

Modelling Wind Turbine Power Curves based on Frank's copula

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ABSTRACT

In the study of wind turbines, one of the most relevant and useful indicators is the power curve. It has been shown to be of paramount importance in evaluating turbine performance and therefore reducing operation and maintenance (O&M) costs. Various techniques can be applied to model and obtain the shape of this curve, which relates the electrical power generated by a turbine to the wind speed. Statistical copulas are used in this paper, whose potential lies in its ability to capture the complex dependency between the variables involved. In particular, the Frank copula is applied to obtain a probabilistic model of the power curve of a wind turbine. This model is compared with the Gaussian Mixture Model. As a result of this comparison, it is observed that the Frank copula model fits the power curve of the wind turbine with greater precision and reliability, which would allow its use for prediction and fault detection.

METHODOLOGY

- Probabilistic model of the power curve will be used to estimate expected value of the generated power, as well as its associated uncertainty.
- Statistical copulas help us to separate the marginal distributions and give information about how they are related to each other.
- Probability density function $f(x_1, x_2)$ for our bivariate case can be decomposed according to expression:

$$f(x_1, x_2) = c(u_1, u_2) f_1(x_1) f_2(x_2)$$

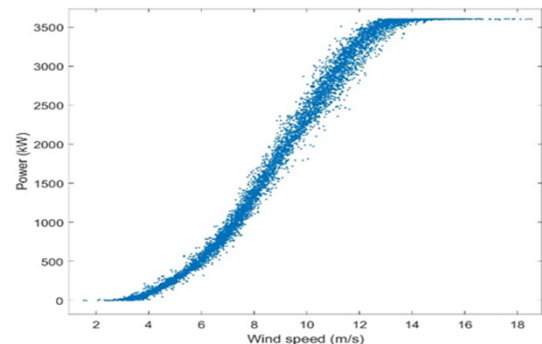
- In the case of power curve of a wind turbine, it presents a strong correlation in both extreme values of the distribution (both for high and low values). Therefore, a good choice for the copula function will be the Frank copula, a type of Archimedean copula:

$$c_{Frank}(u_1, u_2, \delta) = \frac{\delta \eta e^{-\delta(u_1+u_2)}}{[\eta - (1 - e^{-\delta u_1})(1 - e^{-\delta u_2})]^2}$$

- In order to compare the suitability of the proposed technique, it will be compared with one of the most widespread methods: the Gaussian mixture model (GMM).

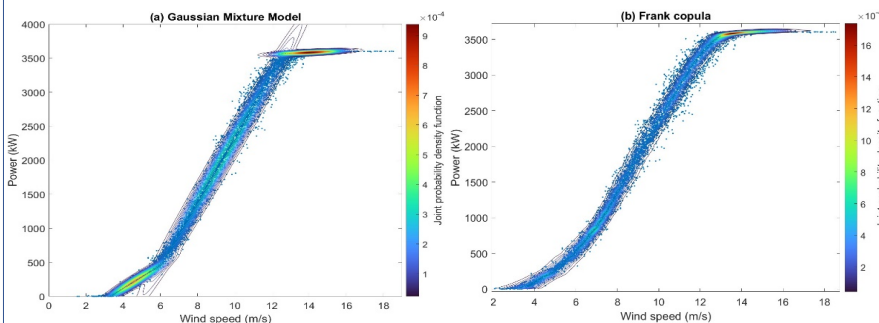
CASE OF STUDY

- Dataset consists of generated electrical power (kW) and wind speed (m/s) acquired through a SCADA system with an average acquisition time of 10 minutes
- Onshore wind turbine at the Yalova wind farm (Turkey)
- Blade pitch regulated Nordex N117. Diameter = 117m
- Rated power = 3,6 MW. Rated wind speed = 13 m/s
- Cut-in wind speed = 3 m/s. Cut-off wind speed = 25 m/s,
- Removal of outliers was carried out in preprocessing stage.



RESULTS

Probabilistic models obtained with GMM and Frank's copula. Joint probability density of power curve overlaid with the dataset is plotted.



Summary of the evaluation metrics

| | BIC | NRMSE |
|----------------|--------|-------|
| Frank's Copula | 125500 | 0.084 |
| GMM | 129880 | 0.093 |

CONCLUSIONS

- ✓ Frank's copula method fits the power curve better than the GMM.
- ✓ Quantitative improvement of the Frank's copula over the GMM is observed.
- ✓ Therefore, it is possible to apply statistical copulas to a faithfully modelling of a wind turbine power curve.
- ✓ As future work, this model could be applied to evaluate different types of turbine failures and loss of turbine's performance.