Offshore Wind

How an Industry Revolutionised Itself

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A disclaimer!

Please note:

- As many of you know, I am a Lidar salesperson!
- This is less of a scientific and more of an overview of various activities that occurred over the last decade that have revolutionised the wind industry.
- I hope it's an interesting story and many of you will have been involved along the way.
- Feel free to leave now on this basis or submit your thoughts to me after the presentation!

15 years ago… in a galaxy not so far away

The response? Go and prove yourselves! And at this time, there were no clear standards, no IEC guidance on remote sensors, no authorities in this area.

2002 **Garrad Hassan introduction to lidar by ZephIR / QinetiQ**

July 2006

GARRAD HASSAN

Remote Sensing Positioning Statement – Issue A
First statement globally assessing and evaluating the acceptance of remote sensing. ZephIR enters Stage 1, completes Milestone 1, enters Stage 2:

"Provided suitable off-site and/or onsite validation steps as defined above are carried out, and the results of these validations are positive, then GH consider that data recorded using the ZephIR device may be used in a quantitative sense for the formal assessment of the wind speed and energy production of a potential wind farm site."

Advice stated to provide tall mast verification - ZephIR launch UK Remote Sensing Test Site.

July 2007

Remote Sensing Positioning Statement – Issue B
ZephIR demonstrates Stage 2 progress with body of evidence being developed for Stage 3.
ZephIR 'Best practice verification methodology' endorsed by Garrad Hassan.

August 2010

GL Garrad Hassan

Remote Sensing Positioning Statement – Issue C
ZephIR enters Stage 3:

"For relatively simple terrain sites… data from the ZephIR device may be used in a quantitative sense with reasonable error bars for the purpose of the assessment of the wind regime at a potential wind farm site."

October 2012

Remote Sensing Positioning Statement – Revised document
ZephIR achieves Stage 3 acceptance:

"DNV GL considers ZephIR 300 to be at Stage 3 under "benign" conditions - accepted for use in bankable / finance-grade wind speed and energy assessments with either no or limited on-site met mast comparisons. "

10 years to receive formal approval for ground-based wind resource assessment with Lidar…

ZephIR Lidar

LEOSPHERE
THE ATMOSPHERE IS YOURS

So how did the offshore industry differ?

Not so much ‘how’ but ‘why’ - the then only available option for wind recourse assessment offshore – an offshore met mast:

- Massive “at risk” investment if looking at installing a new platform
- Mast anemometry is difficult to achieve at modern offshore hub heights
- Increased interest in the full rotor swept area
- Ongoing maintenance, health & safety inspections and calibration of anemometry
- Impact on Levelised Cost of Energy
- Time to get to results – planning etc.
- Representation of wind resource at a single point across the site
- … Floating Wind!

Let’s just say Lidar was knocking on an already open door!

Project needs and adoption

What did that open door look like?

- Time to market for a disruptive technology vs. rate of industry growth
- Quality of wind data
- Quantity of wind data
- Data across a site
- Health & Safety improvements
- Through-life risks – Day 1, Day 100, Day 1000, Day 10,000?
- Through-life costs

The first movers / innovators

ZephIR Lidars were the first to be deployed offshore on fixed platforms.




2005, Beatrice Platform, North Sea
2006, NaiKun, Hecate Strait
2010, Robin Rigg, Solway Firth
2014, Bell Rock Offshore Windfarm, Dundee

Roadmap to acceptance

NaiKun demonstrated a low-cost Lidar platform could work but only went part of the way to reducing cost and time to water.

But in 2010 Deepwater Wind demonstrated that a floating Lidar could work just as well.

Just 3 years later - 2013 – a range of floating Lidars were tested and validated as part of the UK's Carbon Trust Offshore Wind Accelerator (OWA) programme.

Knowing the time pressures / scale of offshore wind growth, the OWA published a set of recommendations to give the industry the formal framework needed to accelerate the commercial deployment of the technology while standards were being developed. The IEA build on this work to offer recommendations for using floating lidar including wider considerations; H&S, Deployment, Moorings,..

Commercial deployments of floating Lidars accelerated significantly!

Research Council of Norway

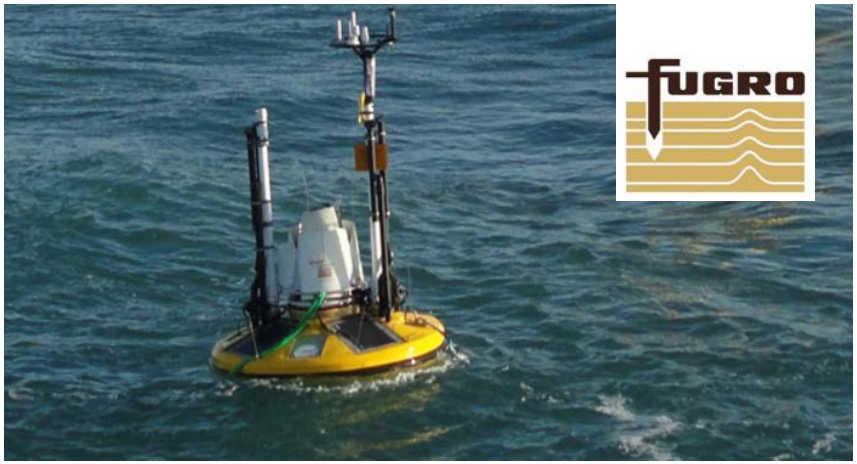
[Picture from lidar comparison test (CMR)]

One of the earlier publicly available assessments was conducted here in Norway.

Financed by NRC and Statoil with in-kind support from Fugro Oceanor, UiB and CMR.

This directly led to the further development and adoption of the Fugro Seawatch buoy (based 5 minutes walk from this event)

The rise of the truly floating Lidar



The industry pulls sideways

Lidar is now accepted as a proven technology by the wind industry from a practical, contractual and, increasingly, from an industry standards' perspective.

Perfect timing as the hub height and swept area of offshore wind turbines surpasses using mast anemometry as an economically viable option.

- Use of Lidar for Resource Assessment demonstrates Best in Class data
- Reliability demonstrated on industry firsts with floating lidars going into their third year of continuous operation
- Known boundaries of use through research studies – important! And help to define new areas of research and validation
- Cost advantages demonstrated on projects coming to fruition
- … Look at the US market, there are no masts and most sites will progress without one

Operational Assessments

No platform to use from met mast?

Deploy Lidars on wind farm substations!

Merkur Offshore Windfarm

- Lidar is coupled to met data acquisition systems, data is transmitted to client platform for access.
- Data is integrated with SCADA systems.
- Lidar is used for power performance analysis using hub height measurements.
- Combined with other sensors to support helicopter landing ops including personnel winching.

Energisation and Start of Warranty

Offshore, contractual power curve verification tests according to IEC 61400-1-12 standards remains highly impractical as they require the installation of a met mast and this only permits the testing of one turbine in such large arrays.

The March 2018 update permits the combination use of Lidar and mast and whilst this has progressed the use of verifications onshore it still requires significant investment offshore to accommodate the requirements.

Nacelle mounted Lidar delivers accurate measurements, across multiple turbines, at a significantly lower cost point, with high availability and low uncertainties.

2014 – A project conducted by a consortium made of DTU Wind Energy (formerly Risø Wind Energy Department), DONG Energy, Siemens Wind Power and Avent Lidar Technology, and funded by the Danish Energy Technology Development and Demonstration Program (EUDP). The procedure provides the basis for a new, industry-wide best-practice for performance verification with nacelle LIDARs.

The shear size and cost of offshore wind projects is focussing more on commercial agreements than IEC standards whereby development wind specialists are defining power curve verification tests with the turbine OEM's.

Many leading OEM's now accepting a nacelle mounted Lidar power curve test (Lidar calibrations, test methodologies and result analysis has already been defined)

2017 – Look at where we were

London, 18 July 2017. Leading wind measurement experts gathered in London claimed that LiDARs have been replacing met masts to become the sole wind measurement tool used for offshore resource assessment and power curve verification purposes

Deutsche WindGuard, Klause Franke, Project Engineer: *"Application of Nacelle Based Lidar for Offshore Power Curve Tests"*

ECN, Hans Verhoef, Project Leader Measurements: *"Offshore wind development with standalone Lidar"*

EDF EN, Cedric Dall'Ozo, Senior Wind Resource Assessment Engineer: *"Reducing uncertainties: vertical profiler, floating, scanning and nacelle Lidars"*

MHI Vestas, Tue Hald, Senior Specialist: *"Power curve verification with nacelle two-beam Lidar on V164-8.0 MW"*

RES, Iain Campbell, Technical Analyst and Wind Resource Manager: *"Lidar: Just better than a mast?"*

Siemens, Pedro Salvador, rotor Performance engineer: *"From R&D to Plug & Play: 8 years of nacelle Lidar experience"*

SSE, Gordon Day, Offshore Wind Analyst: *"Replacing masts with Lidar for financing and performance assessment"*

UL DEWI, Beatriz Canadillas, Senior Researcher: *"Offshore Wind Lidar since 2009: from R&D to commercial applications"*

Construction Monitoring

Block Island Windfarm

ZephIR 300 was installed on Fred. Olsen Windcarrier's Brave Tern jack-up vessel - used to compare wind speeds against those measured with the main boom tip crane wind sensor.

Measurements were used as a "live" instrument during all phases of construction and specifically during critical points of component lift. 1 second live data was displayed with wind shear curves in the user interface.

Where wind behaviour was difficult to explain i.e. when wind at the tip of the crane was lower than on the crane A-frame, or bridge level, ZephIR 300 could identify and explain the difference across the full lift height.

During WOW (Waiting-On-Weather) downtime, ZephIR 300 provided a very accurate picture of the wind conditions to enable effective decision making.

During high winds when the crane was in the boomrest, ZephIR 300 was used to confirm when it was worth lifting the crane out of the boomrest again before making any unnecessary movements.

Today we see Lidar included as standard in offshore tenders for vessels operating on wind farm construction

The industry has revolutionised itself

In the space of 5 years since the first OWA analysis of offshore Lidars, there is adoption for fixed and floating platforms with Lidar, across all project phases – something not even achieved onshore yet!

What next?

- The full range of capabilities offered by Lidar in any format continues to be developed and validated.
- This will lead to further pull sideways in to other applications and project phases.
- The industry continues to drive down LCOE.
- Safety First across everything we do.
- Innovation time is getting faster.

The industry has revolutionised itself

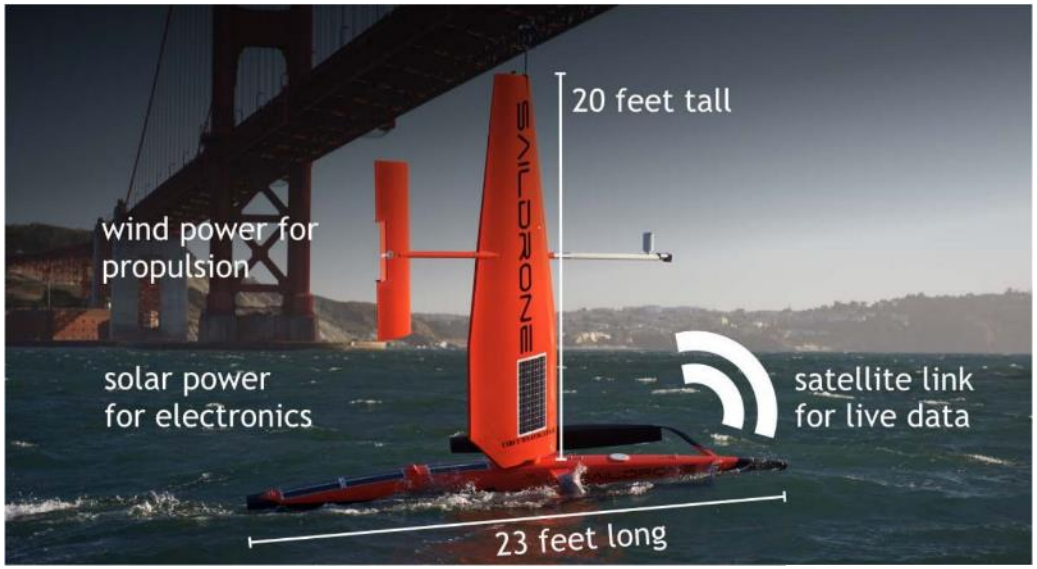
Our guess?

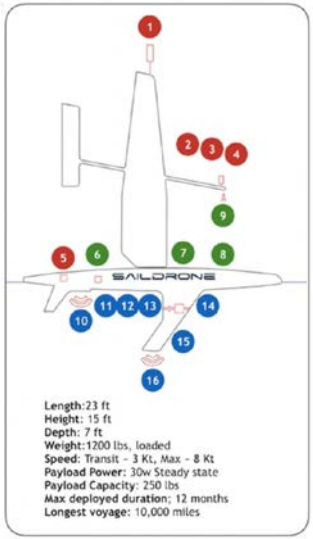
All of these drivers, particularly offshore, will move towards:

- Turbine control (passive, i.e. look and learn, and active) and load management to allow for life extension, asset sweating or opportunities for repowering with new innovations e.g. blade extensions
- Wake effects will be quantified and strategies implemented to better manage power loss / irregular loading
- Wind sector management will be more appropriately applied with Best in Class wind sensors
- Power forecasting will be more inline with new grid and trading requirements

Lidar is 'just' a sensor – others need to build systems around this technology – through partnerships the value can be realised

It certainly hasn't finished yet.....





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