REPORT ON DATA VALIDATION OF OFFSHORE LIDAR (LIGHT DETECTION AND RANGING) INSTRUMENT WITH 120 M MET MAST

नीवे NIWE

(ISO 9001:2008)

PREPARED BY

NATIONAL INSTITUTE OF WIND ENERGY

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FACILITATING OFFSHORE WIND IN INDIA

EXECUTIVE SUMMARY

The EU Delegation to India, in close cooperation with the Indian Ministry of New and Renewable Energy, awarded the "Facilitating Offshore Wind in India (FOWIND)" project to the Global Wind Energy Council (GWEC) led consortium under the Indo-European Cooperation on Renewable Energy programme. The FOWIND project seeks to facilitate India's transition towards low carbon development by supporting implementation of national policies and programmes for offshore wind. FOWIND is a four-year project to develop a roadmap for offshore wind development in India, with a focus on the states of Gujarat and Tamil Nadu. In order to carry out onsite offshore wind profile measurement an offshore LIDAR was procured and handed over to NIWE.

The pulsed Offshore LIDAR was placed near 120 m meteorological mast located at Wind Turbine Test Station, Kayathar Tirunelveli district, Tamilnadu, India to validate the measured data from LIDAR with met mast. The terrain of the selected area is a homogeneous terrain, which is already known for its wind potential. The study area was selected by NIWE officials after a site visit This study tries to validate the LIDAR data by comparing it with measurements from the met mast for the same period in order to determine the correlation of the wind Data from both LIDAR and Mast and determine the correlation coefficient. The document explains the findings of the study.

Based on the analysis it was found that the LIDAR gives good correlation coefficients with the metrological mast wind speed & direction at inspected heights (60m, 90m, 120m) as shown below.

Correlation Coefficient (R^2) for Wind Speed

Description	120m	90m	60m
Mast v/s Lidar	0.998	0.997	0.997

Correlation Coefficient (R^2) for Wind Direction

Description	120m	90m	60m
Mast v/s Lidar	0.998	0.998	0.999

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REPORT ON DATA VALIDATION OF OFFSHORE LIGHT DETECTION AND RANGING (LIDAR) INSTRUMENT WITH MET MAST

1.0. INTRODUCTION

The EU Delegation to India, in close cooperation with the Indian Ministry of New and Renewable Energy, awarded the "Facilitating Offshore Wind in India (FOWIND)" project to the Global Wind Energy Council (GWEC) led consortium under the Indo-European Cooperation on Renewable Energy programme. The FOWIND project seeks to facilitate India's transition towards low carbon development by supporting implementation of national policies and programmes for offshore wind. FOWIND is a four-year project to develop a roadmap for offshore wind development in India, with a focus on the states of Gujarat and Tamil Nadu.

The business case for offshore wind farms relies on accurate wind resource assessments. Wind data for such an assessment may stem from various sources. Today, the most accurate wind data are generated using offshore meteorological masts, which are very expensive. LIDAR technology potentially provides a cost effective solution. In order to measure on-site offshore wind profiles in Gujarat offshore zones; an offshore LIDAR has been purchased and temporarily handed over to NIWE.

To make sure LIDAR provide reliable data, validation studies are necessity. National Institute of Wind Energy, Chennai has meteorological masts across the country with ranging from 50 m to 120 m. A pulsed Offshore LiDAR was placed near a 120 m meteorological mast located at Wind Turbine Test Station, Kayathar Tirunelveli district, Tamilnadu, India. The terrain of the selected area is a homogeneous terrain, which is already known for its wind potential. The study area was selected by NIWE officials after a site visit. This study tries to validate the LIDAR data by comparing it with measurements from the met mast for the same period in order to determine the correlation of the wind Scope:

SCOPE

The scope of the project is as given below:

- Finalization of the site for conducting the wind monitoring study using LIDAR and also visiting the location
- Installing the LIDAR at the selected location in parallel to the reference mast.

- Collecting and processing the data from met mast and LIDAR for an Analysis of data collected at the site.
- Prepare and submission of the report.

2.0 METHODOLOGY

1) The favorable site area was identified for the validation study. The location was visited by the team of scientists and Engineers for collecting ground truth information.
2) As briefed in the objective, the LIDAR was installed at a distance of 40m apart from the reference mast in parallel to the met mast.
3) Data have been collected for 52 days (22.05.2016 - 13.07.2016) from the met mast and from the LIDAR instruments.
4) The data sets have been analyzed and the validation results have been prepared.

3.0 SITE DESCRIPTION

The study area, which is chosen for the project is located at Kayathar, Tirunelveli district, Tamilnadu, India. The study area is a homogeneous terrain, which is already known for its wind potential. The land around the study area is having scattered bushes not more than 1m height. The study area is chosen in such a way that there are no obstructions to the wind flow from any direction. The study area was selected by NIWE officials after a site visit. The reference mast is located in the geographical coordinate of 8°57'13.25"N, 77°43'12.27"E. Geographical coordinates of LIDAR is 8°57'42.44"N, 77°43'12.16"E

Fig 1. Lidar and Mast position at Kayathar

4.0. INSTRUMENTATION

4.1. Description of Meteorological Mast

The meteorological tower (120m height) is used as reference for the wind LIDAR measurements validation (Fig. 4). The met tower layout follow the International Electrotechnical Commission (IEC) standards .Anemometers are fixed at 120m, 95m, 90m, 60m, 30m, 10m . Wind Vanes are fixed at 120m, 90m, 60m. Temperature Sensors mounted at 120m and 10 m height . The anemometers and the wind vanes are fixed on booms having length of 1.2m to avoid mast wakes. Lightning arrestor system is provided and grounded through copper conductor.

The data were logged in the EOL Zenith, the 3rd generation data logger from Kintech Engineering. The EOL Zenith measured with 1Hz sampling that can collect the time series data for wind speed, direction, temperature. The logger was programmed to store data averages, standard deviations, extended turbulence calculation (TI30), MAX and MIN for all input channels and advanced sensor error diagnosis (e.g. wind vane std. dev.) etc. from anemometer and wind vane. 10 minutes averaging interval has been chosen. The anemometer model is NRG40. Wind Vane model is NRG200P. Temperature sensor model is GaltechKPC.

4.2. LIDAR

Wind Cube LIDAR manufactured by Leosphere (France) was used for the study. The WindCube LIDAR is an active optical remote sensing instrument that transmits a continuous wave laser beam into the ABL (Atmospheric Boundary layer) and measures the scattered radiation received back at the instrument. Wind Cube has the capacity to capture the wind nature up to 300 m agl heights.

The instrument was fixed at 6m in north direction from the mast. It was programmed to measure at 10 levels from 40m to 200m. The parameters like horizontal wind speed, vertical wind speed, wind direction, turbulence intensity, standard deviation, minimum and maximum wind speed are recorded at 10 min interval as average values.

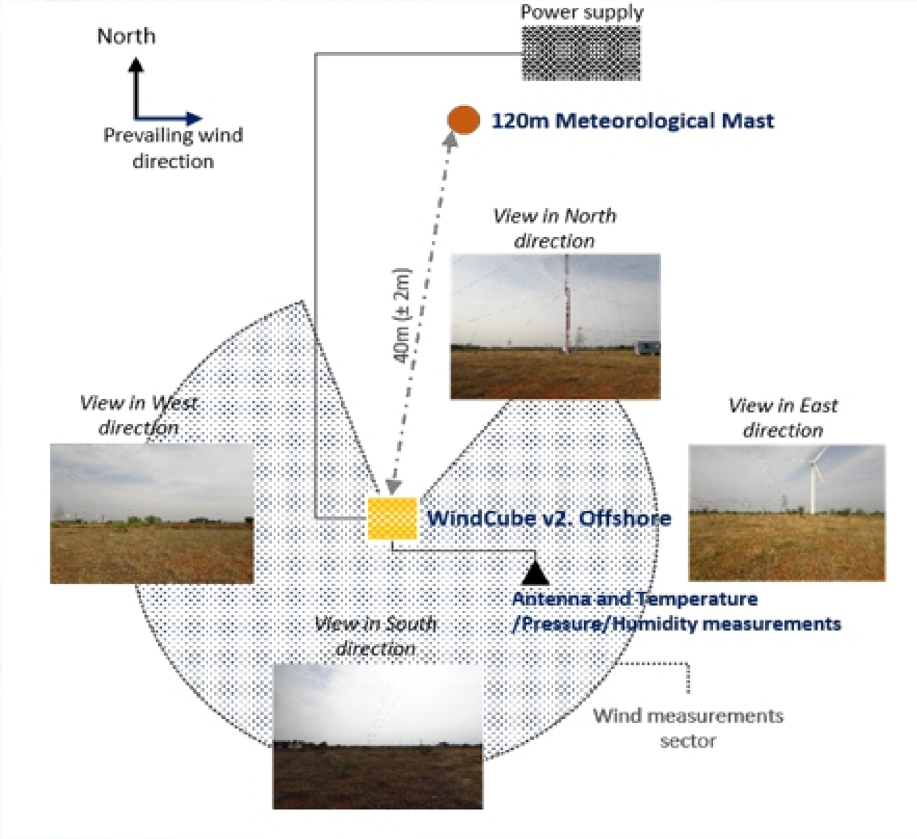

Fig 2. Installation of LIADR (Wind Cube)

Fig 3. 120m Mast

Fig 4. LIDAR setup

5.0. DATA ANALYSIS: CORRELATION COMPARISON

Since the LIDAR can measure from only from 40 m height onwards and the met mast has 10,30,60,90 & 120 m, a common height of 60m, 90m, 120m height values have been taken for validation and correlation analysis. All three data sets for the above said heights were checked for quality prior to the analysis. The concurrent period of data (52 days) has been taken for the analysis. The validation has been performed with respect to the following three parameters.

- Horizontal Wind Speed
- Wind Direction
- Turbulence Intensity

5.1. Wind Speed Comparison

The horizontal wind speed correlation has been carried out by linear regression method and by time series analysis. Time series analysis and wind speed distribution is performed in order to graphically visualize variation of wind speed. and the correlation results at all three heights (60m, 90m, 120m) can be shown in Table1 and Figs 2-5. Scatter plots of 10-min averaged horizontal wind speed for one height are displayed in Figure 9-14. Two models of the linear regression analysis (with (y=ax+b) and without (y=mx) offset) are considered. 99.8% of the measured data have been considered for the wind speed analysis. The correlation analysis shows that the wind speeds from the LIDAR system agree well with the tower measurements with values of R^2 higher than 0.99 for all heights.

Table 1.Correlation Coefficient (R^2) for Horizontal Wind Speed

Description	120m	90m	60m
Mast v/s Lidar	0.998	0.997	0.997

The graph (Fig 5-8) shows the comparison of the wind speeds measured by the LIDAR with those of the 120 meters onshore met mast at Kayathar.

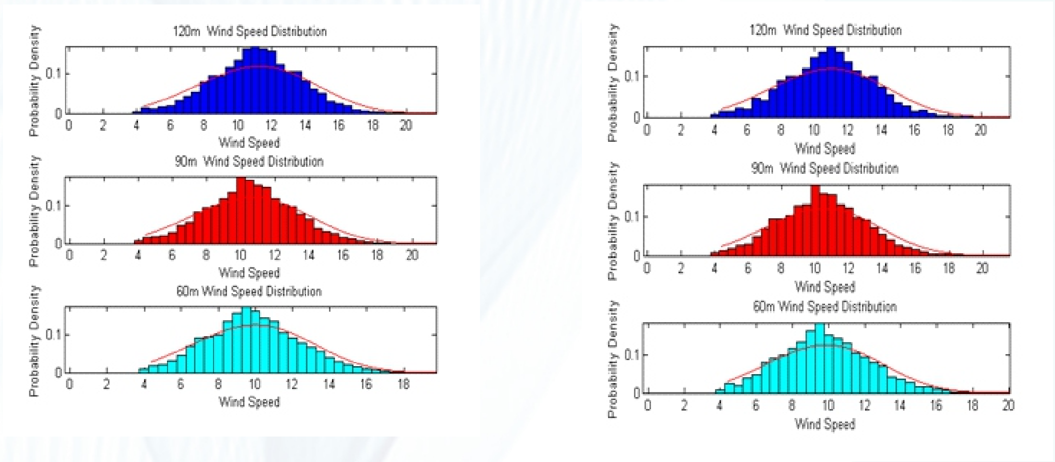

Fig 5. Wind Speed distribution of LIDAR v/s Met-Mast

Time Series Analysis - Mast VS LIDAR

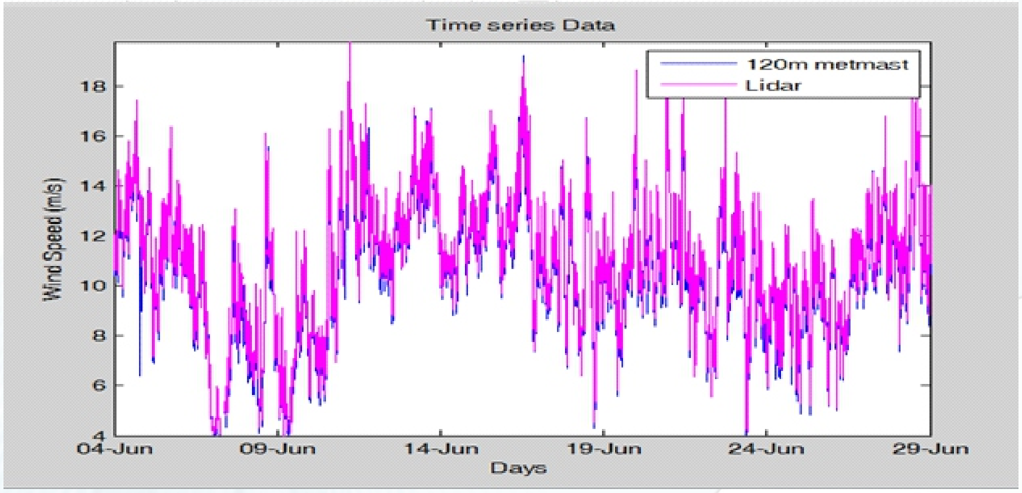

Fig 6. Time series Analysis at 120m level met mast and LIDAR

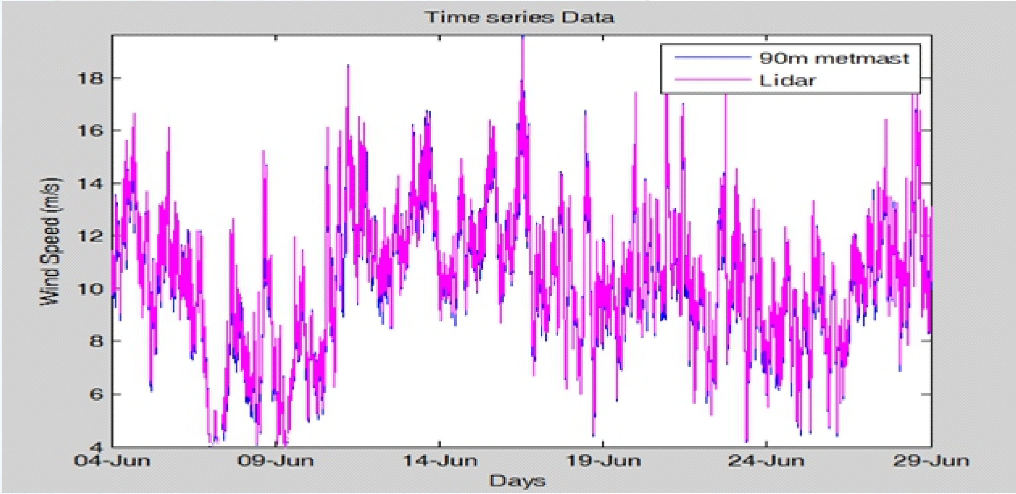

Fig 7. Time series Analysis at 90m level Wind Mast Vs LIDAR

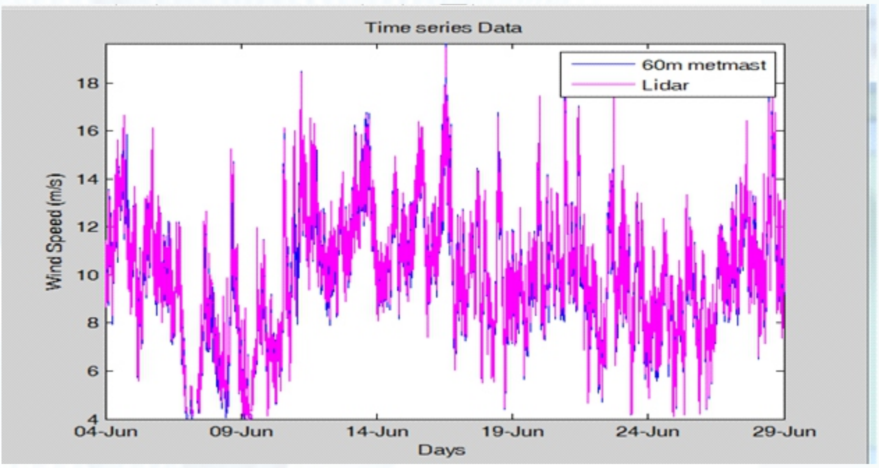

Fig 8. Time series Analysis at 60m level met mast and LIDAR

Correlation of Mast and LIDAR at 120m Wind Speed (y = ax+ b)

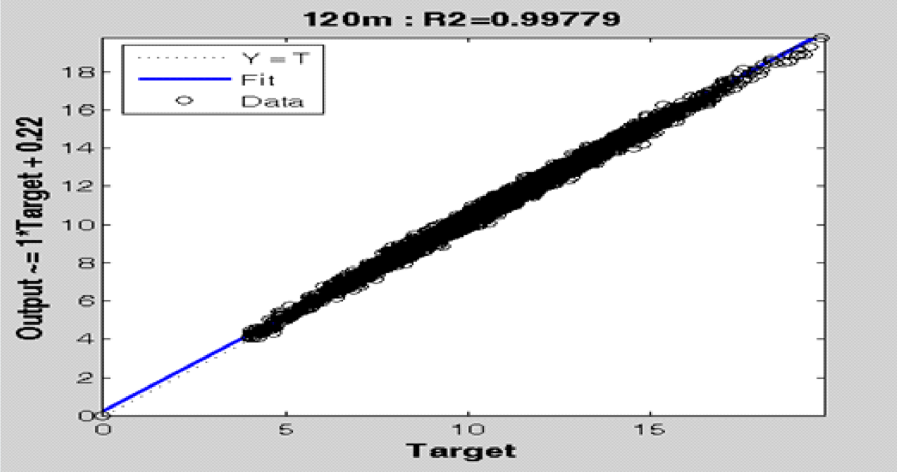

Fig 9. Regression plot for 120m

Correlation of Mast and LIDAR at 90m Wind Speed (y = ax+ b)

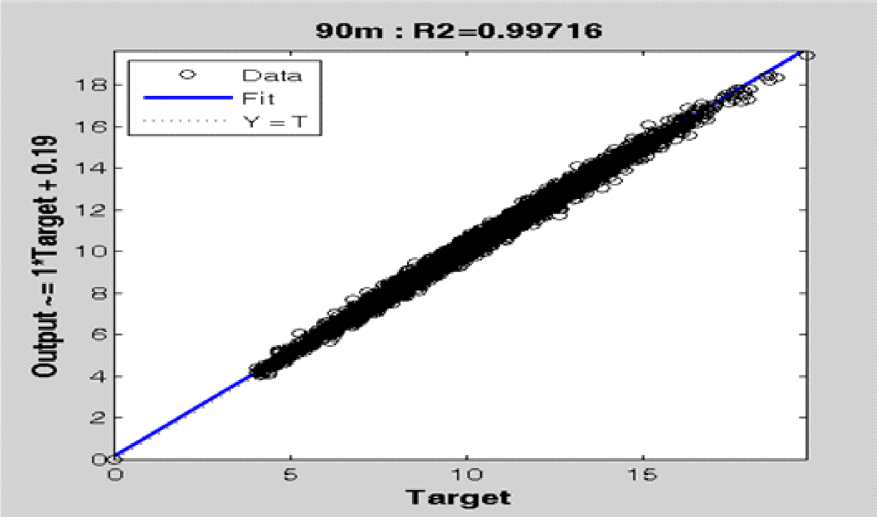

Fig 10. Regression plot at 90m

Correlation of Mast and LIDAR at 60m Wind Speed (y = ax+ b)

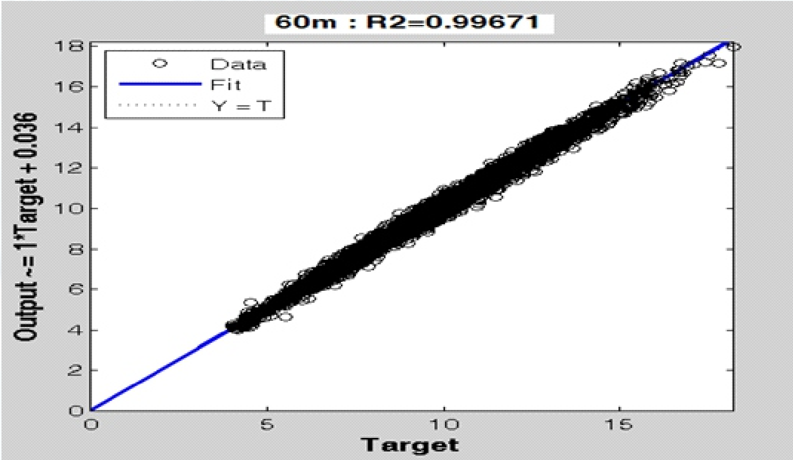

Fig 11. Regression Plot at 60m

Correlation of Mast and LIDAR at 120m Wind Speed (y = mx)

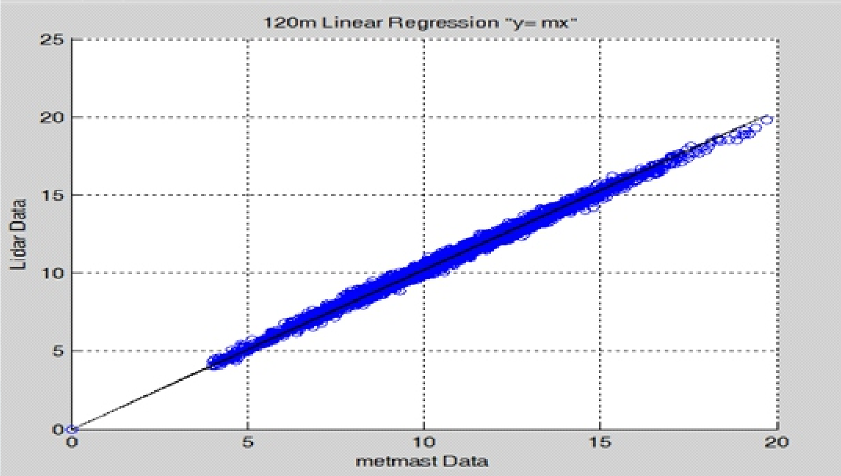

Fig 12. Regression plot for 120m

Correlation of Mast and LIDAR at 90m Wind Speed (y = mx)

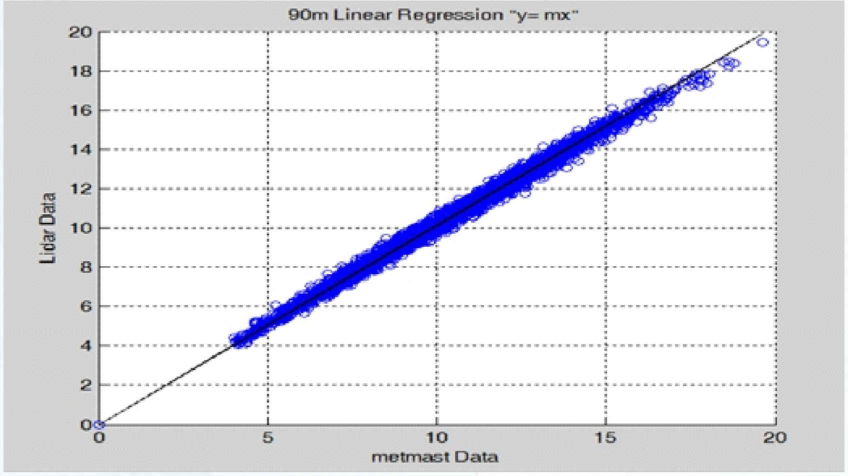

Fig 13. Regression plot for 90m

Correlation of Mast and LIDAR at 60m Wind Speed (y = mx)

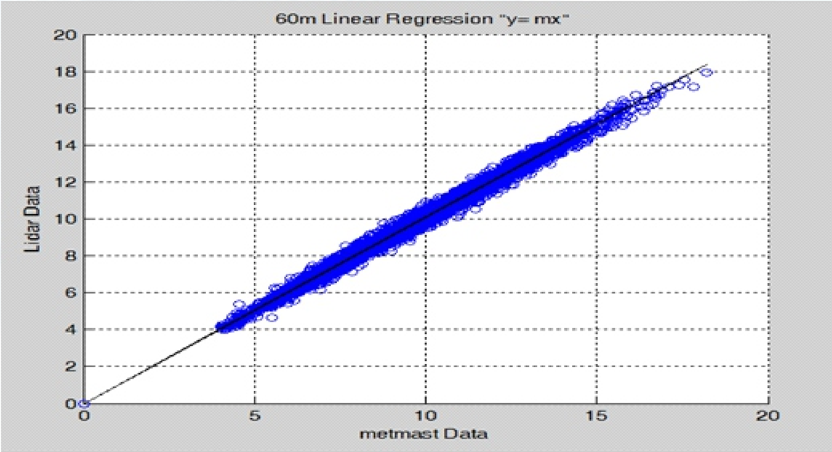

Fig 14. Regression plot for 60m

5.2. Wind Direction Comparison

Wind direction measured from all the three measuring instruments are used for the correlation analysis. The momentum effects of cup anemometers may cause poor correlation at lower wind speeds. Hence wind direction values for low wind speeds (less than 2 m/s) have been filtered out from the data sets.

Further there are some erroneous values found with LIDAR measurements have also been filtered out. After removing those values, the correlation has been done and the results are shown in Table 2 and Figs 15-17. The data availability is also shown along with the figures.

Table.2 Correlation Coefficient (R^2) for Wind Direction:

Description	120m	90m	60m
Mast v/s Lidar	0.998	0.998	0.999

Correlation of Mast and LIDAR at 120m

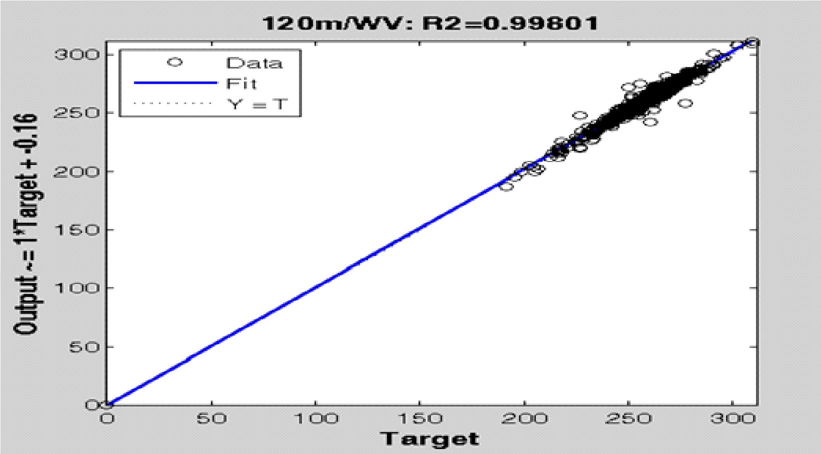

Fig 15. Regression plot for Wind direction at 120m

Correlation of Mast and LIDAR at 90m

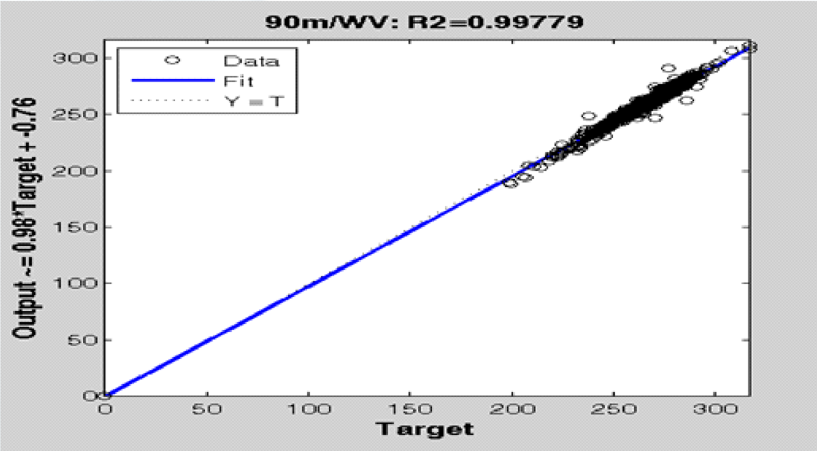

Fig 16. Regression plot for Wind direction at 90m

Correlation of Mast and LIDAR at 60m

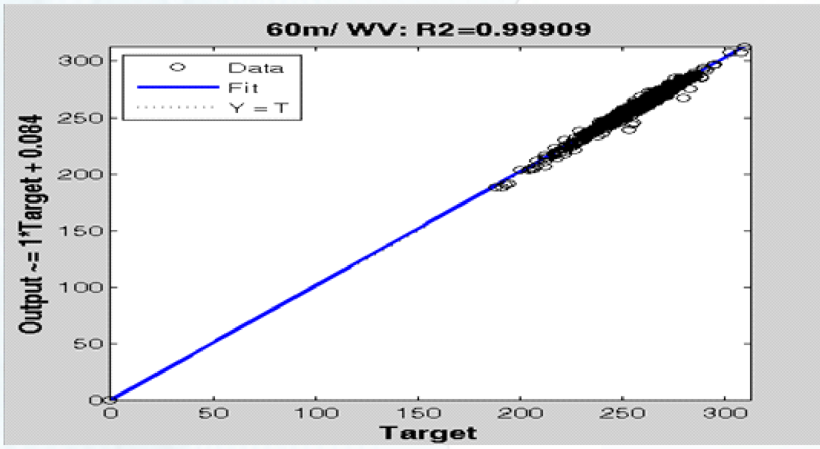

Fig 17. Regression plot for Wind direction at 60m

5.3. Turbulence Intensity Comparison

Turbulence Intensity analysis graphs for Mast and LIDAR are shown Fig18. Turbulence intensity (TI) measurements from the LIDAR are inherently different from those from the meteorological tower. The LIDAR measures over a volume and the meteorological tower measures at a single point, and while the meteorological tower measures the horizontal component of the turbulence, the remote sensing instruments capture mainly the vertical variability. This could be the main reason for the variation.

Turbulence Intensity - Mast VS LIDAR

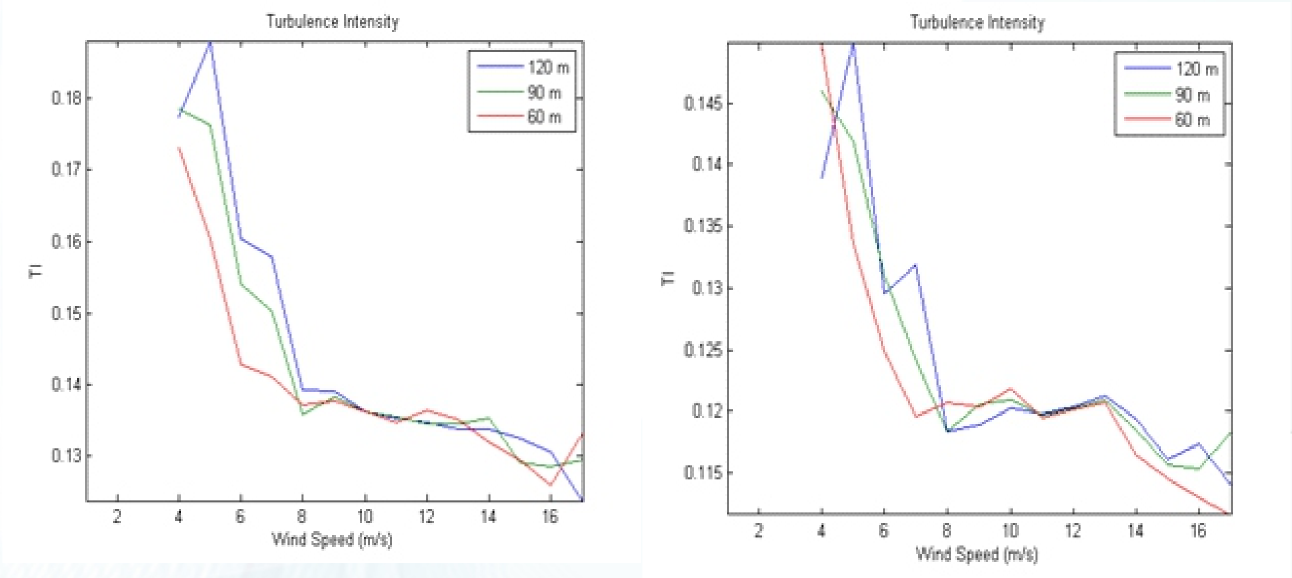

Fig18. Turbulence intensity graph of Mast and LIDAR

6.0. CONCLUSION

LIDAR with the help of 52 days measurement data obtained from 120 m height Met Mast validation has been completed. 10 minutes' average data samples are considered for the analysis. As per the study LIDAR gives good correlation coefficients with the meteorological mast wind speed & direction and LIDAR wind speed & direction at all the three inspected heights (60m, 90m, 120m). The comparison of the 10 min Lidar wind speed data with mast data shows a high correlation of R^2 higher than 0.99 for all heights. From the results presented in this work, it is clear that the wind Lidar is capable of measuring the wind resource to at least the same standard as a met mast, with very comparable values of wind speed and wind direction

Correlation Coefficient (R2) for Wind Speed

Description	120m	90m	60m
Mast v/s Lidar	0.998	0.997	0.997

Correlation Coefficient (R^2) for Wind Direction

Description	120m	90m	60m
Mast v/s Lidar	0.998	0.998	0.999

7.0 ACKNOWLEDGEMENTS

This work is part of the offshore wind resource assessment programme on "Facilitating Offshore Wind in India (FOWIND)" project to the Global Wind Energy Council (GWEC) led consortium under the Indo-European Cooperation on Renewable Energy. The authors are grateful for the considerable technical support from the staff of WRA, NIWE and FOWIND forum.

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NATIONAL INSTITUTE OF WIND ENERGY (NIWE)
Chennai 600 100

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