

New approaches to increase the acceptance of lidar measured TI in standardization

New recommended practice DNV-RP-0661

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27 February 2024

NEW Recommended Practice (RP) Lidar measured turbulence intensity (TI)

The complication:

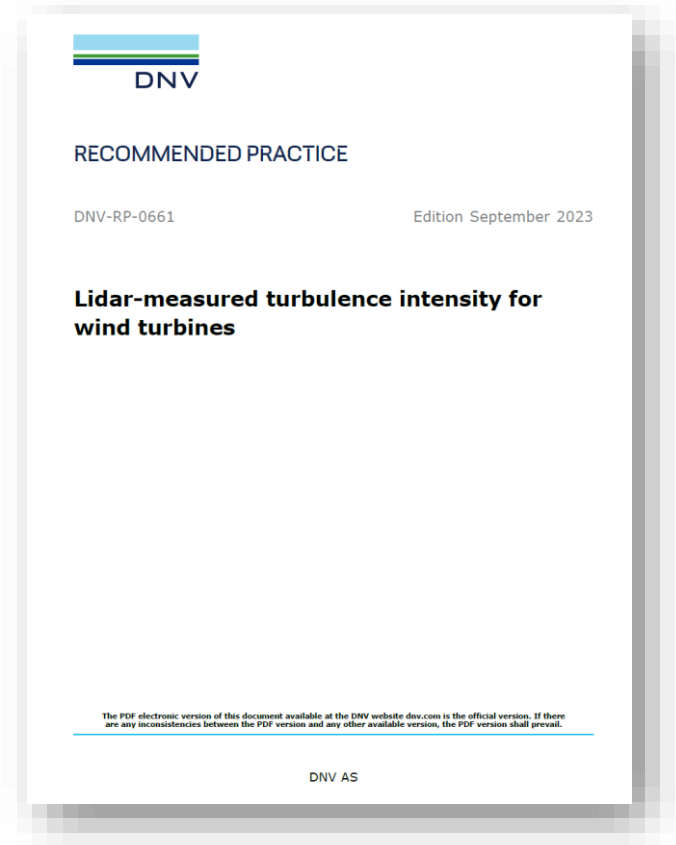
- Existing standards like IEC 61400-13 still require use of cups or sonics

Approach by DNV Joint Industry Project “Lidar Measured TI”

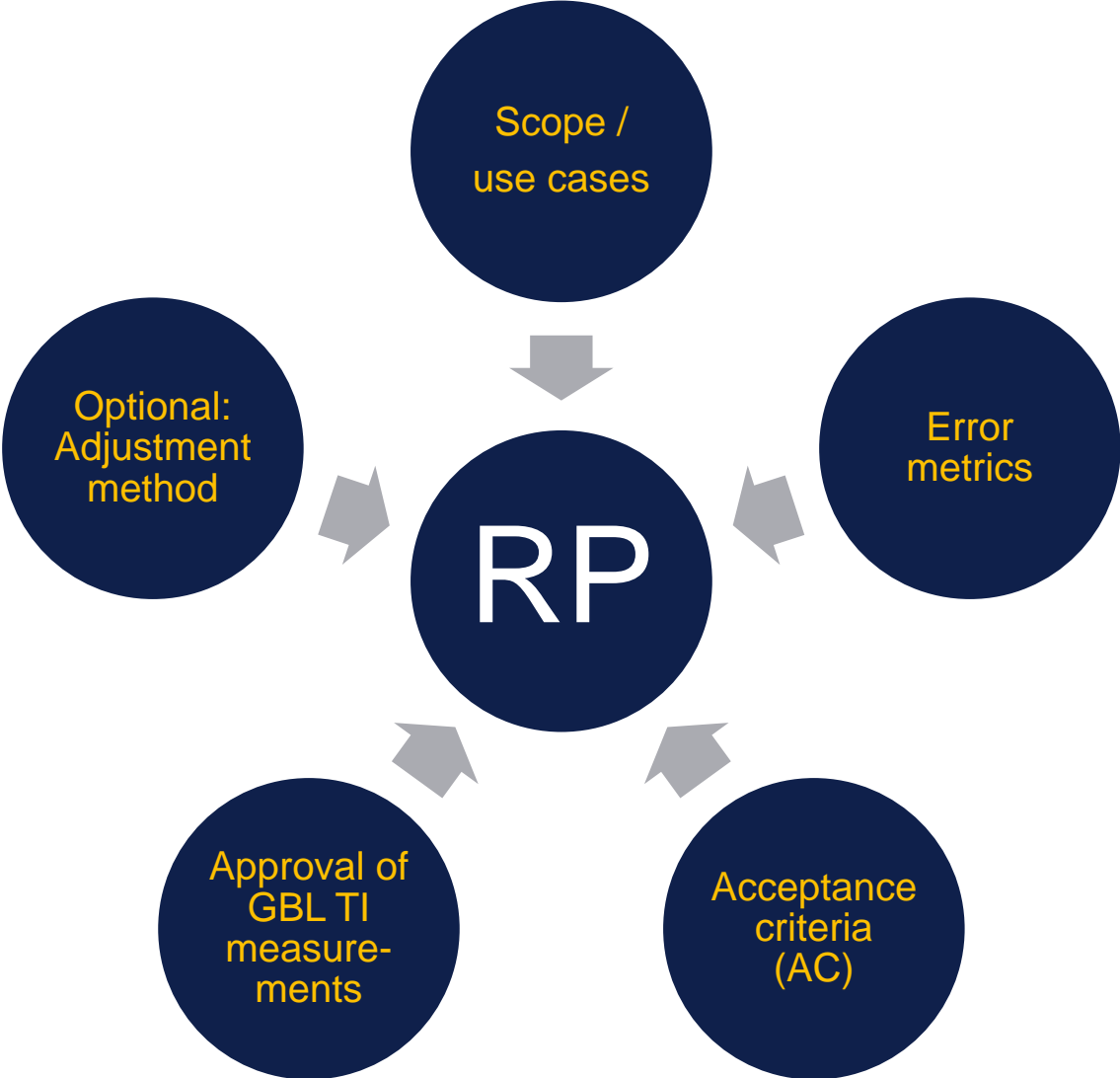
- Provide entry to the use of ground based lidar (GBL) TI data in certification by comparison to met mast data
- Issue RP

JIP partners:

EDFRe, EnBW, Equinor, Goldwind, IFPEN, Leosphere, RWE,
Shell, Southern Company Services, Vattenfall, ZX Lidars, DNV



DNV-RP-0661



Scope

Use cases for Ground Based Lidar (GBL)

- Loads:
 - site suitability
 - load validation type testing
- Energy assessment

Site complexity

- Onshore sites, flat terrain
- Offshore sites

Error metrics

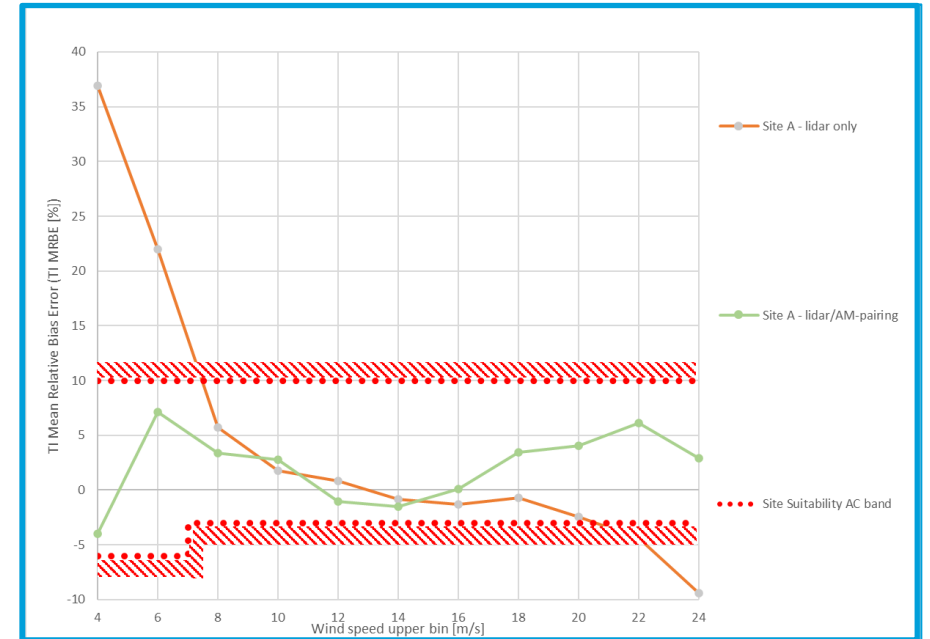
- Mean Relative Bias Error (MRBE) to indicate the mean deviation and Relative Root Mean Square Error (RRMSE) to describe the scatter between the observations
- Application in use cases requires bin wise processing of error metrics

$$TI MRBE_i [\%] = \frac{1}{N_i} \sum_{n=1}^{N_i} (TI_{lidar,n,i} - TI_{cup,n,i}) / TI_{cup,n,i}$$

$$TI RRMSE_i [\%] = \sqrt{\frac{1}{N_i} \sum_{n=1}^{N_i} ((TI_{lidar,n,i} - TI_{cup,n,i}) / TI_{cup,n,i})^2}$$

AC – use cases “loads”

- Stipulation of Acceptance Criteria for *site suitability, load validation type testing*



| Use case | MRBE requirement | RRMSE requirement | Condition |
|------------------|-----------------------------------|-------------------|-----------------------------|
| Site suitability | $-6\% \leq \text{MRBE} \leq 10\%$ | $\leq 30\%$ | for wind speeds below 7 m/s |
| | $-3\% \leq \text{MRBE} \leq 10\%$ | $\leq 15\%$ | for wind speeds above 7 m/s |
| Load validation | +/- 5% | $\leq 15\%$ | ./. |

AC – use case “energy assessment”

- **Guidance** for sensitivity of energy production based on TI

| Use case | MRBE requirement | RRMSE requirement | Condition / comment |
|-------------------|------------------|-------------------|--|
| Energy assessment | <±2% | - | Leads to modelled energy production changes by less than ±0.10% for approximately 95% of projects |
| | <±5% | - | Leads to modelled energy production changes by less than ±0.25% for approximately 95% of projects |
| | <±10% | - | Leads to modelled energy production changes by less than ±0.50% for approximately 95% of projects |

- Stipulation of **Acceptance Criteria**

$$TI \text{ MRBE} \leq \pm 10\%$$

(impact on modelled energy production is reasonable in comparison to other typical uncertainties in energy production assessments)

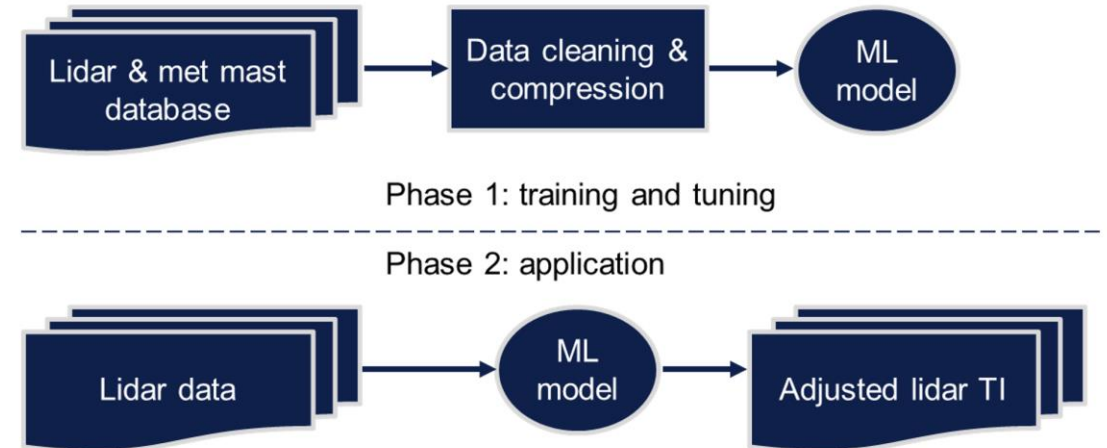
Approval of GBL TI measurements

- By comparison to co-located met mast TI measurements
- GBL TI can replace cup TI when AC are fulfilled; further requirements regarding wind speed range, min. number of data points
- Third party approval

- Measurement at site may continue without met mast.
- Relocation of lidar in vicinity of the verification site with the same wind flow exposure and characteristics

Add-on: turbulence intensity adjustment

- Adjustment method (AM): application able to reduce the error and scatter between GBL and cup TI
- Obtain GBL TIs that resemble cup TI to the best possible extent.
- Increase chances to comply with AC



Example flowchart for training and application of a machine learning based AM

➤ RP specifies a process that allows application of AM

Let's talk!

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