Journal of Climatology & Weather Forecasting 2023, Vol. 11, Issue 1, 001-003

Mini Review

Natural Hazard Risks for Farms

Ricardo Daniel*

Editorial office , Journal of Climatology & Weather Forecasting, United Kingdom

Corresponding Author*

Ricardo Daniel
Editorial office,
Journal of Climatology & Weather
Forecasting United Kingdom
E-mail: Climatolres@journal.com

Received: 15-Jan-2023, Manuscript No. JCWF-23-21649; **Editor assigned:** 17-Jan-2023, PreQC No. JCWF-23- 21649 (PQ); **Reviewed:** 23-Jan-2023, QC No. JCWF-23-21649 (Q); **Revised:** 28-Jan-2023, Manuscript No. JCWF-23-21649 (R); **Published:** 31-Jan-2023, DOI: 10.35248/2332-2594.23.11(1).1-3

Abstract

In recent years, technological innovation has resulted in larger and higher Wind Turbines (WTs) with increased power generating capacity. Natural hazard risk quantification may be used safely and productively. This research focuses on the threats to WTs posed by earthquakes, high winds, hurricanes, tsunamis, and lightning. In response to these dangers, the structural failure of the blades, towers, and foundations was explored. Furthermore, research from the last few decades on failure modes such as foundation overturning, tower tilting, tower buckling, blade buckling, deformations, and blade delamination was examined. Analytical, statistical, and data-based models, as well as experimental research, were discovered to be utilised by researchers.While earthquake, wind, and hurricane threats have previously been investigated using analytical, experimental, and statistical models, future research should focus on the most recent methodologies incorporating data-based models, data integration, and physics-based models.

Keywords: Wind turbine • Natural hazard• Earthquake • Tsunami • Hurricane

Introduction

Wind energy has emerged as a significant source of clean, renewable energy and an essential component of the global energy portfolio . The cumulative worldwide wind power capacity has reached 837 GW. Wind power contributes for more than 20% of total renewable energy In 2020, the global installed wind power capacity was 745 GW, including 135.843 GW in the United States of America. Offshore Wind Turbine (OWT) installations have increased at an exponential rate. In 2022, the installed global OWT capacity will be 54.9 GW [1]. The worldwide OWT market forecast appears to be optimistic, with average annual growth rates of 18.6% through 2024, then 8.2% until the end of 2030.

Offshore wind generation is predicted to contribute 20 GW by 2025, followed by another 30 GW by 2030. When compared to 2020, worldwide offshore wind capacity expanded by 50% in 2021. Major European governments are investing in OWTs, with the goal of generating 150 GW of power from them by 2030. According to the World Energy Outlook Report 2016, wind power might meet 22% of global energy consumption, or 9318 TWh, by 2050.
The output of wind energy is proportional to the square of the wind velocity. Wind turbine heights have grown as technology has advanced, allowing for greater winds at higher elevations.

Risks from earthquake for onshore wind farms

Seismic activity and intensity vary regionally, with certain places experiencing high-intensity seismic loads; hence, wind turbines must be designed for specific locations [2]. Agbayani employed seismic loading based on the Uniform Building Code in his site-specific seismic study. Professional groups and manufacturers often produce standards that focus on overall safety and performance analyses, such as response spectrum analysis and time history analysis. Building requirements for wind turbine design differ, but the goal is to minimise interruptions in operations caused by mechanical components.Turbines should meet Serviceability Limit States (SLS) such as the tilt at the tower top, to guarantee normal operation. Another distinguishing feature of wind turbines is that they have a longer natural period than other buildings of the same height.For example, the mass at the tower top (blades and nacelle) might be more than the tower's mass, resulting in a lengthy natural period. Given the structural differences between wind turbine towers and buildings, evaluating wind turbine structural performance is critical. Seismic loads may be divided into two categories: near-fault and far-fault loads. Slender structures, such as wind turbine towers, might be predicted to respond differently to near-fault and far-fault seismic activity.

The reactions of structures to the same loading characteristics have been discovered to change depending on the structure's attributes. Anderson and Bertero investigated uncertainty in earthquake design. According to the authors, the type of a structure has a major influence on the response characteristics. Near-fault earthquakes with long-duration velocity pulses produce dramatically different reactions than far-fault earthquakes in the same structure [3].Patil et al. assessed the structural performance of parked wind turbines subjected to seismic stresses using probability-based fragility algorithms. To examine the structural performance of an 80 m tall wind turbine tower, the authors investigated 15 close faults and 17 distant faults with seismic loads scaled 2.5 times.Lavassas et al. investigated wind turbine towers in seismic locations using eigenvalue analysis and response spectrum analysis in accordance with Eurocode criteria. The investigation revealed that the von Misses stress was larger around the door opening at the foot of the tower. Despite the fact that larger stresses were reported as a result of wind loading, the authors] emphasised the need of seismic analysis for structural design.

Wind turbine failures are uncommon due to the long return period and paucity of high-magnitude seismic occurrences; yet, they are projected to occur. Even if a wind turbine does not completely collapse, a partial failure of one turbine can impede the regular operation of a whole wind farm for an extended period of time. Interrupted power generation and turbine failure result in massive financial losses for wind energy developers, operators, owners, and insurance companies; hence, wind turbine structures must undergo performance evaluation, vulnerability assessment, and risk assessment.

Risk from strong wind for onshore wind turbines

High-wind-speed designs are recommended in codes and standards. The International Electrochemical Commission (IEC) [4] covers several areas of wind turbine design, such as general design standards (IEC61400-1:2005 + AMD1:2010) and design requirements for OWTs (IEC61400-3:2009). Despite adherence to these criteria and certifications, wind turbine failures due to high-velocity wind events, such as hurricanes, occur often. Due to high-velocity wind, a wind turbine tower fell at the bottom part.

Using probability-based statistical methodologies, researchers have investigated and assessed wind turbines for dependability and performance throughout the last few decades. Quilligan et al. investigated steel and concrete towers using displacement-based fragility analysis. Kawai et al. devised a technique for estimating the force acting on the blades, nacelle, hub, and tower of a wind turbine owing to severe storms.

Rose et al.utilised empirical formulae to determine which thin-walled cylinders would be suitable for perfect structures. Wind turbines are not perfect constructions, with varied stiffness, geometry, and mass distributions [5]. The reaction of a turbine was discovered to be affected by the door and cable opening at the bottom . Wind direction and strength are not consistent and change all the time.

Because of this transient element of load, the response characteristics of thin structures, such as wind turbines, are subject to transitory uncertainty. The most appropriate strategy for dealing with such uncertainty is fragility analysis. Fragility analysis has been applied to analyse wood structures , wind turbine long-term design loads , and bridge fragility in an Applied Technical Council paper.Various scholars have also constructed fragility curves using analytical approaches. Analytical approaches for fragility curves include the elastic spectra method , the nonlinear static method, the nonlinear dynamic method, and Hwang and Huo's hazard curves . For highway bridges, component fragilities were employed to assess system fragility.

Risk from hurricanes for offshore wind farms

Offshore wind farms are vulnerable to hurricane wind and waves. For intense windstorms, researchers employed catastrophic modelling approaches, Monte Carlo simulation, the log-logistic function, and the Weibull distribution to assess financial risk for insurers and owners of Offshore Wind Farms (OWFs). Hallowell et al. investigated the probability of a single OWT from hurricane forces using structural models and a synthetic database in 2018.Rose et al. (2012) conducted a risk assessment to evaluate hurricane risk for OWTs in the United States' Atlantic and Gulf coastal waters. According to the study, the highest speed during hurricanes exceeds the design limitations, resulting in buckling failures. In reaction to hurricanes of categories 3, 4, and 5, almost 90% of wind turbines bowed.

Sun et al. investigated complicated electrical systems and their interference using copula functions. Su and Fu (2014) investigated the effect of wind speed on subassemblies using the causal and BN models. Chen et al. used Supervisory Control and Data Acquisition (SCADA) data to examine problem diagnosis in OWTs [6]. Several sophisticated structural analysis models have been constructed to analyse the performance of individual wind turbine towers, earthquakes, and wave and wind forces; however, little research has been conducted to integrate OWF vulnerability analyses with operational failures.

Another research, 2022 by Lu and Zhang, employed a physics-based model and a Bayesian network model to anticipate power outages during a storm. Li and Soares investigated the reliability and failure behaviour of OWTs using a hybrid Bayesian network model to propose maintenance intervals. Bayesian network models that use system reliability to solve faults have gained favour in the investigation of causal linkages and conditional probability.

Risks from tsunamis for offshore wind farms

Tsunamis are a sequence of waves with large wave lengths and durations that occur as a result of geological disturbances such as earthquakes or volcanic eruptions. Significant wave forces and scour caused by tsunamis pose significant hazards to the foundations of OWTs.

Bhattacharya et al. (2021) address the technological readiness level of wind turbine towers as well as the primary barriers to effective installation. This paper provides an overview of the loads impacting wind turbines, including wind, seismic, and wave activities.

The authors also go through the rules that control serviceability limit states. Furthermore, they cover the verification and validation of models for the foundations (monopile, spar-type floating) of OWTs and their mechanisms (just the foundations, the entire system with an actuator, and the entire system with an eccentric mass) using experimental data. The article discusses hydrodynamic loads and soil-structure interactions, including one-way and two-way cyclic loads.

Sanchez et al. (2019) investigated OWF facilities in use across the world as well as the most common foundation designs, as well as the evolution and specifications of monopiles used in operational wind turbine towers. Furthermore, the study proposed a database model of a monopile that used monomials as features to allow for a better understanding of variable correlation [7]. Foroughi et al. (2009) studied the wave properties and the four types of wave forces that occur during tsunamis (non-breaking wave forces, breaking wave forces, broken wave forces, and uplift forces).

The moment and forces created by the waves influencing the pile foundations were calculated using the Morison equation. The largest force applied on the pile when the angle of the wave impact was between 0 and 20 degrees, according to this study. Amani et al. (2022) provided an approach for seismically liquefiable soil analysis and design.

To augment the existing ten-step technique, the authors presented an additional seven-step methodology.These extra processes comprised seismic data assimilation, site response analysis, assessing the structure's stability (ULS check using the load-utilization ratio concept), input motion selection, prediction of permanent tilt/rotation, and ground settlement post-liquefaction. The strategy was confirmed by the authors using data from offshore and nearshore farms in Japan. Bhattacharya et al. (2021) emphasised seismic design challenges such as liquefaction, which causes issues for monopile-supported foundations.

Risk from lightning

Bouchard et al. used thresholds and weighting functions, neural networks, and belief functions to evaluate the danger of lightning strikes caused by thunderstorms. Wind energy output increases with tower height, but bigger towers are more vulnerable to lightning damage. Rachidi et al. demonstrated the difficulties that modern skyscrapers face, such as upward lightning being overlooked in design and construction.

The scientists also demonstrated that the rotation of blades may affect the amount of hits by triggering lightning [8]. The usage of carbon-reinforced polymers in towers may exacerbate the situation.Using a simplified model, Zhou et al. examined the lightning attachment characteristics of a 2 MW wind turbine engine [9]. LPSs may intercept front- and side-direction lightning but not back-direction lightning, thus downward negative lightning hits occur.Furthermore, increasing the striking distance affects the capture ratio for the blade's insulation.

In India, Boopathi et al. investigated wind turbine damage caused by a variety of factors, including lightning. The authors emphasised the seasonal nature of lightning strikes, which might necessitate emergency repairs and blade bolt replacement. Lightning damage is the most prevalent cause of downtimes, which can last up to 200 days [10]. Strikes have been reported in the Indian states of Maharashtra, Gujarat, and Tamil Nadu. March presented the methods and challenges involved in assessing lightning danger for wind turbines. While the IEC provides a methodology for assessing lightning danger, the author claims that it is insufficient.

The effect of local geography, the variation in the lightning mechanism with the vicinity of turbines, winter lightning, and height above sea level, according to the author, are key elements that determine percentages of upward lightning. The non-convective distribution of monthly fluctuations in lightning at two sites was also examined by the author.

Matsui et al. looked at ways to enhance the lightning damage detection model, which can shut down wind turbines if damage is identified using ML based on SCADA system data. According to the authors, lightning damage might grow owing to centrifugal force and produce substantial secondary damage.

Conclusion

Larger and higher wind turbines are being built as a result of technology improvement, making them more vulnerable to dangers from more common natural disasters such as high-velocity hurricane wind, seismic loads, lightn-

-ning, and hydrodynamic stresses. Given the significant financial investment in wind farms, it is crucial to improve the resilience and efficiency of these critical parts of energy infrastructure. Each component reacts differently to each stress type. This study examined the dangers to wind turbines posed by the effects of several natural disasters (earthquakes, strong winds, and tsunamis) on wind turbine towers, blades, and foundations.

Based on the analysis of the literature, the following conclusions are:

- Researchers emphasise the importance of foundation failures in seismic and high-velocity events harming inland wind farms. The key areas of research include the impacts of higher modes of vibration on design and response, the affects of close fault and far-fault seismic loads, and the implications of seismic and wind load directionality and characteristics. Integration of data-driven and physics-driven models is gaining traction in a variety of sectors.
- Hurricane track simulation is frequently used in hurricane risk modelling for OWTs. This can be computationally hard, thus other, simpler approaches to lower computing costs may be useful.
- There are experimental and analytical approaches for analysing tsunami risk, and increasing research contributions are based on experimental methods using scaled-down models. In tsunami risk, the impact of wave loads, soil-structure interactions, foundation scouring, and permanent settlement on the design and performance evaluation of wind turbine constructions are significant.
- Tall wind turbines are vulnerable to lightning strikes, which vary seasonally and geographically. Detecting lightning damage is crucial because it might spread more damage, resulting in costly repairs and downtime. While mathematical and experimental methodologies are available, experts emphasise the need for greater study on self-triggered lightning, which increases danger even in low thundercloud fields.

References

1. Voth,et al. “Branch plate-to-circular hollow structural section connections.” Diss. University of Toronto, 2010.
2. Larsen, et al. "New lightning qualification test procedure for large wind turbine blades." *International Conference on Lightning and Static Electricity (ICLOSE*), Blackpool, 2003. 2003.
3. Backstrand, J. et al. "Final Report RO 2017: 01." Statens Haverikommission: Stockholm, Sweden (2017).
4. Seong, J., et al. "On seismic protection of wind turbine foundations founded on liquefiable soils." *Soil Dynamics and Earthquake Engineering* 159 (2022): 107327.
5. Prowell, I., et al. Assessment of wind turbine seismic risk: existing literature and simple study of tower moment demand. No. SAND2009-1100. Sandia National Laboratories (SNL), Albuquerque, NM, and Livermore, CA (United States), 2009.
6. Agbayani, N. A. et al. "Design challenges in international wind power projects: From foreign codes to computer coding in a small office setting." 71st Annual Structural Engineers Association of California (SEAOC) Convention. 2002.
7. Iwan, W. D. "Drift spectrum: measure of demand for earthquake ground motions." *Journal of structural engineering* 123.4 (1997): 397-404..
8. DNV Risø National Laboratory. Guidelines for Design of Wind Turbines, 2nd ed.; Wind Energy Department; Risø National Laboratory: Risø, Denmark, 2002.
9. Attalla, et al. "Near-source behavior of buildings under pulse-type earthquakes." Proceedings of the sixth US National Conference on Earthquake Engineering. 1998.
10. Ntambakwa, E., et al. "Seismic forces for wind turbine foundations wind turbine structures, dynamics, loads and control." AWEA Windpower Conf. Vol. 5. 2009.

Cite this article: Daniel, R. Natural Hazard Risks for Farms. J Climatol Weath Forecast. 2023, 11 (1), 001-003