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A novel method for obtaining a wind turbine performance curve

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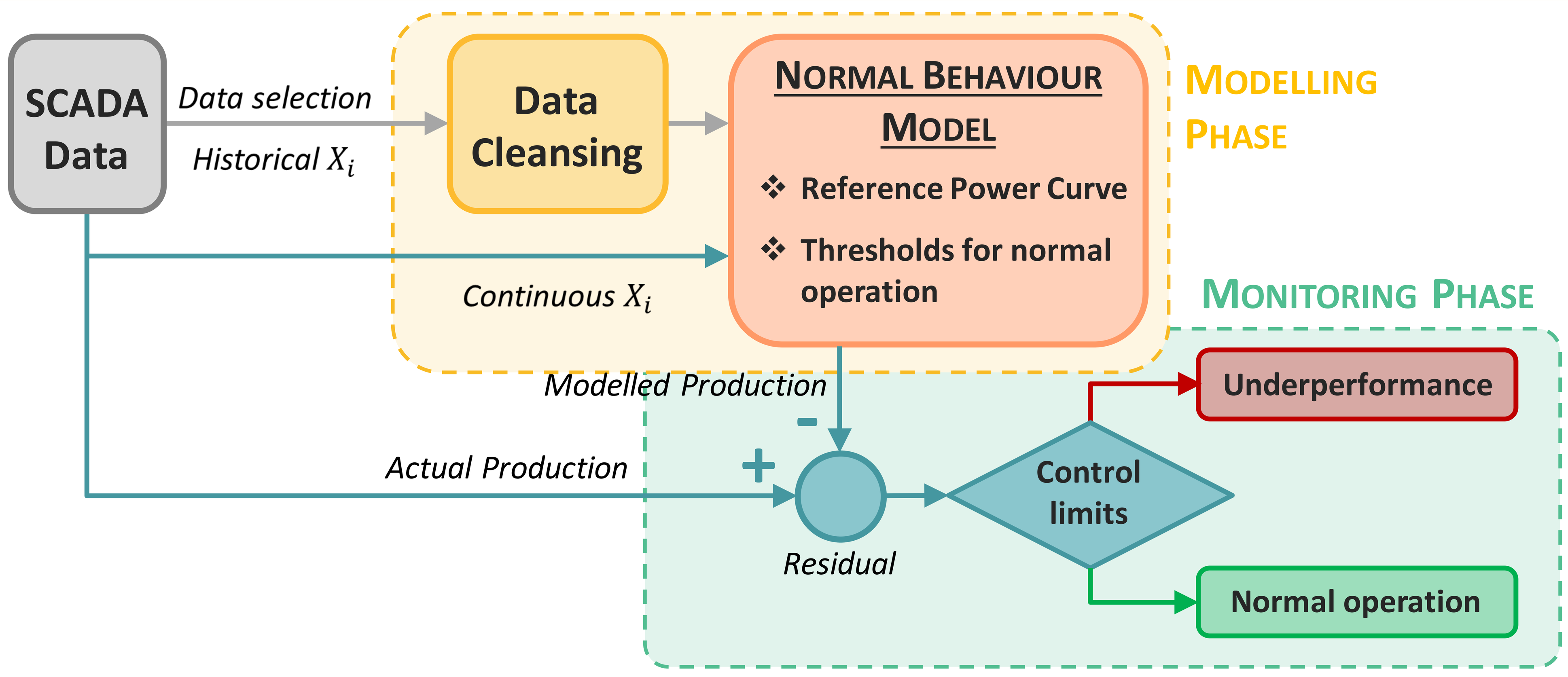
Abstract

- This study presents a novel approach to producing a **Normal Behaviour Model** (NBM) for tracking the performance of a wind turbine (WT). **High-frequency SCADA data** from a small wind farm is used to develop and test the proposed methodology.
- Unsupervised **machine learning techniques** are used to detect outliers, that must be excluded for a clear depiction of WT normal behaviour. From this, a **reference performance curve** and control limits allow to **monitor the WT performance**.

Methodology



- **Data Selection:** High impact of input variables and time resolution on NBM accuracy [1]. Dynamic effects go unnoticed when using 10-min SCADA data.
- **Data Cleansing:** Outliers need to be filtered out for a clear depiction of WT faultless conditions. Classic manual filtering is very time-consuming.
- **Modelling Phase:** Power curve modelling has been vastly addressed in the literature [2]. However, many parameters affect the relation between wind speed and power; it is still difficult to model accurately.
- **Monitoring Phase:** Residuals are usually monitored by the comparison with thresholds [3] or control charts [4]. The effectiveness of underperformance detection is rarely discussed as well as the smallest shift detectable.

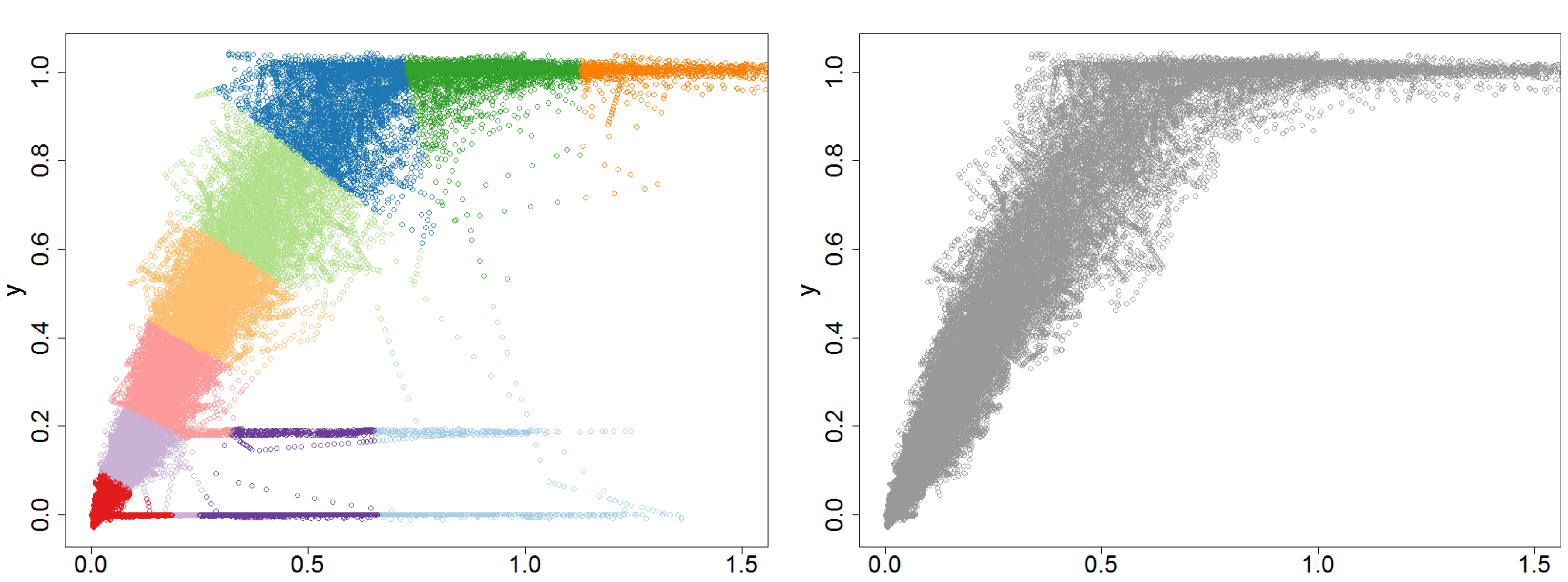
Approach

Data Selection

- Nacelle **wind speed** (v), **ambient temperature** (T), **wind direction**.
- Wind direction used to produce separate models for different sectors.
- $T(t)$ translated into air density ($\rho(t)$) at hub height [5].
- **High-frequency (0.1 Hz) SCADA**.

Data Cleansing

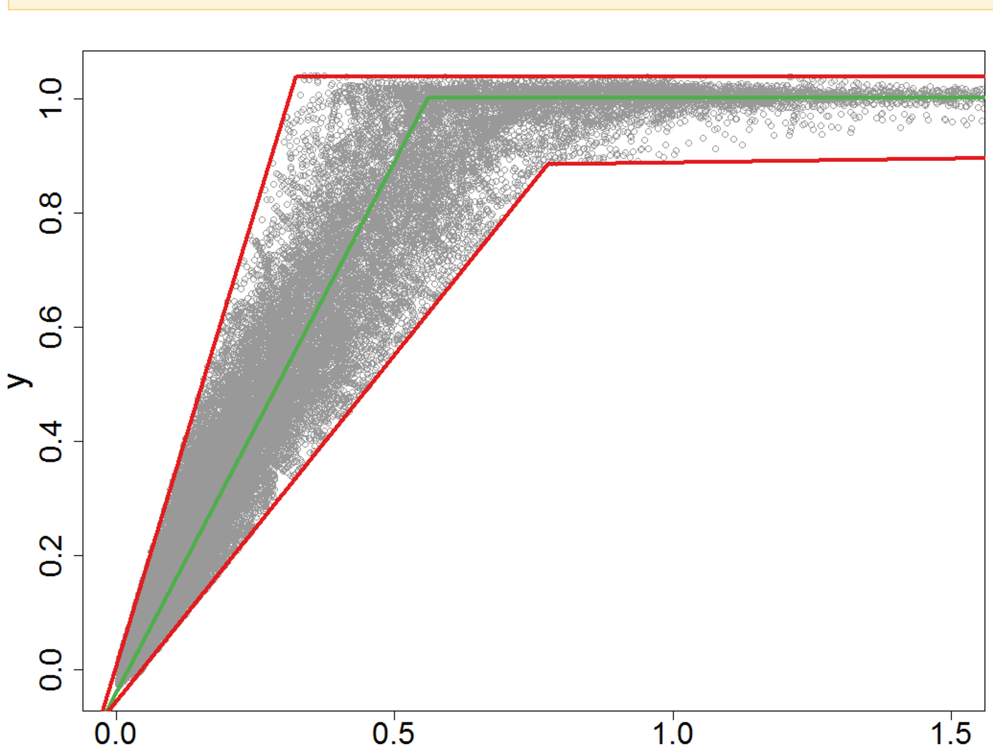
- Partition of the curve into ***k*** clusters, based on the ***k-means* clustering** algorithm [6].
- Outlier removed based on the **Mahalanobis distance** (MD) per cluster. The MD is the distance between an observation and the centroid of the multidimensional cluster [7].



Normal Behaviour Model

- Dataset for wind month M_1 split into training and testing (80/20).
- Iterative algorithm based on linear regression between x and y:

$$y = f(x) \text{ where } y = \frac{P(t)}{P_R} \text{ and } x = \frac{\rho(t)}{\rho_0}\left(\frac{v(t)}{v_R}\right)^3$$



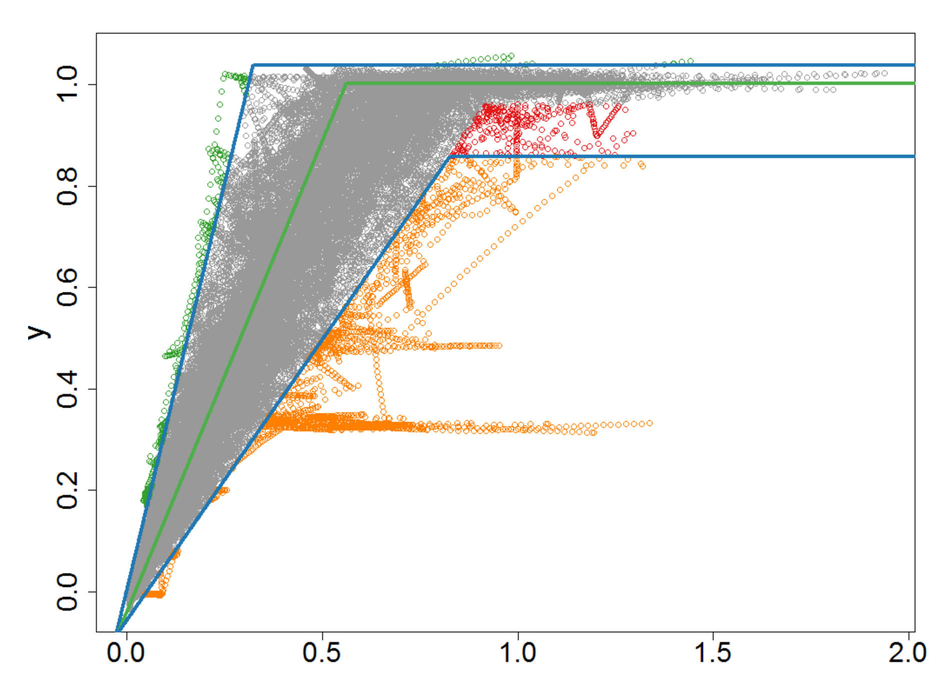
	Month M_1
Number of observations	12 483
R^2	0.91
MAE	0.11
RMSE	0.16

Table 1. Accuracy evaluation for the test dataset

Results

Monitoring phase

- Methodology applied to a spring month M_2 and an autumn month M_3.
- Accuracy evaluation and effectiveness of underperformance detection.



- High accuracy (R_2 and *MAE*) regardless the different seasonal climate conditions.
- High *RMSE* due to high variability of high-frequency data.
- Low rate of False Negatives (*FN*).
- Undeperformance detected prior to a gearbox failure in month M_2.

	Number of observations	R_2	MAE	RMSE	Outliers (%)	FN Ratio (%)	FP Ratio (%)
Month M_2	62 722	0.89	0.15	0.28	2.58	0.45	0.47
Month M_3	98 716	0.91	0.11	0.35	1.59	0.19	0.35

Table 2. Accuracy and effectiveness for the validation datasets

Conclusions and Outlook

- Outliers successfully detected during the filtering phase. The method allows to easily integrate environmental factors affecting WT performance and facilitates the curve modelling process, as the relation is supposed to be linear.
- High-frequency SCADA data offers a better understanding of WT behaviour.
- Results suggest that the methodology is valid for tracking the WT performance and could be exploited for optimising the O&M phase.
- Further work will compare the proposed method with other existing techniques. Real WT failure data will be considered to test the sensibility of each technique.

References

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