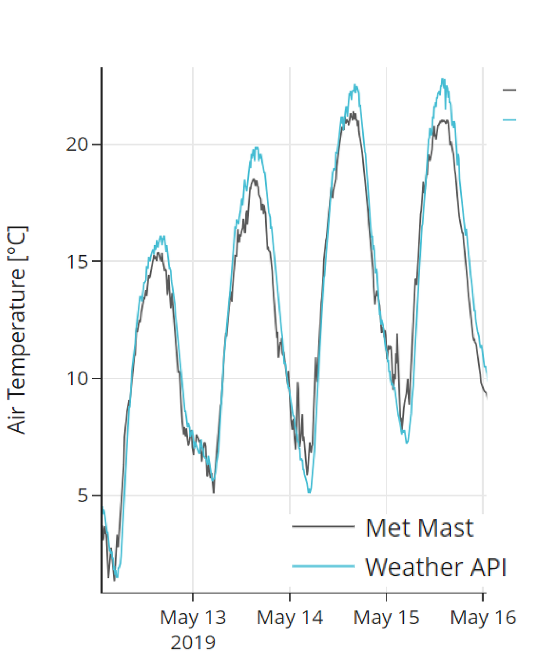
Enlarge SCADA data with Historical Weather APIs

Given a set of geo-coordinates, most weather-data providers can now deliver **worldwide sub-hourly historical dataset**, geographically interpolated from all nearby weather stations within a predefined radius.

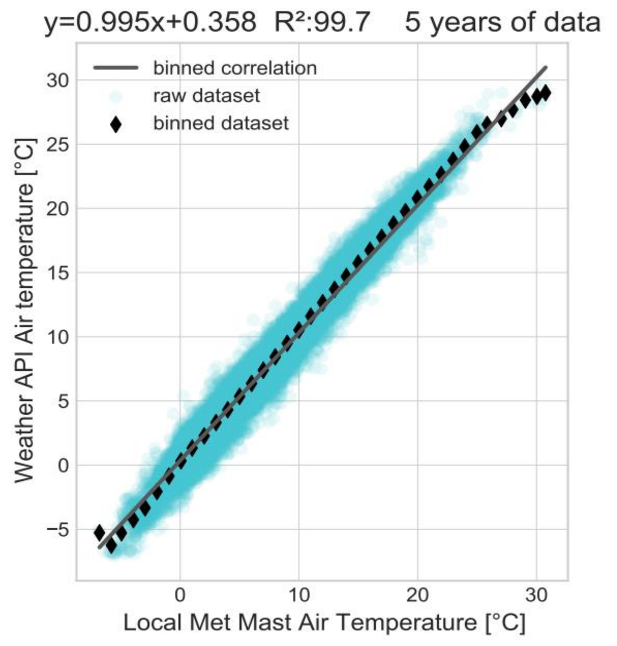
To **sample the quality** of these services, we conducted **several comparisons** with local observations. In the assessment below, we studied **5 years of data** from a local met mast under management against the same period extracted from the selected weather service interpolated at this met mast location.

The graphs below show the **correlations** obtained for temperature and humidity measurement from both datasets as well as a sample of **temporal comparison**.

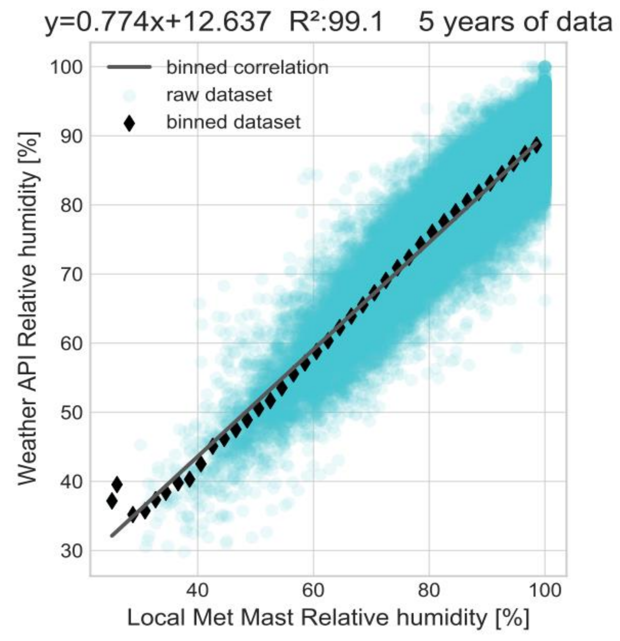
Sample Temporal comparison



Air Temperature correlation
y=0.995x+0.358 R²:99.7 5 years of data



Relative humidity correlation
y=0.774x+12.637 R²:99.1 5 years of data



Thanks to the very high temporal and spatial inertia of the signals needed for air density normalisation, we see a **good correlations** between local observations and the geographically interpolated data from the weather API. As seen in the first graph, **daily variation** at the tested location are **covered with sufficient accuracy**.

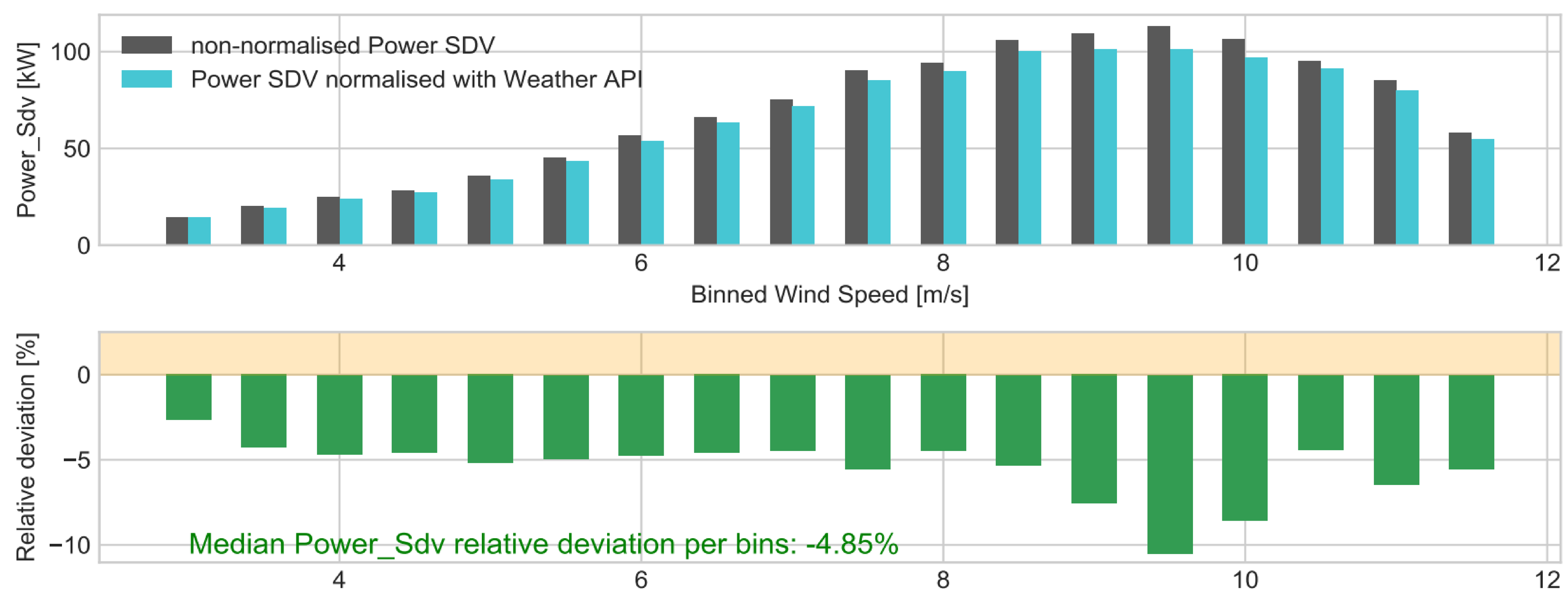
Assessing the effect on the Power Curve

The main expected effect of the normalisation on the dataset is obviously to correct wind speeds the a value equivalent to the reference air density, ρ_0. Since met masts are not available for all WTGs in our portfolio, we cannot automatically check the quality of weather data for each location.

However, an **additional benefit** of the normalisation is also the **reduction of the scatter** of the power curve (PC) when observed across a period where air density had varied. In our case, this **is an effective method to check** whether the process had a positive impact. If that scatter remains the same or increases, it implies that the method had either no effect or a negative one on the dataset. On the other hand, any significant **reduction on the scatter would indicate that the normalisation reduces uncertainty.**

The graphs below compares the standards deviation of the power signal (Power_Sdv) binned using the raw wind speed and the normalized wind speed, i.e. using the Weather API data for one of the WTG in the portfolio.

Comparison of Powed Standard deviation (_Sdv) from PC bins - data:2020_WTG_X



When analysing the PCs over a year, the Power_Sdv is slightly but consistently reduced (-4.85% in the analysis above). When **deploying that metric on** whole **portfolio**, we found an **average reduction** of the binned Power_Sdv of **about -4%.**

Cost and Requirements

The cost of most weather web service **can be considered negligeable** for recurring large-scale fleet analysis. Additional **computational power** for the API requests, data correction, resynchronization and filtering and its additional cost **can also be considered almost negligeable**, if implemented properly.

The sea-level pressure provided by the API should be corrected to hub height. To do so we used the hypsometric equation in combination with the WTG altitude and hub height. The altitude of a WTG, if unknown, can be retrieved automatically using the SRTM database. Therefore, **the only input required** for the implementation of the process **are the coordinates** of the WTG **and** its **hub height**.

Conclusions

- Although the use of a local and controlled PTH sensor is industry standards, the **use of remote weather data is preferable to the current status-quo**, i.e. when no PTH information are available, the normalisation is performed partially or ignored.
- Obtaining **weather data via APIs is a pragmatic solution** to enhances the quality of predominantly SCADA-based analysis. For the case of air density normalisation, it avoids falsely diagnosed under-performance or perceived seasonal effects which in fact may originate from air density variations.
- Given the results of this pragmatic approach, it was deemed **suitable for immediate deployment** and used for regular, automated analysis of the performance of over 3000 WTGs. The **adoption of this method enables** asset managers, often bound to SCADA datasets, to refer to **more accurate power curves** which comply more closely with industry best practices.

References

1. *Electrotechnical Commission (IEC). Power Performance Measurements of Electricity Producing Wind Turbines; IEC 61400-12-1 Ed. 2; International Electrotechnical Commission: Geneva, Switzerland, 2017*
2. *Electrotechnical Commission (IEC). Power performance of electricity-producing wind turbines based on nacelle anemometry; IEC 61400-12-2; International Electrotechnical Commission: Geneva, Switzerland, 2013*

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