

Wind Farm Analytics Newsletter - Spring 2022

Aerodynamic Optimisation, Outlier Rejection, Authoritarianism and Energy Security

In this newsletter we provide an update on recent progress and discuss how the wind industry is going wrong on data analysis, with reference to authoritarian conformity!

On energy security we remind developers WFA offers analysis on how to increase revenue through green hydrogen and/or pumped hydro on existing or future wind farms.

Not all colleagues need to understand the aerodynamic intricacies of pitch control but if you own or operate wind turbines in hilly terrain then please ask whether your business has quantified the value of flow inclination losses. Check pages 4 and 5 of this newsletter and call us about how these diagrams describe cost effective measures for increasing revenue by around £1 million or more per turbine lifetime at minimal cost.

Latest Developments at WFA

- 29 Mar 2022 Notified that a *Japanese floating LIDAR patent is granted*, subject to fee; this will be our twelfth patent granted in major wind markets and manufacturing states.
- 22 Mar 2022 European floating LIDAR granted *patent validated* in member states.
- 15 Mar 2022 We welcomed our 15th investor, rising from 9 investors one year previous (new business or private investors big or small are always welcome to join us; if you understand investment risk but recognise possible (100x) rewards from our turbine controller patents and converging beam LIDAR patents - don't be shy, contact us about the possibility of becoming a shareholder, negotiators also welcome!).
- 17 Feb 2022 European turbine LIDAR granted *patent validated* in member states.
- 9 Feb 2022 Interesting new wind turbine CONTROLLER *patent filed* internationally.
- 22 Dec 2021 *European floating LIDAR patent granted!*
- 17 Nov 2021 *European turbine mounted LIDAR patent granted!*
- 3 Nov 2021 During COP26 WFA and Fraunhofer UK Research have exhibited our tripod mounted LIDAR at the National Manufacturing Institute of Scotland.
- 2 Nov 2021 *Canadian turbine mounted LIDAR patent granted!*
- 21 Sep 2021 *USA floating LIDAR patent granted!*

Embracing Outliers v Evolutionary Stagnation

WFA always argued operational data is gold dust and we make significant gains by using it better. One problem is when industry conducts so-called outlier rejection to unjustly discard unusual data. But its not beneficial to exclude data points just because they differ from the norm, labelling them as "dirt" to be cleaned away. The most interesting data is the abnormal.

With increased enthusiasm for machine learning there has been renewed focus on data but if you are undertaking AI training then its not always a good idea to veto outliers. Imagine a farmer has an AI camera system to recognise his sheep. Imagine during training any "outlier" unusual animals such as wolves were excluded from the training data. The result will be an AI system which learnt no concept of a wolf, or its distinguishing features, and therefore

cannot trigger a protective measure if a wolf comes into view. Its a contrived example but the point is simply that unusual data can signify very interesting cases, and this is also true with regard to wind turbine data including generally unusual cases of extreme flow misalignment.

It may appear orderly for all instances to appear and behave identically but those studying ostensibly identical wind turbines know they individually perform quite differently when faced with changing deployment circumstances such as nearby trees, or in more complex terrain. Therefore adjustment of control parameters is beneficial and total uniformity is sub-optimal.

From work on optimising control parameters using evolutionary algorithms we learnt that outlier "freak" or "mutant" individuals (parameter sets) are key for a population to avoid stagnating within local optima of parametric search space. For subsequent generations to be robust to new situations then it is the outlier who offers innovative options and new capability.

Authoritarianism and Slavery or Freedom?

Most businesses agree workforce diversity is a good thing. Its not just about discrimination. Its about diverse thinking too. All of us have unique life experiences, personal relationships and thoughts. The strength of a rugby team comes not from all team members being identical but from working together with each member of the team contributing their own strengths - speed, agility, strength, intelligence, robustness and leadership all count.

Too much conformity becomes weakness. Are wind turbine manufacturing corporations enabling technological diversity and innovation in the interests of their customers? Imagine wind farm owners can get 10% more revenue from turbines if adopting innovation of Wind Farm Analytics. Imagine then an asset manager feels constrained by authoritarian contracts which suggest modification or tuning of the asset is not allowed, or is discouraged.

The asset manager needs to be liberated from such slavery. One way is for large wind turbine customers to negotiate contracts which specifically enable innovative improvements. This could be limited to one particular turbine in twenty, or with proviso that any testing only occurs after a certain point in the asset operational life. Another approach is to calculate what level of benefit a wind turbine owner obtains by agreeing to such handcuffs. If the value of a warranty is 1% of revenue whereas an innovation is worth 10% of revenue then isn't it logical to remove a turbine from this "insurance" and undertake case study trial with the innovation? Lets shake things up to free our intrinsic potential. Refuse to conform!

Especially for large turbine fleets this makes sense because once proven at (low) risk on one turbine the benefits can be rolled out to many other turbines in the fleet. Obviously innovation testing can include condition monitoring sensors before and after the change in order to give confidence that mechanical loading is not unduly increased. In fact if controller innovation works to counter misalignments then there is a strong chance loading will also decrease since increased flow misalignment is strongly associated with increased loading. WFA innovations can increase asset lifetime whilst simultaneously increasing annual production during that lifetime. In a free market turbine manufacturers must listen to their customers and seek improvement. But also smaller wind farm owners with older wind turbines which already paid for themselves have a good opportunity - if you understand a little about what we have to offer, or would like to explore discussions on that, then get in touch with WFA; maybe we can swap some patent ownership via WFA shares in return for technology demo partnership.

Many corporations pride themselves on sustainability targets enabling net zero. For this reason alone it is imperative that contractual conditions should enable innovation since it is innovation which will provide step change increases apparently needed for accelerating

decarbonisation. Are you a sustainability champion? How about re-visiting innovation handcuffs and removing them from turbine supply contracts, turbine warranties, and maintenance contracts? Lets have out-of-the-box thinking in contracts - it need not be for all turbines but surely as an industry we can make some adequate allowances; please contact WFA if you are a contract innovator sustainability champion and would like to bounce ideas!

This year 2022 is our tenth year in business. Its a struggle as a small independent company fighting for existence in a corporate world but we are still here. Only a minority of start ups survive 10 years and its all a learning experience prior to glory. We are not planning any extravagance because birthday parties are for kids (when you've got no money due to patent maintenance). However, we will exercise our human right to free speech, offering criticism and suggestions to improve the wind industry of which we are proud to say we are a part.

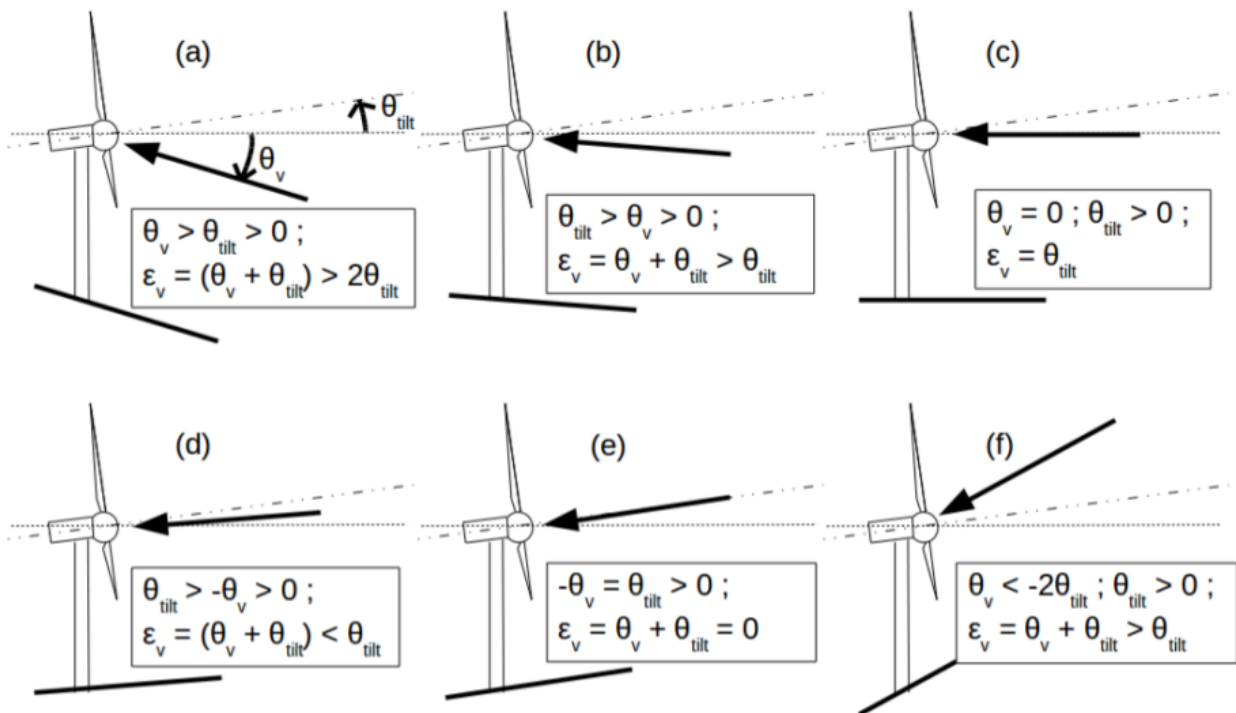
UK Energy Security, Bad Weather Export and WFA Energy Storage Studies

Its not wind energy driving up energy bills, its fossil fuel (oil and gas) prices.

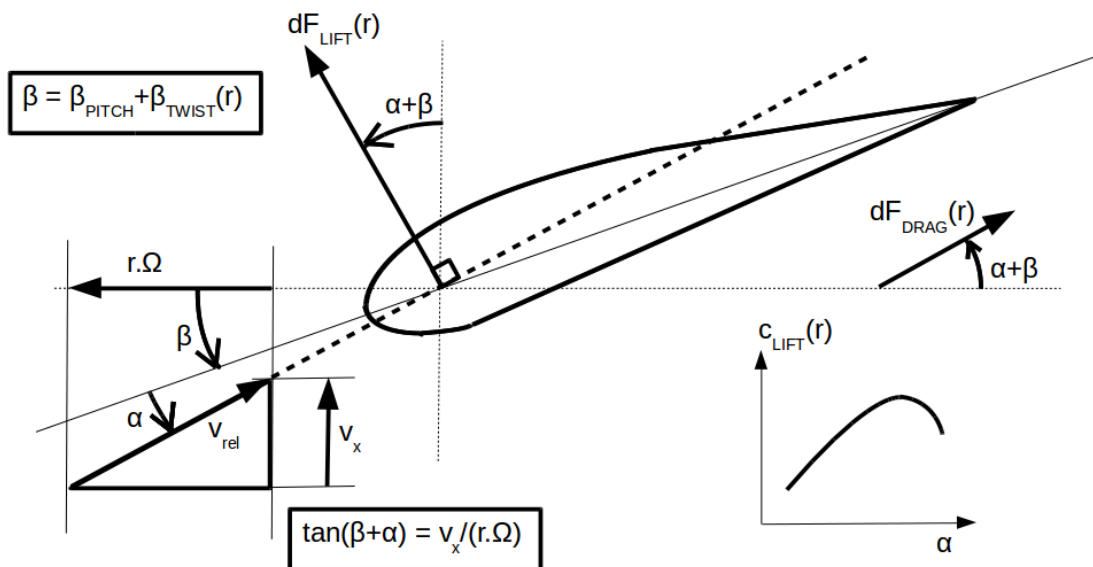
WFA argued since 2012 that to achieve a pure renewable grid, or to accommodate high wind penetration on the grid, installing large scale energy storage is essential to handle massive variability of wind energy including many days with low wind. Lithium batteries don't cut it since the biggest such batteries in the world could only handle a few minutes of UK average demand. Anyway, lithium batteries have a low lifetime and are too costly per MWh stored for bulk energy storage - lithium batteries should be reserved for mobile applications of cars, phones and laptop PCs, or specific grid ancillary services which require very fast response.

Green hydrogen offers long term storage of wind energy as cheaper-than-diesel zero emission transport fuel. Here in the UK nature provides us with abundant bad weather and it makes sense to utilise it and even export it internationally to other countries wishing to escape high prices and pollution of fossil fuel in aviation, shipping and land transport. Lets catch that rainwater and split it with wind energy into green oxygen and green hydrogen. Battery electric car owners are rightly proud of the efficiency of their low carbon solution but green hydrogen has a particular advantage in that it may be stored for long periods of time - both technologies can work well together. Meanwhile pure green hydrogen pipelines will allow direct replacement of the existing gas grid for green hydrogen heating and cooking, whilst simultaneously providing a huge energy storage vessel and cheap fuel transport.

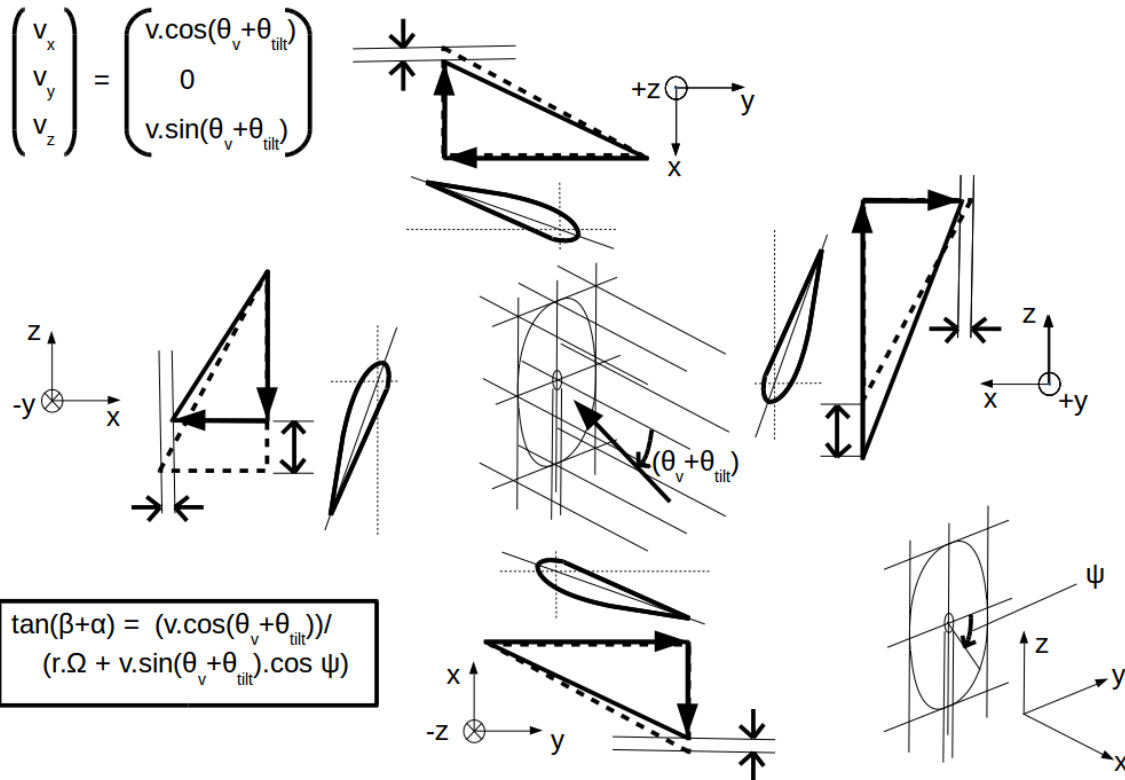
Pumped hydro energy storage is an efficient large scale technology available right now. This is tried and tested, long life, efficient and cheapest for the consumer per MWh stored. If you support renewable energy then you must support cheap renewable energy and its affordable storage for domestic consumers and the wider economy. If you want to escape dependence on foreign gas suppliers then what better than local green planning and construction jobs to develop new pumped hydro infrastructure - this is the only present day technology capable of storing days worth of UK energy without significant wind. This offers energy security by providing controllable flexibility and ancillary services whilst avoiding need for dependence on foreign interconnectors. Pumped hydro energy storage simultaneously saves us money by better utilising existing grid infrastructure, avoiding some need for upgrade. Furthermore by electrical (not necessarily physical) co-location one can capture and sell wind curtailment energy which is presently being dumped when not needed, perhaps at night. Wind farm owners please contact WFA to discuss how energy storage solutions assist the UK grid energy security and increase revenue from your existing assets. Policy makers please hire WFA to explain how investors can be incentivised to commit large capital expenditure up front, without significant cost to the consumer. [Call Dr Theodore Holtom +44 7720767545.](tel:+447720767545)



Drawing 1: Modern wind turbines are axial flow turbines which respond best to wind flow parallel to the rotor axis but a wind turbine situated on a slope will be subject to vertical flow misalignment, further exacerbated by the rotor tilt angle - its like running your wind turbine with a permanent yaw error but rotated into the vertical plane.



Drawing 2: For any given blade pitch setting the aerodynamic angle of attack (AOA) is determined by the axial wind speed and the blade element rotational speed; we can change the AOA (and therefore adjust the aerodynamic lift) by using the blade pitch motor system.



Drawing 3: In presence of vertical flow misalignment the rotational speed is effectively decreased/increased each time the blade element travels up/down around one rotor cycle - this causes the aerodynamic velocity triangle to vary cyclically; for many turbines such flow inclination is the DOMINANT cause of losses in which case cyclic pitch adjustment will eliminate significant losses and thereby increase production and revenue.

 **Join us on our journey**

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