Redefinition of Power Curves: Electric vs. Kinetic Power

Erik Tüxen, Vineet Parkhe, Paul Lawson

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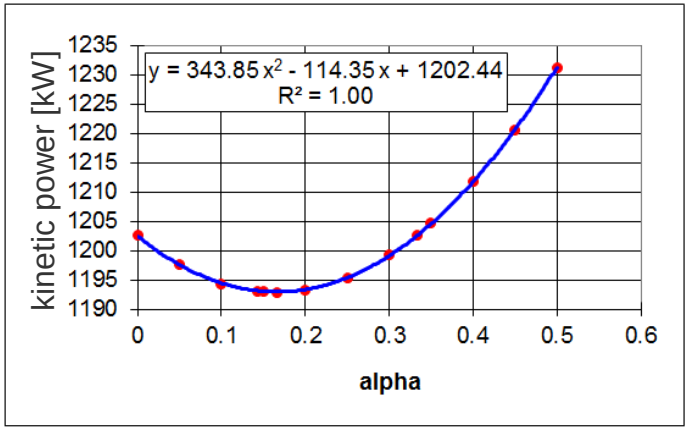
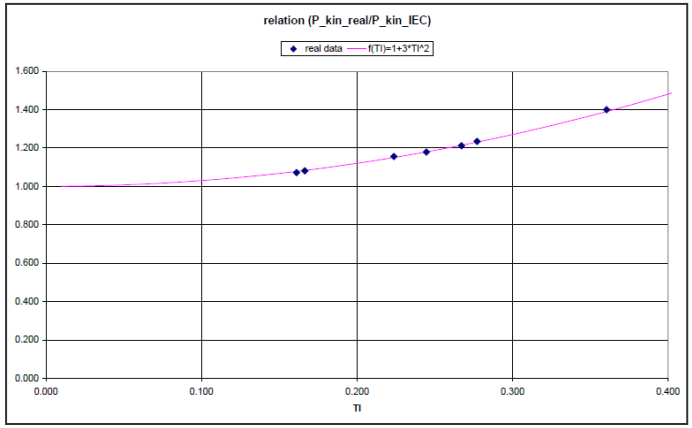
Starting point: What does a wind turbine do?

- Conversion of kinetic power of wind (into mechanical power) into electric power.
- Efficiency is output (electric power) divided by input (kinetic power). (In other words: Output depends on input and efficiency.)
- Input and efficiency are both affected by several parameters, additional to the 10 minute average wind speed at hub height.
- Knowledge and understanding about input and efficiency is the key to avoid expensive surprises, e.g. regarding energy yield or with respect to the results of a power performance verification test.

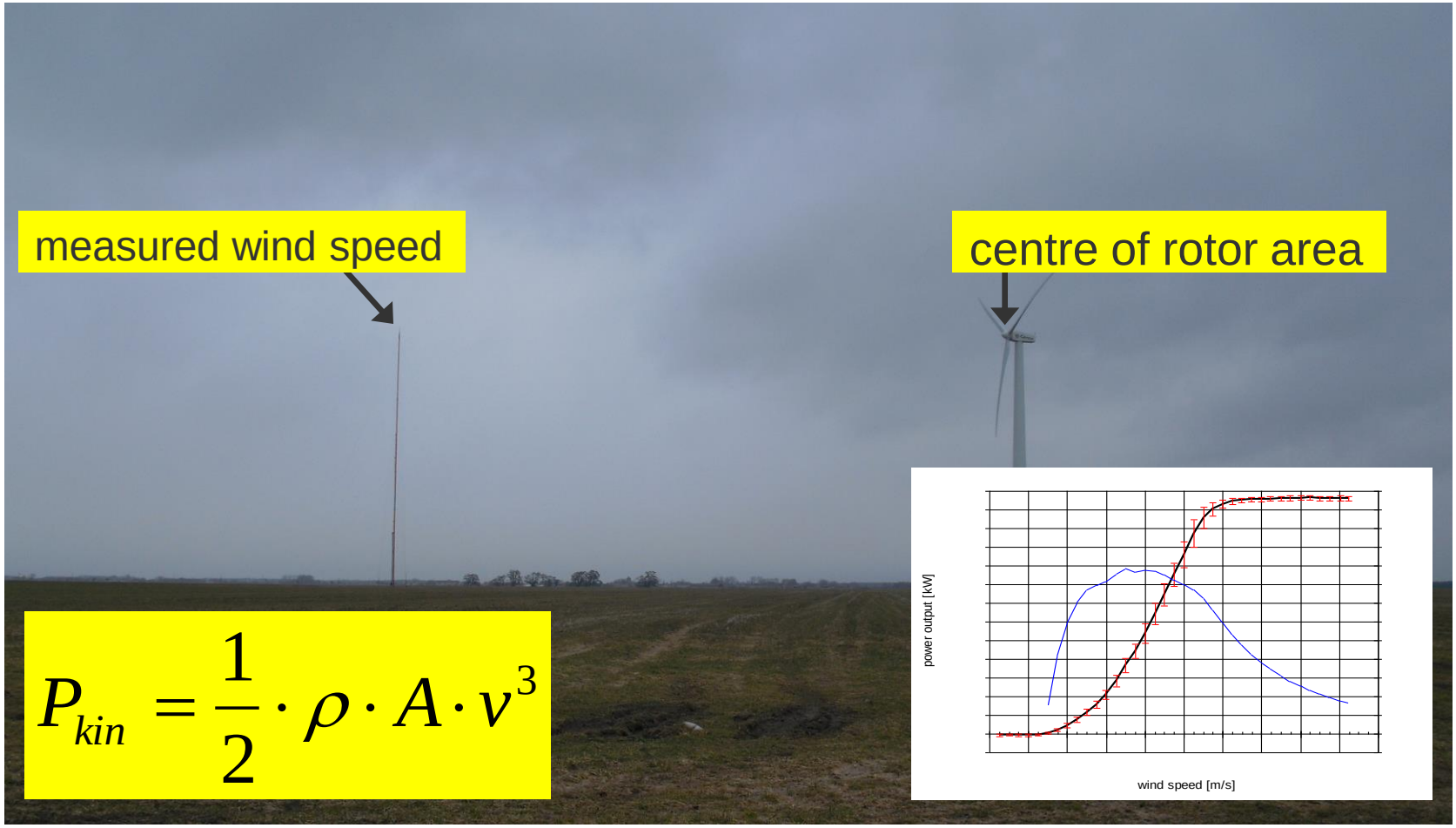
Shear and turbulence intensity (TI)

- Shear causes a non-ideal angle of flow (towards blade) during the rotation (e.g. at lower and/or upper tip height).
- IEC 61400-12-1 Ed. 1 (2005) does not consider the effect of shear on average kinetic power of a 10-minute period.
- TI causes a non-ideal angle of flow (towards blade) after every change of the wind speed until the pitch angle is adjusted to the new wind speed. The rate of this adjustment is subject to physical limitations.
- IEC 61400-12-1 Ed. 1 (2005) does not consider the effect of TI on average kinetic power of a 10-minute period.

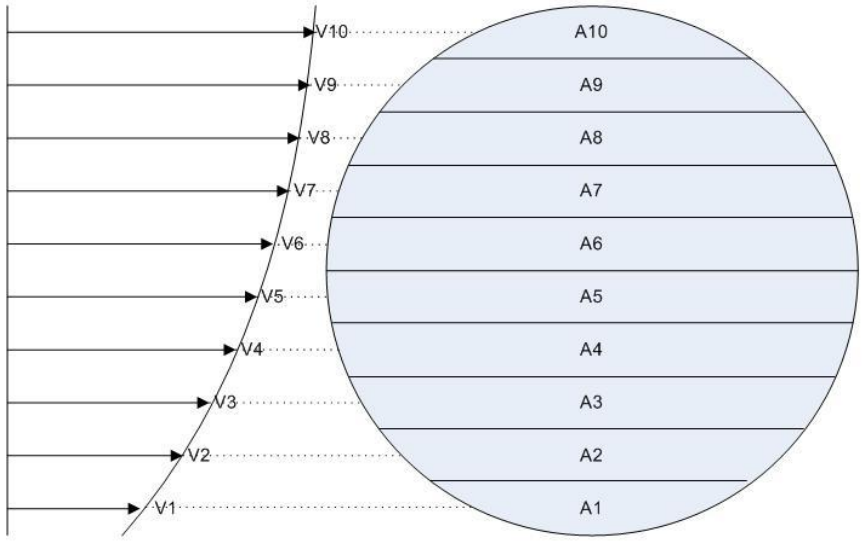


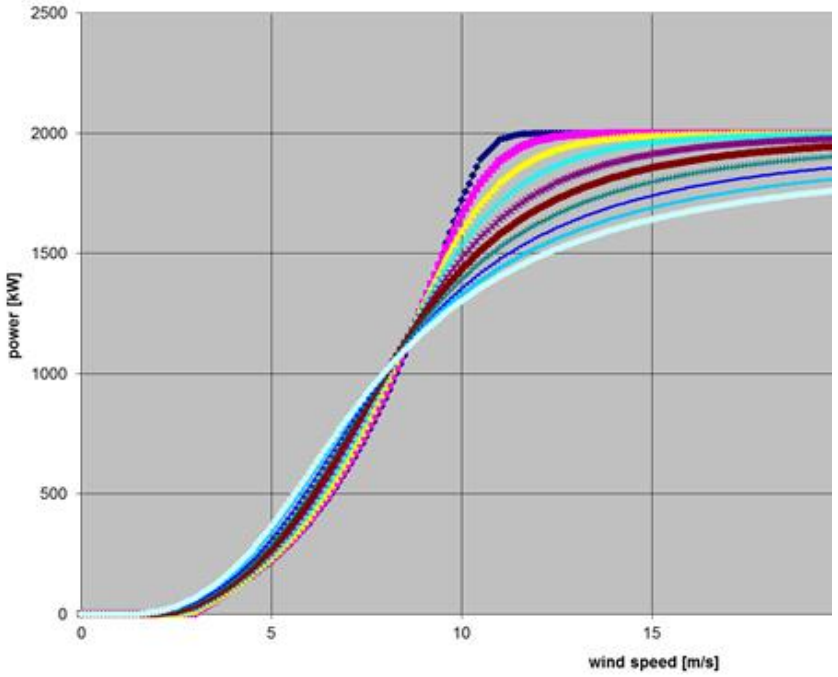


Reconsideration of approaches: Hub Height Power Curve



Reconsideration of approaches: Presently available suggestions





Rotor-equivalent wind speed (REWS) and TI renormalisation

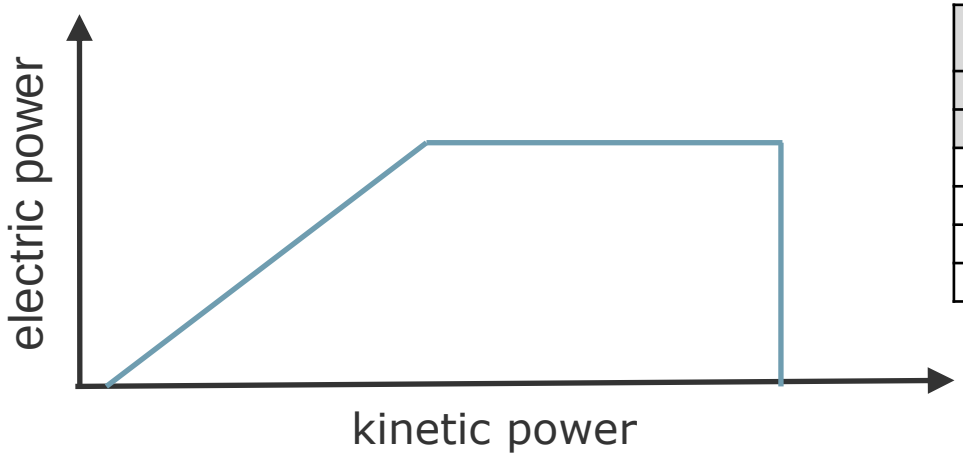
Are we on the right track?

- Rotor-equivalent wind speed (REWS) has gained a significant amount of support, but a certain degree of opposition has also been observed. This can similarly be said about the turbulence renormalisation method which is included as Annex M (informative) in the latest CD of IEC 61400-12-1 Ed. 2.
- Both methods are indirect. (Kinetic power, which is a central element in the theory, is still not shown in the power curve.)

→ Can we apply the useful ideas behind this in a simpler way?

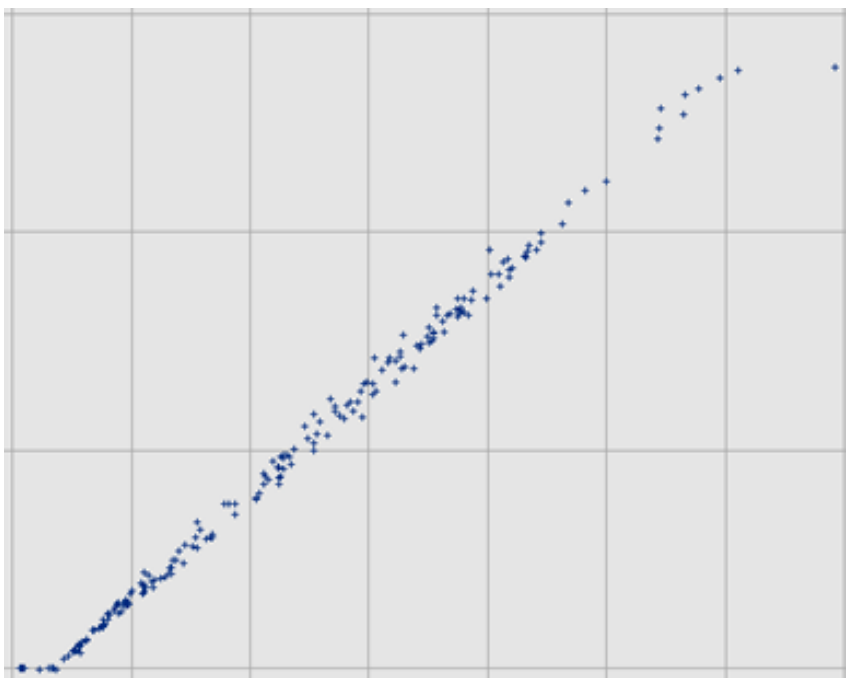
Proposal for a new approach

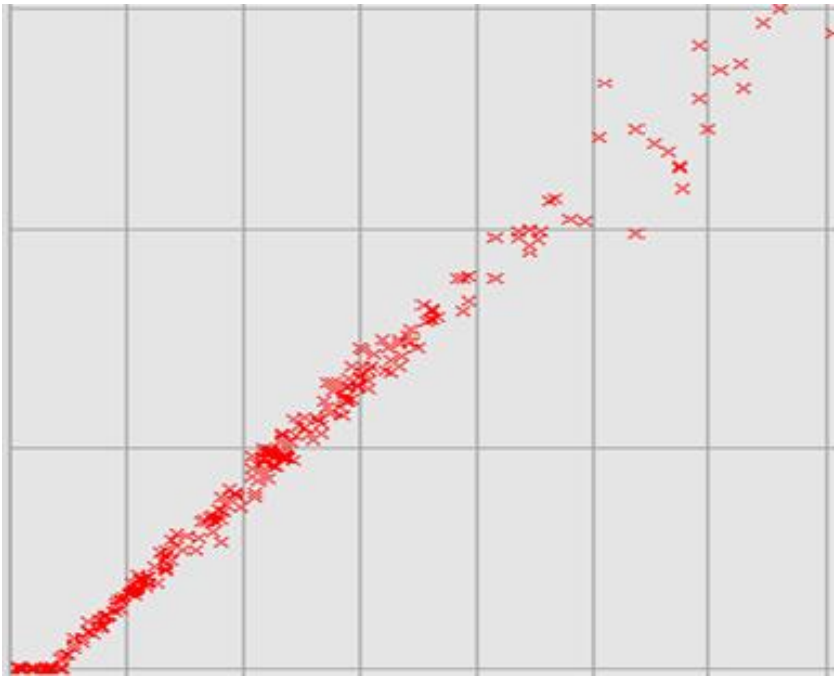
- Let us try to create a new kind of power curve:
  electric power vs. kinetic power (instead of applying various corrections to wind speed and/or electric power, in order to get artificial data which is supposedly more "representative" than the measured data).
- "High Resolution Kinetic Power" (in terms of space and time) can be measured nowadays, due to new types of remote sensing devices and other innovative technology. (Further improvement can be expected.)
- This new method does not mean that the principle of 10 minute averaging will have to be discontinued.



Bin	Kinetic Power	Kinetic Power	No. of	Kinetic Power	Electric Power	Cp
Number	From	To	Datasets	Mean	Mean	Mean
[-]	[kW]	[kW]	[-]	[kW]	[kW]	[-]
1						
2						
3						
4						

Case 1: PPM with ground-based lidar

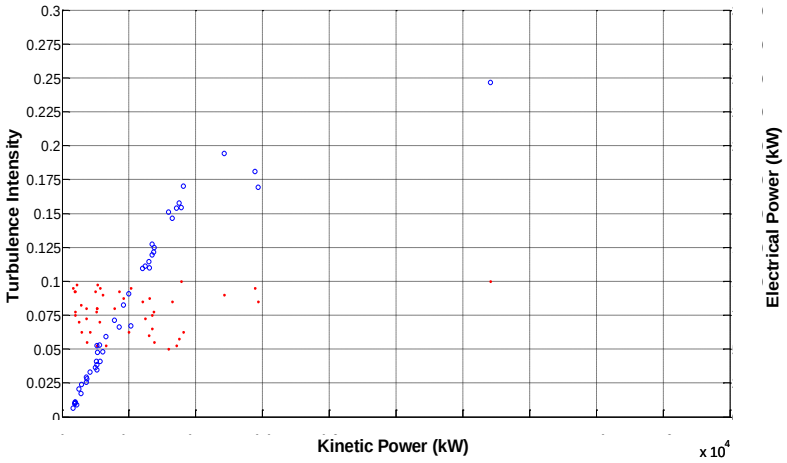


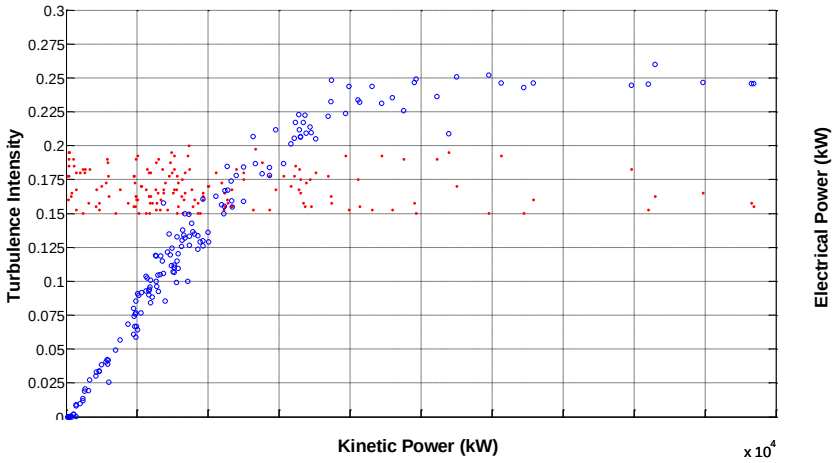


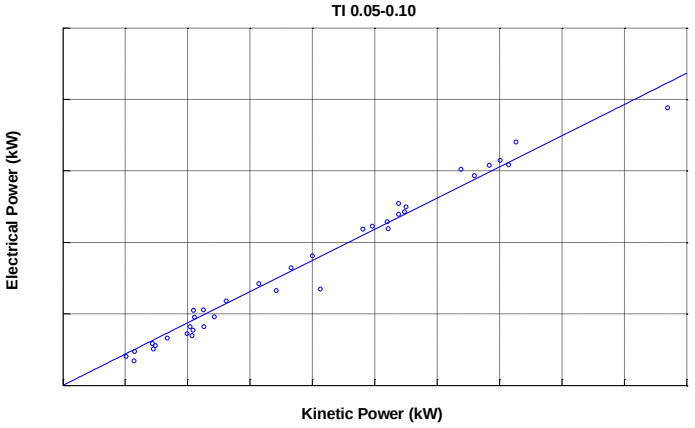
Electric power (y-axis) vs. kinetic power (x-axis)

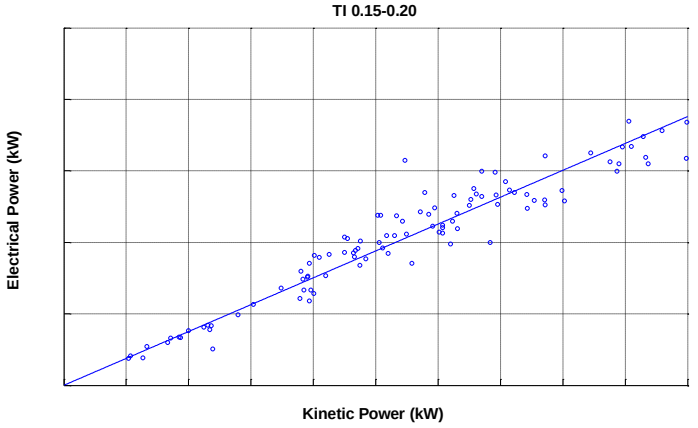
(data filtered on valid sector and turbine availability, then split into subsets for TI ranges)

Case 2: PPM with 3D nacelle-based lidar (Slide 1 of 2)

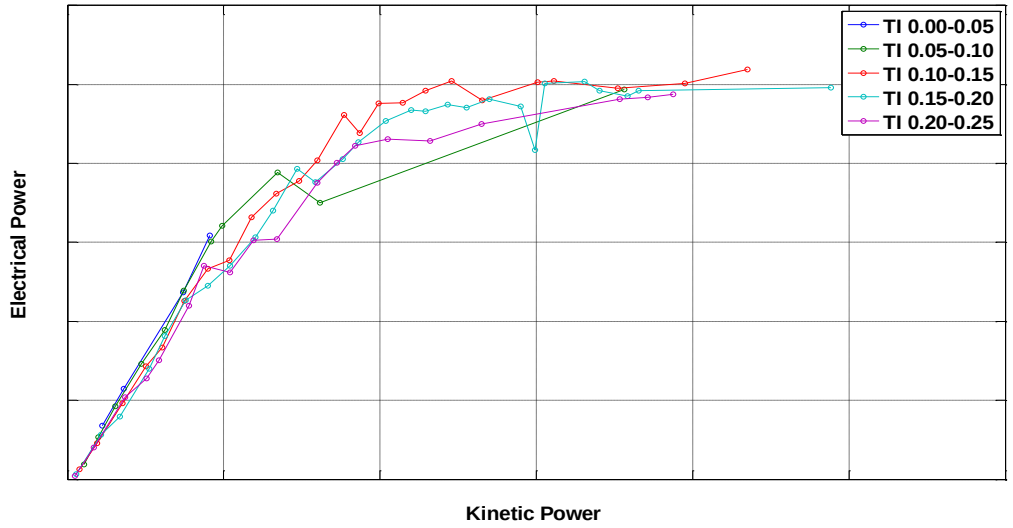


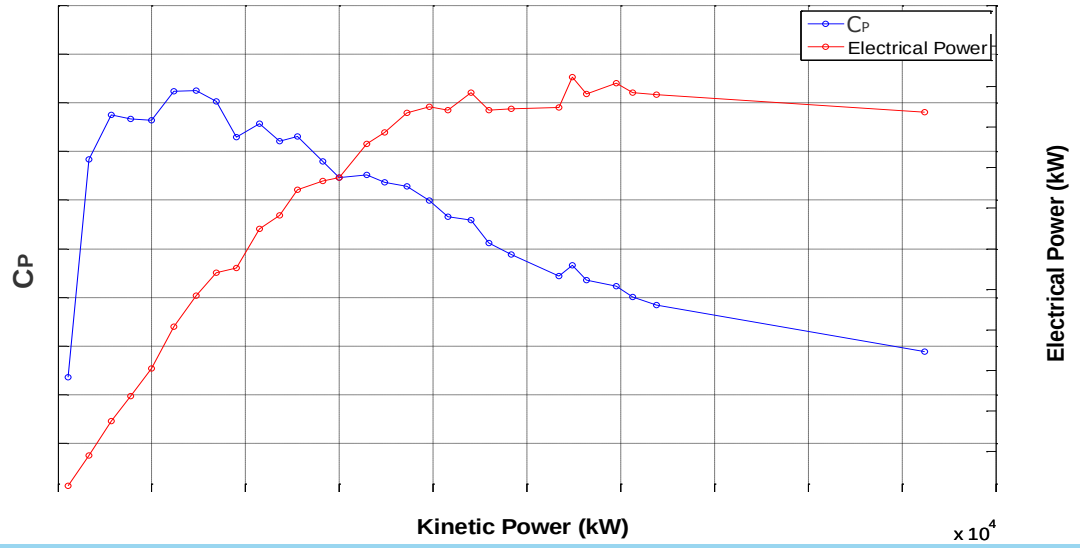






Case 2: PPM with 3D nacelle-based lidar (Slide 2 of 2)





Summary and Outlook

- A new power curve definition is being proposed, focusing directly on input, efficiency, and output of the conversion from kinetic power to electric power.
- Promising starting points have been made regarding the experimental application of the method. (Due to limited amount of data, not all of the intended evaluations have been completed yet – further progress can be expected very soon.)
- The capability of this method to reduce existing problems in energy assessment and power performance verification will be demonstrated, as soon as comprehensive amounts of data are existent.
- Certain aspects of the established method are easily adjusted (e.g. the method of bins), while others will be challenging (e.g. site calibration), but no insolvable issue has been identified so far.

Thank you!

erik.tuexen@dnvgl.com
+49 4856 901 24

www.dnvgl.com

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