Minutes of
IEA Wind Task 32 2019 General Meeting

11-12 December 2019
DTU Risoe, Roskilde, Denmark

The meeting minutes below include the original agenda and notes from the event.
You can find the presentations and other material from this meeting on our website at
https://community.ieawind.org/task32/events/event-information/gm-2019-december.

Thanks

The IEA Wind Task 32 Operating Agents and all participants are deeply grateful to Rozenn Wagner, Elin Svensson, and their colleagues at the Danish Technical University, without whom this meeting would not have been possible. We also thank the more than 40 participants who made the meeting a great success.

Participants **14**

Day 1: December 11

Registration and Poster Session

09:00	**Registration and poster session** The meeting will take place in the Neils Bohr Auditorium at DTU's Risoe Campus. You will have to register with site security before coming to the auditorium. We'll start slowly with posters and coffee in the atrium.

Greeting and round-the-room introductions

10:30	Greeting and round-the-room introductions

What's new from Task 32?

11:00	What's new from Task 32

1. Introduction to Task 32 and the 2019 General Meeting (Andy Clifton)

[Unfortunately Andy was not able to join the meeting. This presentation was made by David Schlipf, co Operating Agent of Task 32]
For more information about the Task, see the Task website at https://community.ieawind.org/task32/.

2. Workshop 15 (Eric Simley)

The joint workshop 15 "Optimizing Wind Turbines with Lidar-Assisted Control" hosted by IEA Wind Task 32 and Task 37 (Systems Engineering) was held in Amherst, MA on October 17+18, 2019. The motivation for the workshop was to identify processes for determining the reduction in levelized cost of energy (LCOE) for wind turbines with lidar-assisted control (LAC), leveraging the systems engineering and optimization expertise of Task 37. Twenty eight participants from 6 countries attended the workshop, which consisted of invited presentations from wind turbine manufacturers, lidar suppliers, consultants, and researchers as well as group discussions on the topics of models and methods for optimizing wind turbines with LAC.

During the workshop, 4 main application areas of LAC for reducing LCOE were identified:

1. Increasing AEP: primarily using lidar to improve yaw alignment
2. Reducing CapEx: taking advantage of load reduction from LAC to reduce mass of turbine
3. Lifetime extension: taking advantage of fatigue load reduction from LAC to extend turbine lifetime
4. Wind class upgrade: Using load reduction from LAC to operate a wind turbine in a wind class with higher wind speeds or turbulence

Four main areas of further research were identified by the participants:

1. Extreme load reduction: methods for reducing extreme loads on wind turbines, addressing finite lidar availability, are needed to reduce LCOE for many turbines
2. Cost models: Generic lidar cost models, including CapEx and O&M, are needed for optimizing turbines with LAC. Additionally, economic models describing the benefit of turbine lifetime extension are needed.
3. Understanding LAC benefits for different wind turbine types and wind classes: LCOE reduction from LAC depends on the combination of the wind turbine specific power (rated power/rotor area) and wind class (mean wind speed). LAC should be investigated using a range of reference wind turbine models and wind classes to identify the combinations with the most potential for LCOE reduction.
4. Formal systems perspective: Use of holistic design optimization frameworks with nested optimization structures to address the complexity of the optimization problem

Next steps after workshop 15 include:

1. Submitting a whitepaper addressing the state-of-the-art and research challenges for optimizing wind turbines with LAC (Torque 2020)
2. Developing a generic lidar cost model
3. Hosting a repository containing common reference wind turbine, lidar, and controller models that the community can use to compare methods for optimizing wind turbines with LAC

Questions:

- To what extent can it be generalized to more sophisticated control systems from other turbines?
    - There are a lot of special cases handled by controllers. It might not be possible to include all of them. But the basic, power production case will be included.
    - An industry wind turbine controller was invented for normal operation by a group of SOWENTO, Flensburg and Uni Stuttgart
    - A collaboration with Task 37 is very helpful
- All of the methods are based on models- is there a plan to validate it with load measurements?
    - There has been field testing on lidar control on smaller turbines (Carts), it is not clear when it will be able to be applied to bigger turbine
    - The biggest obstacle is the confidentiality issue
    - Next year there might be a workshop with an asian turbine manufacturer that is interested in the topic
- Have you done any cost modeling of an earlier adoption of lidars and not based on mass production?
    - There are numbers in the literature using lidars that are used for different applications. There are no good cost models otherwise.
    - A good estimation might be helpful to encourage turbine manufacturers
- What is the lidar simulator reference model require from a lidar manufacturer?
    - The idea is to have a DLL that protects the lidar measuring process. So if lidar manufacturers might provide this DLL this will be helpful.
    - The simulator only gives you line-of-sight wind speed. If a turbine manufacturer wants to simulate they need to think how to process the line-of sight. One idea is to include an application into the lidar directly that then processes the wind speed measurements
- How much more energy would need to be produced to cover the costs?
    - At the workshop there was a presentation of a quick study on this. If 10-15% tower fatigue load reduction there is a 1-2 percent reduction in turbine cost. With newer

control specific lidar this numbers will change. Studies have shown that, 10% of load reduction is worth 1% of AEP is the rule of thumb.
    - It is clear from the workshop that a lidar cost model is needed. Steffen Raach from SOWENTO wants to hand in a paper to the TORQUE conference with a first lidar cost model
- Who is the one who cares about what as there are so many players? Who pays and who gets the benefits?
    - This is a very good question that needs to be looked at further. The traditional idea is that the turbine manufacturer will be able to build a less expensive turbine due to material savings. Applications such as live time extension or yaw optimation would be on the turbine operator side. So it is important to look at different stakeholders.

What's new in the World of Lidar?

11:45	**What's new in the world of Lidar?** Short presentations from participants about new ideas, new technologies, and new solutions in the world of wind lidar: 1. What the EU-funded ITN "LIKE" means for the wind lidar community (Jakob Mann, DTU) 2. The need for a calibration procedure including an uncertainty budget for nacelle mounted lidars (4-beam & scanning lidars). Dominique Held, Siemens Gamesa Renewable Energy 3. DTU spinner lidar for control. Torben Mikkelsen, DTU Wind Energy 4. Using lidar for rain measurements for wind turbine blade leading edge erosion (rain-erosion.dk). Charlotte Bay Hasager, DTU Wind Energy 5. Yet another dual-Doppler uncertainty model (YADDUM). Nikola Vasiljevic, DTU Wind Energy 6. The Consortium for the Advancement of Remote Sensing (CFARS). Reesa Dexter, DNV-GL.
13:00	**Lunch**

1. What the EU-funded ITN "LIKE" means for the wind lidar community (Jakob Mann, DTU)

LIdar Knowledge Europe (LIKE) fosters training and education of young researchers on emerging laser-based wind measurement technologies and their translation into industrial applications. See http://www.msca-like.eu/ for more information.
Reminder to all: some positions are still open: if you know possible candidates, please let them know about the LIKE project.

2. Uncertainty budgets for nacelle lidars used for power curve measurements. (Dominique Held, Siemens Gamesa Renewable Energy)

Presentation Content:

- Brief instruction to power curve measurements with nacelle lidars: How do nacelle lidars measure compared to a met mast? How is the wind speed reconstructed?
- Mentioning previous work that deals with the quantification of lidar measured wind speed uncertainty
- Proposal for 2020:
    - Round-robin for a nacelle lidar uncertainty calculation
    - Output: example documents on how to calculate uncertainties for different lidar types

Discussion:

- Round robin: When is it planned? How will it be with the data?
  - Not clear, yet, already a lot of round robins planned, need to be coordinated.
- Hub height wind speed versus rotor-effective wind speed: Which one should we consider?
  - Rotor-effective is more complicated (sheers and veer impact), but maybe more what is relevant. Both could be considered in the round robin. It is important to differentiate between uncertainties caused by measurement errors or model error (see NAWEA Paper D. Schlipf)
- How is wind field reconstruction related to uncertainties?
  - See WindEurope Paper from Julien Tissot.
  - General method will be very hard to create. The main idea is to get started and see what are the individual steps.

3. **Using lidar for rain measurements for wind turbine blade leading edge erosion (rain-erosion.dk). Anna-Maria and Charlotte Hasager DTU Wind Energy**

Presentation content:

- Wind lidars can be used to measure the number, size and velocity of raindrops for leading edge erosion safe mode to extend lifetime of wind turbine blades
- Lidars could be a robust 2-in-1 sensor - providing wind and precipitation data at the same time

Discussion:

- Does the lidar need to look upward or is nacelle -based possible.
  - It is helpful, but is not necessary.
- Why are laser disdrometers not usable for offshore?
  - Disdrometers erode quickly offshore - they last one year or less. Lidars could help solve this.
- UniTTe collect a lot of data. Is this data useful?
  - In principle yes, but we would like more information about the wind, which was not collected in UniTTe.
- Can acoustic sensors be used?
  - Depends on the location (offshore/onshore). But in general, acoustic sensors are too sensitive.
- Does the erosion-safe mode pay off?
  - Operation and Maintenance cost should pay off, but we have still to investigate, when does it make to enable it? What is a “severe rain” etc.

4. **DTU spinner lidar for control. Torben Mikkelsen, DTU Wind Energy**

Presentation content: The DTU SpinnerLidar concept was presented. Processing of raw DTU SpinnerLidar measurements was described, and examples of use of SpinnerLidar data for wake detection, un-truncated covariance measurements and 3D wind field reconstruction was given.

Discussion:

- How do you choose the beams to calculate the co-variances?
  - We use all possible combinations together

5. **Yet another dual-Doppler uncertainty model (YADDUM). Nikola Vasiljevic, DTU Wind Energy**

[Unfortunately Nikola was not able to join the meeting]

YADDUM is a tool to estimate the uncertainty of dual-Doppler wind lidar measurements. See this link for an example of YADDUM in use.

6. **The Consortium for the Advancement of Remote Sensing (CFARS). Reesa Dexter, DNV-GL.**

CFARS is a consortium of wind energy companies and stakeholders working to derisk future investments in taller and larger wind turbines throgh the use of remote sensing. This is achieved through coordinated working groups and leveraging the large amounts of proprietary data held by the CFARS members. For more information see http://www.cfars.org/cfars-overview/.

Note: Task 32 operates at lower TRL (2-7) compared to CFARS (TRL 7-9) and so the two groups collaborate to ensure that technologies get the support they need, to mature and support the wind energy industry.

What are we doing?

13:00	Lunch
14:00	Lidar and Dynamic Energy Yield Assessment (Peter Clive) Using the idea of lidar-enabled full-lifecycle integrated digital workflow with unified data requirements together with the dynamic risk assessment model familiar from health and safety, to turn an energy yield into a living document.
14:20	The vendor's perspective (Chris Slinger, ZX Lidars)
14:40	Coffee
15:00	Nacelle Lidar for power performance measurements in complex terrain (Rozenn Wagner) Introducing the Task 32 Comparative exercise on nacelle lidar for power performance measurements in complex terrain
15:20	The DNV-GL JIP for LIDAR-measured Turbulence Intensity (Johan Olaison, DNV-GL) Introducing the DNV-GL JIP.
15:40	Wind Lidar in Complex Terrain (Alexander Stoekl) Introducing the Task 32 comparative exercise.
16:00	Wind Lidar in Cold Climates (Nicolas Jolin) Introducing the joint Task 32 and Task 19 Working group for Wind Lidar in Cold Climates.

Lidar and Dynamic Energy Yield Assessment (Peter Clive)

Using the idea of lidar-enabled full-lifecycle integrated digital workflow with unified data requirements together with the dynamic risk assessment model familiar from health and safety, to turn an energy yield into a living document.

- How to reduce the cost enough before?
    - There's a lot of cost drivers. All drivers have to be informed by the best data.
    - What are the next steps
    - What are the key barriers to implement the change?
        - As an industry we are bad at collaboration. There is a need for platforms that adopt these ideas and handle e.g. user rights and thus facilitate data management.
        - We are not seeing enough innovation willingness from end users. There's a need for earlier strategic commitment from end users to research.

- Move from internet of things to internet of impact - there are huge wind farms offshore that have a big wake. Depending on the stability the impact from this wind farms reaches kilometer wide. Lidars are able to measure and trace the impact.
    - Absolutely. Also forecasting is improved. All those sensors are joined up.
    - This should be started at research level and pushed to government level.

The Vendor's Perspectives (Chris Slinger)

The presentation gave a short overview of some Task32-relevant perspectives from ZX Lidars. Topics covered included the use of turbine-mounted lidars in offshore power curve measurements, turbine wake detection and visualisation, measurement campaigns in complex terrain (including various results from measuring inside the induction zone), lidar assisted control and the benefits of through life turbine performance monitoring using nacelle mounted lidars.

- Updated best practice document for power performance measurements (get rid of two beam lidar)
- Why is it important to measure outside of the induction zone?

Nacelle Lidar for power performance measurements in complex terrain (Rozenn Wagner)

Introducing the Task 32 Comparative exercise on nacelle lidar for power performance measurements in complex terrain.

- Is the flow where the nacelle lidar is based also affected whether the turbine runs or not?
    - The goal is to measure the flow in front of the turbine with the lidar. The goal is not to measure a NCL.
- Where do the 50 m come from. Does that come from technology?
    - This is something we need to find out. 10m is too close and 50m might be fine. 50m is just an example
- There is a need to plan more campaigns- everybody is welcome to offer lidars for such campaigns

The DNV-GL JIP for LIDAR-measured Turbulence Intensity (Johan Olaison, DNV-GL)

Introducing the DNV-GL JIP.

- Do the corrections not depend on the type of lidar and other factors. Does that mean you will have to implement quite a broad range?
    - The acceptance criteria should not be based on the type of lidar but on the application (e.g. load assessment). But it is clear that the first recommended practice (RP) will not be perfect or comprehensive, but we need to start somewhere and the industry wants and needs to have something soon. The RP will grow and evolve over the years.
    - There is quite a wide landscape also just coming from one lidar manufacturer. It is going to be a big undertaking, so we are going to start.
- Are you going to evaluate the alternative methods in WP B, e.g. with a scorecard?
    - There is probably not enough time and budget for that.
    - It also depends on the method that is found. But there will be definitely a report.
- There is no university in this list of participants
    - That's what we are missing at this stage. We would like to have such a partner.
    - Nice to have or need to have? Really really like to have - but not necessary
- There was not the fear of competing between Task 32 and CFARS and the JIP. But a fear that there would be something put in stone that only a certain stakeholder group represents (the industry). Therefore it might be good to get other stakeholders in as well.
    - There should be a collaboration with Task 32, CFARS, and the JIP
- Torben Mikkelsen and others have shown this nice method using spinner lidars for TI. Is it possible to evaluate this different methods?

- The hope is that this is within the scope.

Wind Lidar in Complex Terrain (Alexander Stoekl)

Introducing the Task 32 comparative exercise for wind lidar in complex terrain.

- How long are the data sets? Stratification is important?
  - Several weeks to several months.
- The rights of the data owner: we need to remove the most obvious geographical information.
- There should be data available from Uni Stuttgart from a site in the south of Germany
- I like the idea of the 10 minute data - that's the data the developer is collecting.
- Have you thought of connecting complexity to the wind field reconstruction models? Depending on the slope a different model is used for WFR
  - There is certainly a way to do this. But it is not clear if that is possible with off the shelf lidars
- Ayden Keen at Wood has been doing work (not with 10 min data) looking at data of individual beams and how this can be used to derive information from the flow. Also looking at the importance of how many beams have to used. Some of the other lidar OEMS are looking into this as well
  - The limit is that there has to be an open description of the methods
- Are you differentiating between terrain and forestry effects?

Wind Lidar in Cold Climates (Nicolas Jolin)

Introducing the joint Task 32 and Task 19 Working group for Wind Lidar in Cold Climates.

- Will you have a meeting at the General Meetings or is there also a workshop planned?
  - There will be a common general meeting with IEA Wind Task 19
- Are you planning to quantify aerosol quantifications regarding low ranges?
  - Yes, if there is a need, we are planning to do this.
- Do you have internal work going on to improve recovery?
  - Nothing to share yet?
  - ZX: there are thoughts about increase of integration time
- What is it that keeps you from looking into SODARS?
  - Nothing really, just Task 32 is looking into lidar.
  - The topic is applicable to all remote sensing

Speed Dating

16:40	Speed Dating Get to know the community!

Day 2: December 12

0900	Arrival with coffee

World Cafe

09:00	World Cafe Discussions over themes and topics identified during the meeting. Decide on next steps, plan an event, or do whatever you think makes sense.

The World Cafe concept was introduced. Several themes were identified for discussion:

- Complex terrain
- Cold climate
- Turbulence intensity
- Lidar-assisted control
- Uncertainty quantification
- Floating lidar

The discussions and results of the World Cafe section are included below.

10:00	Reporting Sharing results from the World Cafe and identifying possible activities for the session after the break.

Complex Terrain

- Some of the lidars have the ability to distinguish simple flow from complex flow- could this help to define the complexity of the site?
    - Yes, it would be useful. If would be good to know this beforehand.
- I think there are KPIs and definitions missing for classifying of uncertainties of the results.
    - The goal of the proposed exercise is to come up with such KPIs.
    - Also a KPI
    - A residium from the wind field reconstruction could also be a good indicator: how much does the reconstructed wind field differ from the LOS
- We have ice classes - why not have those classes also for the complexity
    - The icing classes are of limited usefulness. They just give an order of magnitude. But the methodology could definitely also be helpful here.

Cold Climate

- Is CFARS also working on this topic?
    - Not really.
- The climate is a challenge for every device - also data loggers shut down when it's too cold
- Is it a purely technical issue that vendors should solve, or is this also something you get from data analysis?
    - It's a mix of both. There can also be things that can be done on the data analysis such as increasing the data accumulation.
    - Vendors have different recommendations for cold climate (such as a jacket)

    - There should be information from the vendors on how lidars behave in low aerosol conditions

Turbulence Intensity

- IEA workshop in 2020 to provide an overview of all activities from CFARS, JIP and other stakeholders
- The idea will solve a lot of issues and concerns

Lidar-assisted control

- Goldwind might be willing to host a workshop
- The Smart lidar idea is also very good to talk to in more detail
- Estimating the costs of a lidar to justify it's benefits could also be a topic
    - Yes! Coming up with a generic cost model is definitely a goal
    - If comparing the cost of a lidar with a e.g. 50 million euro wind turbine, the lidar is not significant. But as this is a point that always comes up in discussions, there is a need for explaining it.
    - Maintenance costs for lidars have to be included as well
- Is it a hurdle to integrate this into the software?
    - Lidars should be more ready to use for control. The topic is very multidisciplinary, which makes it difficult to apply.
    - An idea is to have workshops with turbine manufacturers to educate them better
    - Turbine manufacturers were wondering how to retrofit their turbines with a lidar.
    - It boils down to providing more interfaces. This would make communication of lidar and end user more easy
- Not trying to have a lidar that serves all purposes might help here as well. Thinking about a hierarchy on different applications might be useful. E.g. detecting simple gusts would only need a very simple lidar - little steps rather than sophisticated models. Here the cost model could reflect that
- Focus on a few of the applications of simple lidars might help and then identify who are the stakeholders of the different benefits
- What about design load cases - are you planning to look into this? What happens if the lidar fails?
    - That was talked about in the workshop. There are load cases that need to be considered.

Uncertainty quantification

- The uncertainty topic popped up several times in recent years so it is good that there is an initiative now that gets started
- The starting point is to be to quantify a nacelle-based based lidar in flat terrain
- Could the level of uncertainty be a link to the JIP about Turbulence intensity
    - It should be kept as simple as possible
- The starting point would be to organize the round robin using a data set and then start it from there. The work should be based on the standard.

Floating lidar

- Do you feel like we have to update the recommended practices based on your experience
    - There has to be a convergence. There is a new standard coming up. If there is only one document, this would be better. With the increasing trust in the systems, new insights have been made. More open discussion would be beneficial.
- What's the feedback from the energy consultants? Have they torn your measurements to pieces?
    - No, they want pre- and post validations. These have been carried out successfully
    - A complete data set is the most important for the consultants

- Is there a statistical approach that tells you how many months you need to measure?
    - Not sure.
- Should we combine satellite approaches with floating?
    - There will be a phd on floating lidar at DTU with IWES, including wind information from satellite data
- There is a trend to move lidars from bouys to bigger ships.

10:15	Coffee

Get Stuff Done!

10:30	Get stuff done! A quick introduction and then 90 minutes to make progress on the ideas that have come out of the meeting so far. You could set out your plans for the next step(s), get started on some work, or do whatever helps. The important thing is that you feel like you've used your time here productively.
12:00	Reporting Sharing what you discussed in the World Cafe session or worked on afterwards
13:00	Lunch

Calibration

- 3-4 months campaigns are impractical→ there is an appetite to change
- Different stakeholders want to change
- The suggestion is to establish a working group on this subject.
- People interested in the working group are asked to contact the Operating Agent.

Floating lidar

Two topics were discussed:

- How does different mooring impact the device? RP 18 does not go into detail.
- There is a need for a protocol for swapping instrumentation.

FAIR lidar data

A group discussed the lidaco common data format (outcome from the E-Wind Project)

- DTU has additional work on the topic and will share with interested parties (USTUTT, IWES, ZSW, EnBW)

SMART Lidar for control

- The controls group discussed the idea of a smart lidar where users can install custom “apps” to process the raw lidar measurements for control applications. The idea is that these software modules can be used in simulation as well as in the lidar hardware, making certification easier.
- The group also talked about providing an open repository to foster LAC research by the community with a common simulation environment for lidar control applications together with reference turbine models

- DLLs can be provided for wind field reconstruction, baseline controller, feedforward controller, maybe lidar

DTU Site Tour

13:00	Lunch
Afternoon	DTU site tour

Meeting Ends

16:00	Close

Participants

The following people attended all or part of the 2019 General Meeting.

Jacob Burrows	EDF Energy R&D UK
Ines Würth	SWE, University of Stuttgart
Carolin Schmitt	EnBW
Iaonnis Antoniou	Siemens Gamesa Renewable Energy
Tobias Ahsbahs	DTU
Pedro Santos	DTU Wind Energy
Katherine Dykes	DTU Wind Energy
Torben Mikkelsen	DTU Wind Energy
Alexander Stökl	Energiewerkstatt
Paula Gomez	DTU Wind Energy
Dominique Held	Siemens Gamesa Renewable Energy
Christos Tsouknidas	SGRE
Peter Clive	Black & Veatch
Masaharu Imaki	Mitsubishi Electric Corporation
Wiebke Langreder	EMD International A/S

David Schlipf	WETI
Sebastian Streitz	Nordex Group
Elin Svensson	DTU Wind Energy
Jakob Mann	DTU Wind Energy
Rozenn Wagner	DTU Wind Energy
Charlotte Hasager	DTU Wind Energy
Anna-Maria Tilg	DTU Wind Energy
Patrick Jones	Independent
Patrick Schwenk	Offshore Wind Consultants
Nicolas Jolin	Nergica
Eric Simley	National Renewable Energy Laboratory
Christopher Slinger	ZX Lidars
Atsushi Yoshimura	Green Power Investment
Reesa Dexter	DNV GL
Marie Hundhausen	Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW)
Guillaume SABIRON	IFP Energies Nouvelles
Will Laird	Wood
Jens Riechert	DNV GL
Alkistis Papetat	Fraunhofer IWES
Mikael Sjöholm	DTU Wind Energy
Hailong Zhu	Nanjing Movelaser Co., Ltd
Peter Rosenbusch	Leosphere
Wei Fu	sowento
Anders Pedersen	DTU Wind Energy
Adria Miquel	EOLOS Floating Lidar Solutions
Guillermo González Rilova	Windar Photonics A/S
Nikolaos Kouris	Windar Photonics A/S
Hans Verhoef	ECN part of TNO - Wind Energy

Jochen Cleve	Ørsted
Johan Olaison	DNV-GL
Rebecca Rivera Lamay	DTU Wind Energy