

# Visualisation and automation data to decisions

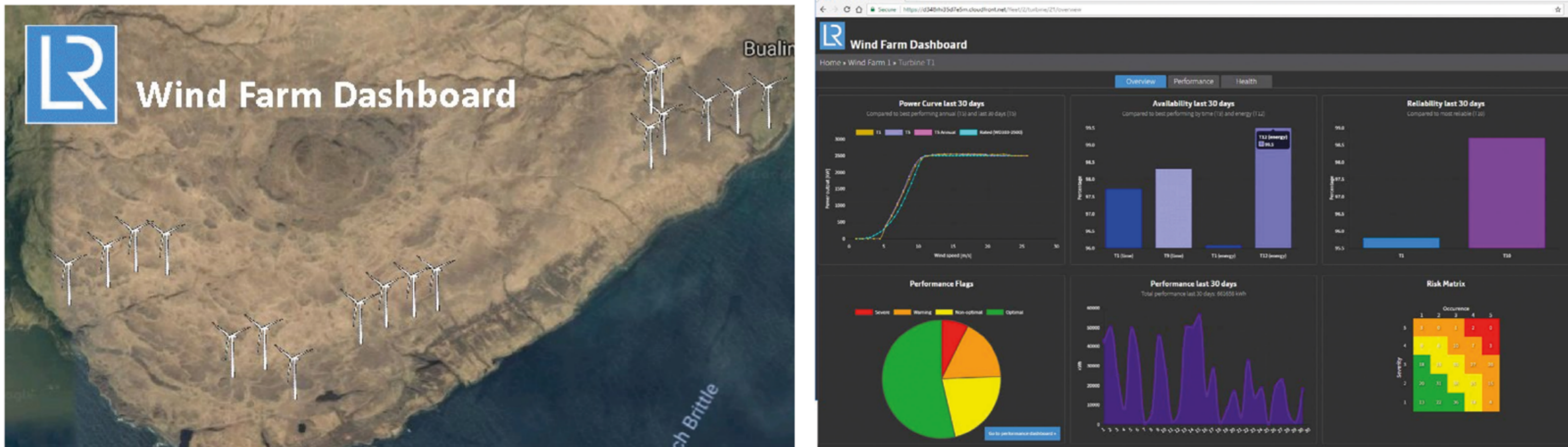
Matthew Zhang, Philip Knaute, Priyanka Raina & Mark Spring  
Lloyd's Register



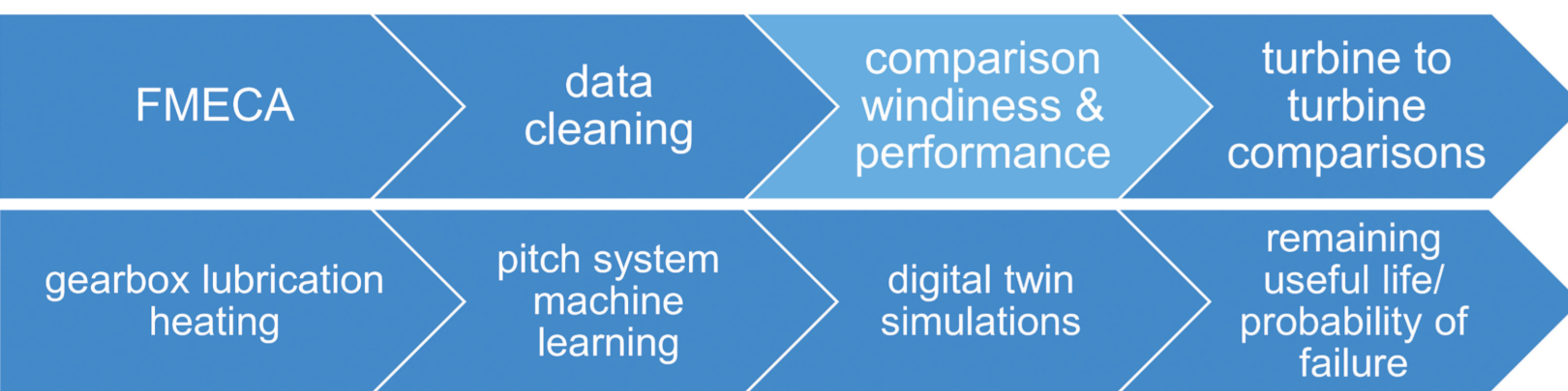
PO.004

## Overview of contents and objectives

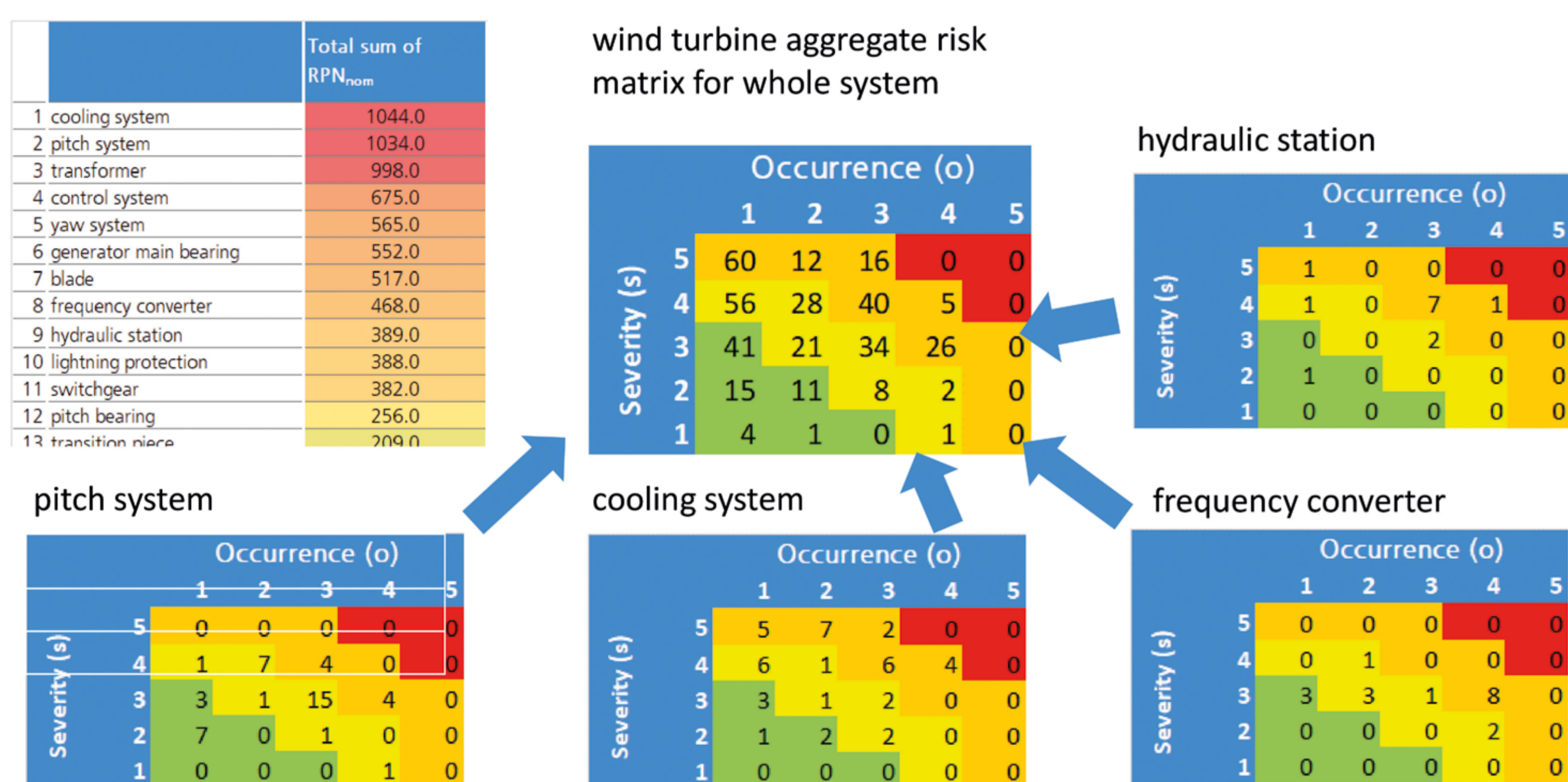
Through working with wind farm owners it has become clear that improvements in performance are hampered by limited access to comprehensive turbine operational and contextual information. New software tools developed have enabled both an increase in revenue from electricity generated and a reduction in operational costs, due for instance to on-site interventions. We have succeeded in automating the display of key relationships and combinations of data. By using domain knowledge from design engineers, technicians, business managers and specialists with relevant experience from outside the wind sector, we have trained the data science tools so as to automate the process of diagnosis and simulation of future operation.



The functionality described is being developed as new modules within the LR wind farm platform, based on 12 months' data at 5s resolution from an operating wind farm

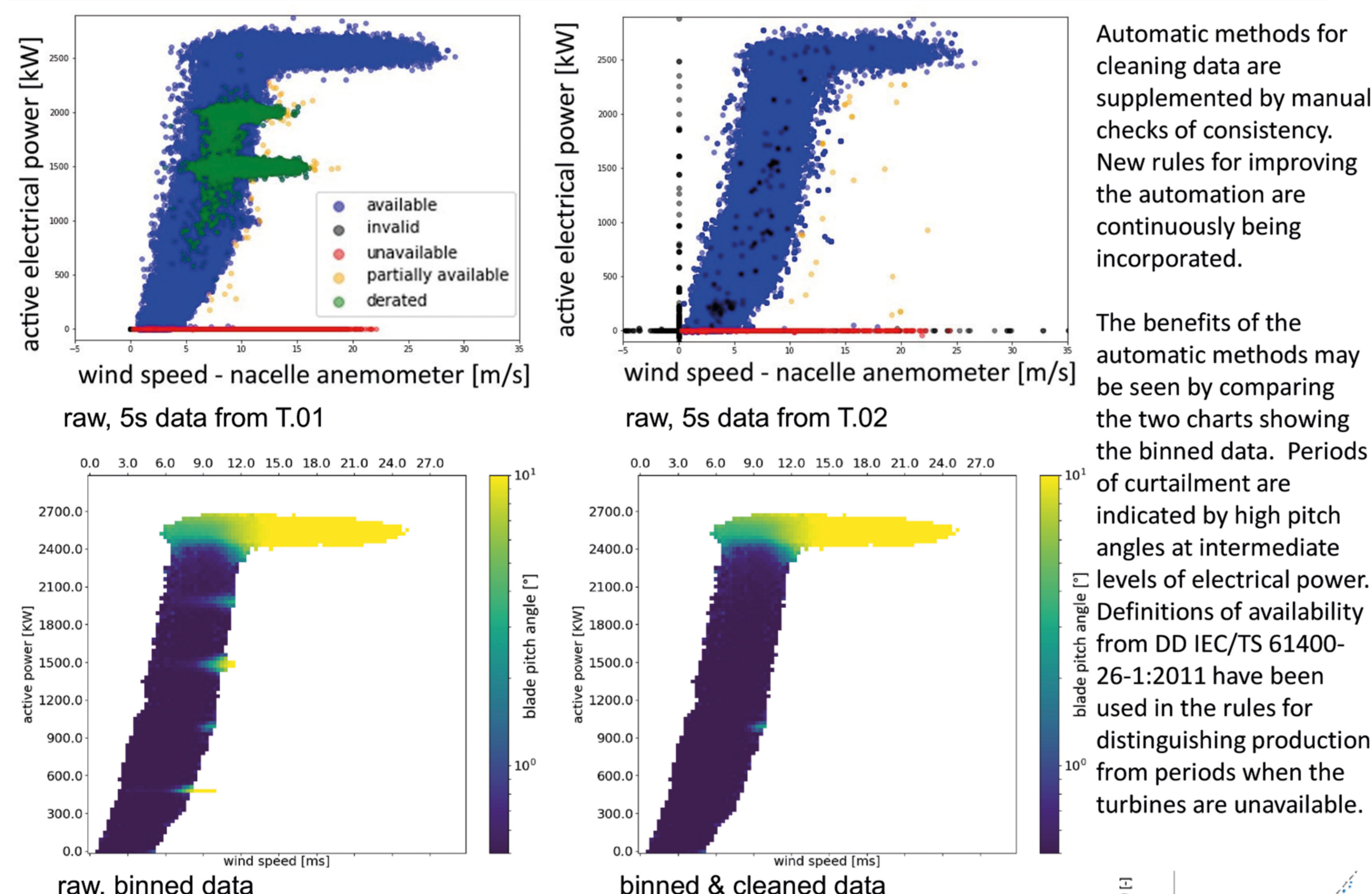


## Risk matrix for each mode of failure



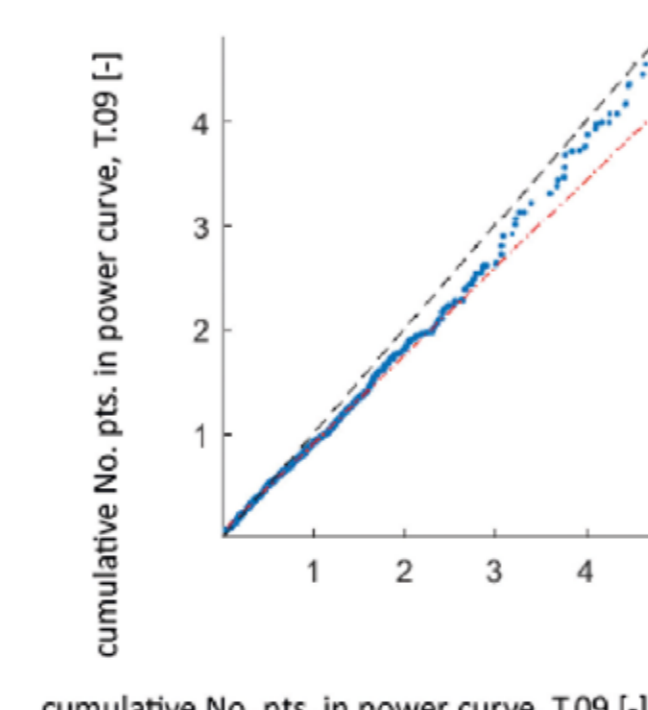
Risk matrices were derived from FMECA, in accordance with BS EN 60812:2006, undertaken prior to collection of operational data – severity and occurrence were enumerated for each failure mode during workshops in which a number of experienced technicians and operations managers participated.

## Data cleaning, categorizing data using power curves

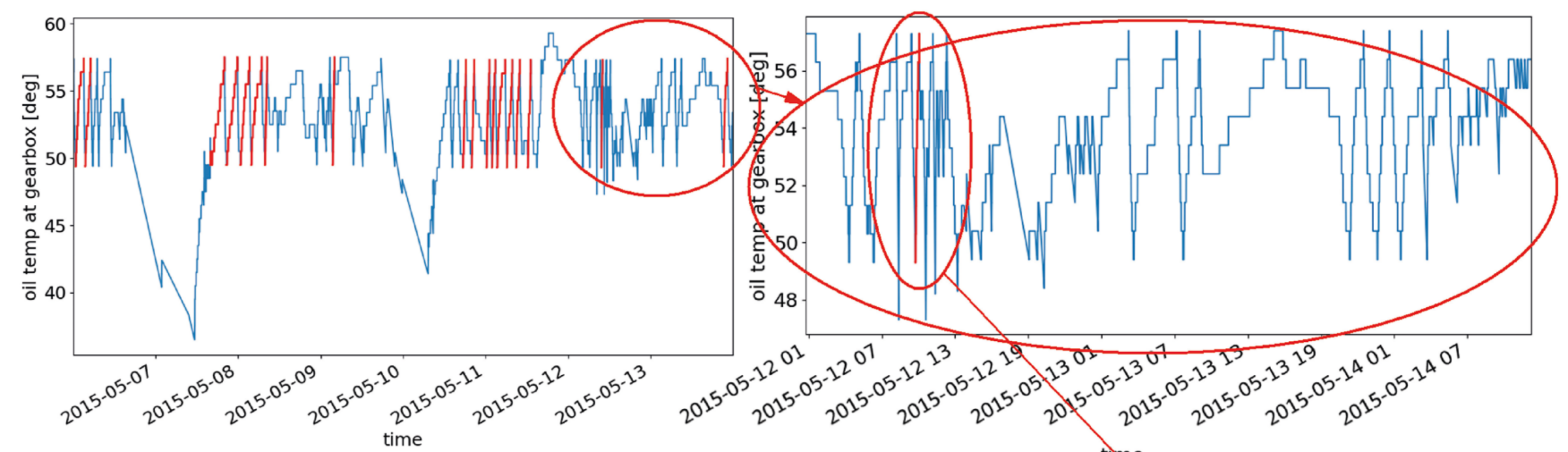


## Comparison – power curve comparisons

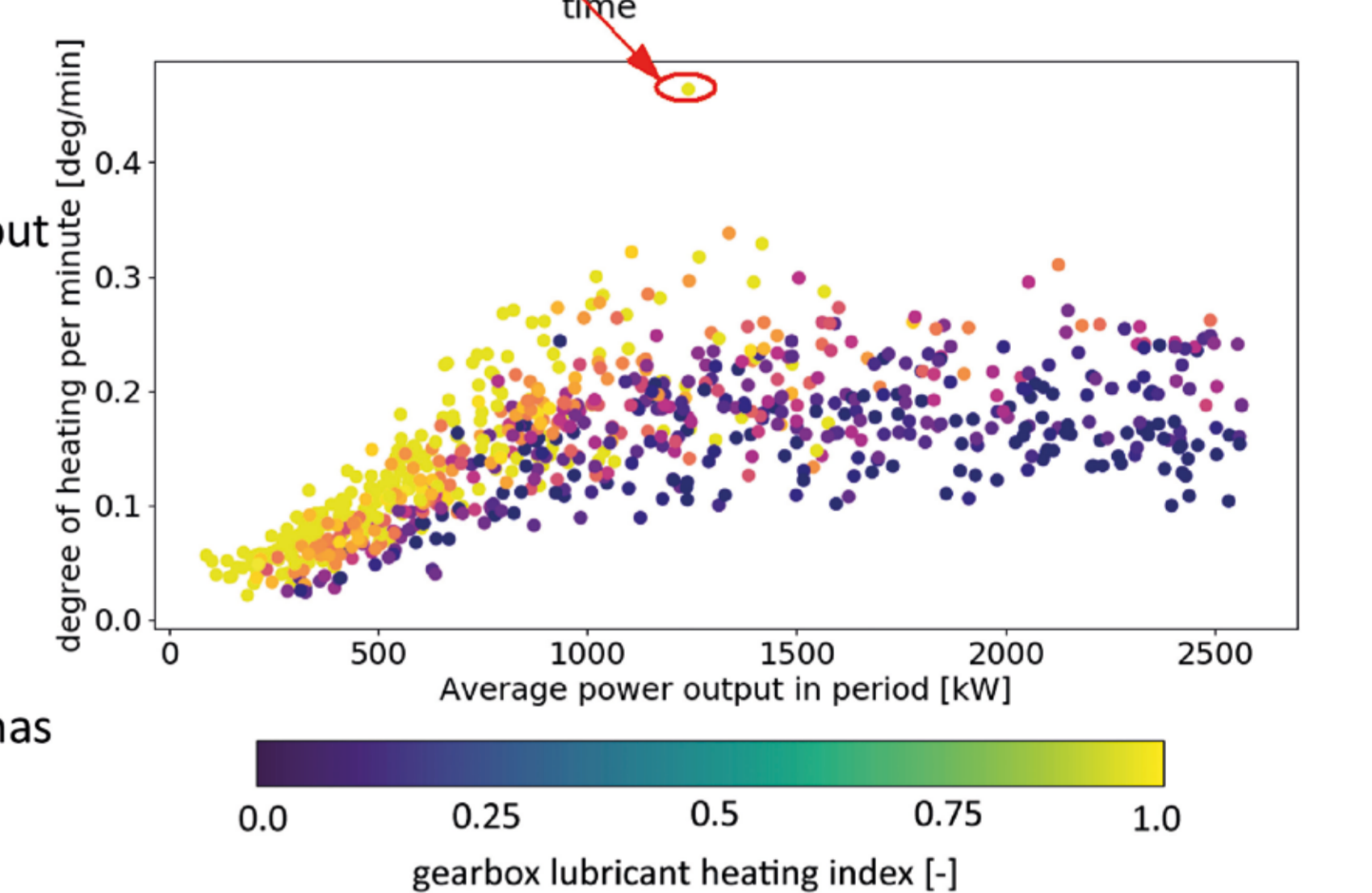
By plotting the cumulative number of points from one power curve against another, comparisons between the behaviour of the two machines may be used to indicate quickly which has been under-producing. The process of identifying periods of anomalous or degraded performance may be automated more reliably.



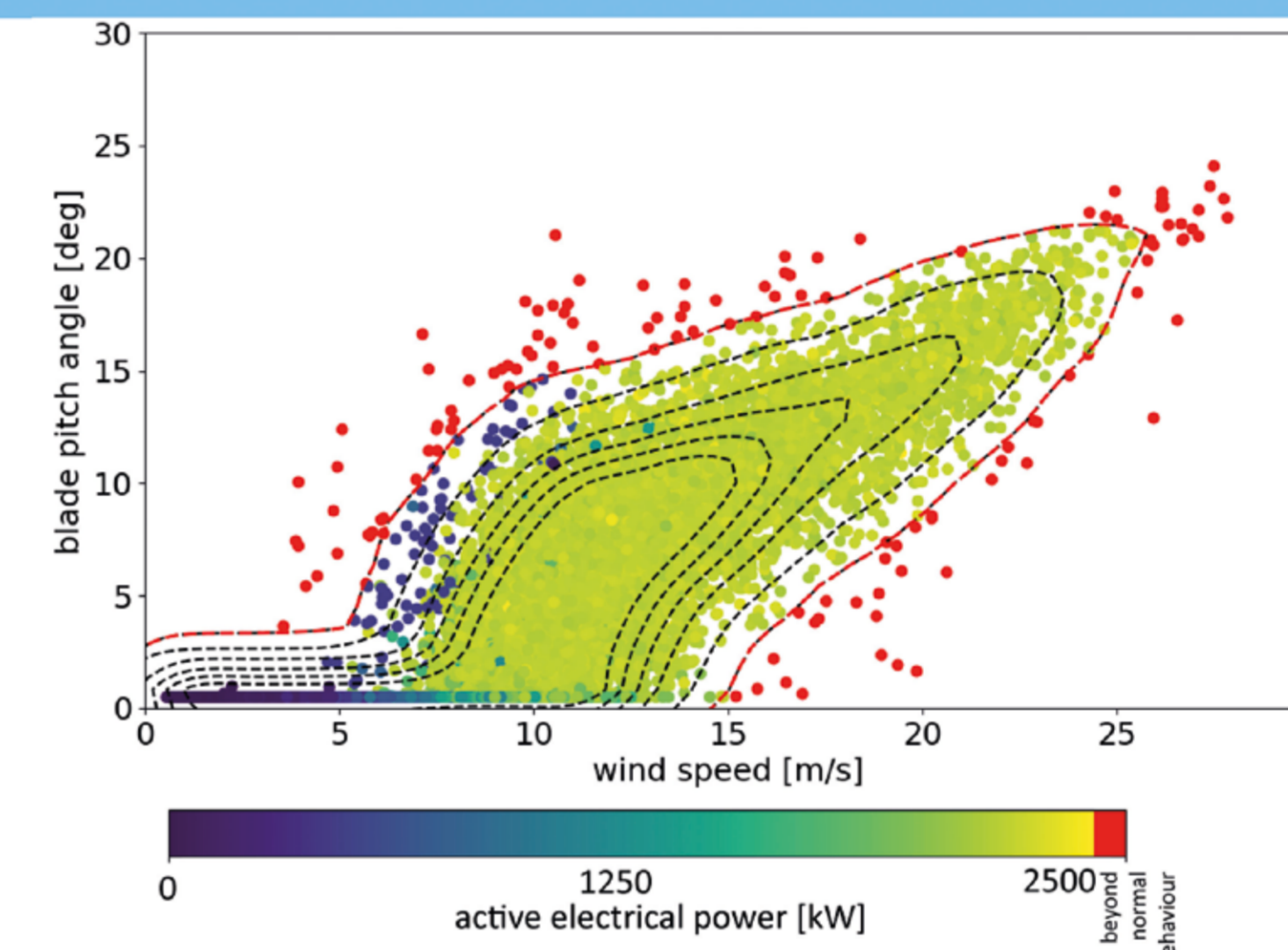
## Gearbox heating and cooling



The because of the way the cooling system is switched on intermittently in response to elevated oil temperatures, the heat generated by the gearbox has been enumerated in a novel way, relying not simply on the temperature of the oil but on the rate of heating of the oil. The parts of the time series which correspond to heating of the lubricant have been detected automatically and from each one an approximate gradient calculated with respect to time,  $dT/dt$ . This has enabled an anomalous period of time to be detected easily (see right hand chart). This point warrants further investigation. If it turns out that extreme values such as this one become more frequent over time, it is likely that there has been permanent deterioration of the gearbox mechanical components such as gear teeth, bearing rollers or bearing races.

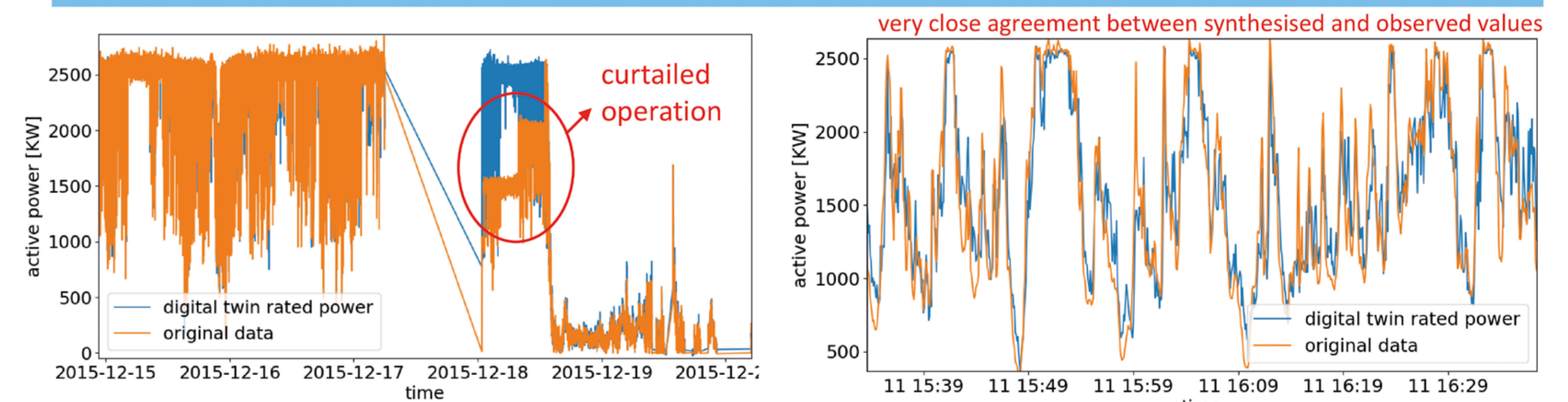


## Pitch system anomalies

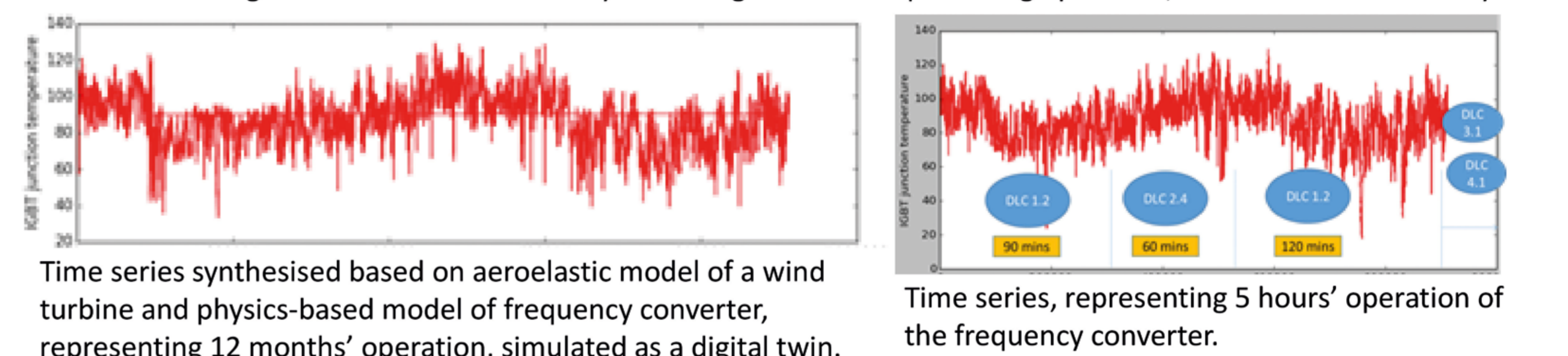


Through implementation of Support Vector Machine (SVM), a more advanced method of machine learning, the points which are far from normal, healthy behaviour of the turbine may be identified, shown in red. The contours represent the distance of the points from the hyperplane in multidimensional space. Electrical power has been used for the colour of the points categorised as normal. This gives a "fingerprint" of healthy operation of the pitch system for this type of turbine. Deviations can rapidly be detected visually or automatically, as indicated by the points outside the threshold contour. These points may indicate anomalous behaviour of the pitch system and warrant further investigation.

## Synthetic results using machine learning



Statistical multivariate regression has been used to derive a relationship between various SCADA signals and the electrical power, as a digital twin. By comparison between the measured power and the synthetic power time series the period of curtailment during December 2015 can clearly be distinguished from preceding operation, without manual scrutiny.



## Conclusions

- cleaning of data sets, classification of points, categorisation of periods of operation may be further automated, saving time, improving accuracy and repeatability.
- these methods need further training, taking on board additional guidance from experienced maintenance technicians
- refinement of these methods will be further improved via adjustment and tuning of thresholds, definitions and model parameters throughout the early period after application to an operating wind farm
- the benefits of applying these methods may be quantified during a pilot project, taking into account a model of the costs associated with all modes of failure

## References

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