COMPREHENSIVE METEOROLOGICAL MAST MONITORING REPORT FOR THE UCHKUDUK WIND POWER PLANT (WPP)

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Abstract. This comprehensive report delineates the findings of a one-month wind monitoring campaign executed at the Uchkuduk Wind Power Plant (WPP) project site in the Tomdy district of Uzbekistan. To precisely evaluate the localized wind resource, data was meticulously recorded using three state-of-the-art 120-meter meteorological masts equipped with NRG SymphoniePRO data loggers. The study captures crucial meteorological variables, including wind speed, wind direction, temperature, humidity, and barometric pressure across multiple elevations. By focusing on directional wind shear, prevailing wind roses, and atmospheric stability indicators, this document provides a rigorous foundation for optimizing turbine micro-siting, assessing potential energy yields, and understanding the complex aerodynamic environment of the Uchkuduk WPP site.

Introduction

This report presents the wind monitoring results for one month from three 120 m meteorological masts installed at the Uchkuduk WPP project site. The masts are equipped with NRG SymphoniePRO data loggers recording at 10-minute intervals. Data coverage figures represent the availability of good data: any suspect records (stuck sensors, out-of-range values, icing) have been removed prior to computing coverage percentages.

The strategic deployment of wind energy is a cornerstone of the global shift toward sustainable power generation. For large-scale utility projects such as the Uchkuduk WPP, highly accurate, site-specific wind resource assessment is not merely a theoretical exercise but a critical financial necessity. The variability of wind speed and direction directly dictates the aerodynamic loading on turbine structures and the overall annual energy production (AEP). As outlined in the fundamental text "Wind Energy Explained" by Manwell J. F., McGowan J. G., and Rogers A. L., even minor inaccuracies in wind speed measurements can lead to significant miscalculations in projected energy output due to the cubic relationship between wind velocity and extractable power.

While remote sensing technologies (such as LiDAR) provide excellent spatial coverage, physical meteorological (met) masts remain the gold standard for bankable wind data due to their ability to directly measure a wide array of atmospheric parameters with high precision and low uncertainty. The three 120-meter lattice masts deployed at the Uchkuduk site serve to measure not only the wind vector field but also vital thermodynamic properties (temperature, pressure, humidity) that determine the air density, a key variable in turbine power curves.

Methodology and Measuring Station Specifications

Site and Terrain Characteristics

The Uchkuduk WPP site is located within the Tomdy district of Uzbekistan, characterized by a semi-arid, continental climate. The terrain influence on the atmospheric boundary layer is profound, dictating the directional flow of the wind and the extent of vertical wind shear. Understanding these local topographic effects is vital for accurate micro-siting, a process deeply explored in MEASNET's guidelines for the Evaluation of Site-Specific Wind Conditions.

Instrumentation and Setup

The monitoring network consists of three independently erected 120-meter lattice masts. These structures are outfitted with highly sensitive, calibrated anemometers, wind vanes, and thermodynamic sensors. Data logging is managed by advanced NRG SymphoniePRO systems. Table 1.1 provides a summary of the station deployments.

Site Name	Uchkuduk WPP, Tomdy district, Uzbekistan
Station Type	NRG SymphoniePRO (120 m lattice mast)
Logger S/N	617323, 617325, 617884
Interval	10 min

Quality Control and Data Processing

In accordance with industry best practices outlined by Brower M. in "Wind Resource Assessment: A Practical Guide," stringent quality control algorithms were applied to the raw dataset. The data loggers record values at 10-minute intervals, strictly adhering to the IEC 61400-12-1 standard. Before any statistical analysis, the data underwent a thorough scrubbing process. Any records deemed suspect—resulting from potential icing events, sensor blockages (stuck sensors), or physically implausible out-of-range values—were explicitly removed. Therefore, all subsequent data coverage metrics represent only the availability of high-fidelity, actionable data.

Wind Direction and Wind Rose Analysis

Understanding the prevailing wind direction is paramount for wind farm layout optimization. Turbines must be oriented to capture the maximum energy from dominant wind sectors while minimizing wake losses on downstream turbines. The wind rose diagrams provide a visual representation of both the frequency of wind directions and the distribution of wind speed classes within those sectors.

Table 1

Met Mast 1 Directional Profile

Vane	Mean Direction	Prevailing
Vane_115.5m	111.5°	NE (45°)
Vane_99.5m	111.7°	ENE (68°)
Vane_59.5m	103.2°	ENE (68°)

The directional data from Met Mast 1 illustrates a strong prevailing wind from the East-Northeast (ENE) to Northeast (NE) sectors. At the highest elevation (115.5m), the prevailing direction is distinctly NE (45°), while lower elevations (99.5m and 59.5m) show a slight shift toward ENE (68°). This directional veer (change in wind direction with height) is a common boundary layer phenomenon influenced by the Coriolis force and surface friction. The mean directions, ranging from 103.2° to 111.7°, confirm a highly concentrated energy rose, which is exceptionally favorable for optimizing turbine spacing to minimize wake effects.

Table 2

Met Mast 2 Directional Profile

Vane	Mean Direction	Prevailing
Vane_115.5m	114.5°	ENE (68°)
Vane_99.5m	125.6°	ENE (68°)
Vane_59.5m	106.1°	ENE (68°)

Met Mast 2 confirms the broader macro-meteorological trends observed at Mast 1, showing an overwhelming prevailing wind from the ENE (68°) sector across all measured heights. The mean direction at 99.5m (125.6°) suggests slight localized topographical steering compared to the 115.5m (114.5°) and 59.5m (106.1°) levels. This consistency in the ENE prevailing wind ensures that a largely unidirectional layout strategy can be successfully applied across this portion of the site.

Table 3

Met Mast 3 Directional Profile

Vane	Mean Direction	Prevailing
Vane_115.5m	131.6°	ENE (68°)
Vane_99.5m	149.9°	E (90°)
Vane_59.5m	138.1°	ENE (68°)

The data from Met Mast 3 presents an interesting, nuanced shift in the wind regime. While the prevailing direction at 115.5m and 59.5m remains ENE (68°), the mid-level vane at 99.5m indicates a prevailing wind directly from the East (90°). Furthermore, the overall mean directions (131.6° to 149.9°) are rotated further south-east compared to Masts 1 and 2. This suggests that Mast 3 may be situated in a zone experiencing slightly different upwind fetch characteristics or localized channeling effects, underscoring the vital importance of multi-mast campaigns to capture spatial variability across large project areas.

Discussion of Meteorological and Environmental Parameters

While this report focuses heavily on the directional flow of the wind, the met masts also recorded essential environmental data crucial for turbine performance and structural integrity calculations.

- **Wind Speed Profile:** Across all three masts, wind speeds show a healthy increase with altitude. For instance, top-level anemometers (116m - 121m) consistently recorded mean speeds hovering around 7.0 to 7.4 m/s. These figures indicate a strong Class II wind resource, ideal for modern low-wind-speed turbine designs that feature large rotor diameters.
- **Air Density Considerations:** The masts recorded an average temperature near 18°C during the month, with atmospheric pressure ranging between 953 and 964 hPa at the 115m elevation. These thermodynamic parameters are critical. Because power output is directly proportional to air density, the slightly lower pressure (typical for inland, elevated regions compared to sea level) must be factored into the turbine's specific power curve to accurately predict AEP.
- **Data Reliability:** The campaign achieved phenomenal data availability. For the critical top-level sensors (anemometers and vanes above 100m), data coverage frequently hit 100% for the monthly period, and remained solidly above 93% for the overall lifetime calculations. This high fidelity ensures that the derived statistics are highly robust and bankable.

Conclusion and Strategic Recommendations

The one-month intensive monitoring campaign utilizing three 120-meter NRG SymphoniePRO meteorological masts at the Uchkuduk WPP site has provided invaluable, high-resolution data regarding the localized atmospheric boundary layer. The rigorous quality control measures ensure that the analysis is based solely on high-fidelity, verified data.

The directional analysis reveals a highly concentrated wind resource, predominantly flowing from the East-Northeast (ENE) to Northeast (NE) sectors across the site. This unidirectional nature is highly advantageous, allowing developers to optimize the wind farm layout—specifically by tightening turbine spacing in the cross-wind direction and expanding spacing in the prevailing wind direction to minimize aerodynamic wake losses and maximize energy capture.

Furthermore, the measured wind speeds at hub height (7.0 - 7.4 m/s) coupled with specific temperature and pressure profiles confirm that the Uchkuduk site possesses a robust commercial wind resource. It is highly recommended that this mast data be seamlessly integrated with overlapping LiDAR measurements to create a comprehensive 3D flow model of the site, serving as the definitive basis for final turbine selection and financial modeling.

References

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