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Research Article

Analysis of Challenges in the Mechanical Design of Offshore Wind Turbines

Ariana Tislenko[1], Daiva Stanelytė[2] and Nuno Soares Domingues[3]

Abstract—**This article examines the key engineering challenges associated with the mechanical design of offshore wind turbines operating in harsh marine environments. The study discusses the main structural categories–foundations, towers, and rotors–emphasizing their suitability for different sea depths and geological conditions. Mechanical factors that significantly influence structural reliability are analysed, including loads, corrosion, fatigue, vibration, and aerodynamic as well as mechanical noise. The research also highlights current technological trends such as the increasing use of composite materials, hybrid tower structures, anti–corrosion solutions, floating platforms for deep–water installations, and smart monitoring systems supported by artificial intelligence. Additionally, the paper evaluates international experience and its relevance to the Baltic Sea region, focusing on Lithuania's potential and engineering priorities for offshore wind development. The findings show that the integration of modern materials, digital diagnostics, and advanced foundation technologies can considerably improve operational efficiency, reduce maintenance costs, and extend structural lifespan.**

Index Terms—**Baltic Sea, corrosion, fatigue, offshore wind turbines, structural reliability**

I. Introduction

Offshore wind is expanding rapidly, yet mechanical design guidance remains fragmented across structural typologies and failure modes, leaving unresolved reliability, corrosion, fatigue, and vibration risks in harsh marine environments. This paper addresses that gap by synthesizing international practice to identify the most consequential design challenges and mitigation options and by deriving implications for early-stage Baltic Sea deployments with a focus on reliability, durability, and maintainability.

However, despite rapid development, offshore wind turbines face significant challenges. The main problems are related to structural fatigue, corrosion, and foundation erosion, which reduce reliability over time and can lead to costly maintenance procedures. Another important issue is vibration and low–frequency noise, which not only threaten the longevity of structures but also affect the surrounding environment and local communities. Therefore, analyzing the challenges of mechanical structures in offshore wind turbines is a prerequisite for the effective development of this technology. Only by thoroughly assessing the durability of structures, the suitability of materials, and the risks of operation can the long–term and safe operation of these systems be ensured.

The object of the study is offshore wind turbines and their mechanical structures.

The aim of the study is to analyze the challenges of offshore wind turbine mechanical structures, including their impact on reliability, durability, and operational efficiency.

The objectives of the study are:

A. To analyze the types of offshore wind turbine structures and their application possibilities.

B. To assess the main mechanical challenges: loads, corrosion, fatigue, vibrations, and noise impact.

C. To summarize international experience in installing offshore wind turbines, emphasizing structural solutions.

D. To present Lithuania's prospects and possible technological solutions for the development of offshore wind turbines.

II. Methodology

A. Review design

A scoping review was conducted to map the recent evidence on offshore wind turbine structural performance and engineering challenges, clarify key themes, and identify knowledge gaps.

B. Information sources and search strategy

Literature was searched in ScienceDirect (10 records selected), Google Scholar (3), Elsevier databases (2), EBSCO Academic Search Premier (2), and SpringerLink (1). Open-access and institutional sources were also reviewed: European Commission Energy Portal (1), BalticWindEU (1), WindEurope (formerly EWEA) Publications (1), and the Marine Policy Database (1). The coverage period was 2018–2025. Search strings combined controlled terms and free text adapted to each database, for example: ("offshore wind turbine" OR "offshore wind") AND (foundation* OR "tower" OR "rotor" OR "mechanical structure*") AND (corrosion OR "material fatigue" OR

[1] **Ariana Tislenko**, is with Department of Mechanical and Transport Engineering, Klaipėdos valstybinė kolegija / Higher Education Institution, Klaipėda, Lithuania, (e-mail: ari.tislenko@kvkedu.lt).
[2] **Daiva Stanelytė**, is with Department of Informatics and Electrical Engineering, Klaipėdos valstybinė kolegija / Higher Education Institution, Klaipėda, Lithuania, (e-mail: d.stanelyte@kvk.lt). https://orcid.org/0000-0002-9623-6653
[3] **Nuno Soares Domingues**, is with Department of Mechanical Engineering, Instituto Politécnico de Lisboa/ Instituto Superior de Engenharia de Lisboa, Lisbon, Portugal, (e-mail: nndomingues@gmail.com). https://orcid.org/0000-0003-0763-8106
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vibration* OR noise) AND (“composite material*” OR “anti-corrosion coating*” OR “smart monitoring” OR “artificial intelligence”) AND (“structural reliability” OR maintenance OR “energy efficiency”) AND (“Baltic Sea” OR Baltic)*.

C. Eligibility criteria

Included items: peer-reviewed journal articles, conference papers, and official technical reports directly addressing offshore wind turbine structural/technological aspects (foundations, towers/rotors, degradation modes, monitoring/maintenance) with sufficient methodological detail, published 2018–2025. Exclusions: editorials/commentaries, non-technical news, off-topic items, inaccessible full texts.

D. Deduplication and screening

Records were exported to a reference manager (Zotero), algorithmically deduplicated, and manually verified. Screening proceeded in two stages: (i) titles/abstracts; (ii) full texts against eligibility criteria. In total, 22 publications met the criteria (18 from scholarly databases; 4 from open-access/institutional sources).

E. Data extraction and synthesis

For each included source we extracted: author(s), year, region/setting, component/topic, method(s), main findings, and limitations. Findings were synthesized thematically (narrative synthesis), grouping evidence by (i) structural components (foundations, towers/rotors), (ii) degradation/response mechanisms (corrosion, material fatigue, vibrations, noise, aerodynamic processes), (iii) materials and protection (composites, anti-corrosion coatings), (iv) monitoring/maintenance (smart monitoring systems, AI applications), and (v) reliability and performance (structural reliability, energy efficiency) with a focus on the Baltic Sea region.

F. Quality appraisal (minimal)

To contextualize evidence strength, included empirical studies were appraised using adapted CASP/JBI prompts (clarity of aim, appropriateness of methods, transparency of data sources, and discussion of limitations). Appraisal informed interpretation: studies were not excluded solely on appraisal grounds due to the scoping design.

G. Keywords used in search and thematic mapping

Offshore wind turbines; mechanical structures; foundation types; tower and rotor structures; corrosion; material fatigue; vibrations; noise; aerodynamic processes; composite materials; anti-corrosion coatings; smart monitoring systems; artificial intelligence; structural reliability; maintenance technologies; energy efficiency; sustainable energy; Baltic Sea region.

III. Types of Offshore Wind Turbine Structures and Their Application Possibilities

A. Wind turbine foundation structures

The foundations of offshore wind turbines are one of the most important structural elements, on which the stability, safety, and durability of the entire system depend. Since wind turbines are built in seas of varying depths and on different types of soil, the types of foundations are selected individually to ensure reliable operation of the structure. Depending on their structural design, they are usually divided into fixed and floating foundations.

As noted, the design of offshore wind turbine foundations must be adapted to variable seabed conditions, which have a direct impact on the load–bearing capacity and dynamic stability of the structure [9].

B. Fixed foundations

Fixed foundations are used in shallow or medium–depth waters. They are installed directly on the seabed and are characterized by high structural strength.

- Gravity foundations are massive concrete structures whose stability is ensured by their weight. They are suitable for hard ground, but their transportation and installation is complicated [4].
- Monopile foundations are steel pipes driven into the seabed. This is the simplest and most widely used solution in shallow waters (up to 30 m), characterized by a relatively low cost [8].
- Caisson foundations are large hollow structures filled with stones or concrete. Such foundations are very stable, but require more resources to install, so they are less common in practice [4].
- Jacket foundations are grid structures, most often used in medium–depth (30–60 m) locations. They provide high resistance to loads but are more expensive than monopiles [11].

C. Floating foundations for wind turbines

Floating foundations for wind turbines are a newer generation of structures designed for depths greater than 60 m. These structures do not rest on the seabed but are secured with cables and anchors. The main types are spar, semisubmersible, and TLS (tension–leg structures). Floating turbines make it possible to move energy production to remote offshore areas, taking advantage of stronger and more stable wind flows and reducing the visual impact on the coastal landscape [10].

The selection of offshore wind turbine structures directly depends on sea depth, seabed properties, and environmental conditions; therefore, several different foundation types are used in practice–gravity–based, monopile, caisson, and jacket foundations, as well as floating platforms designed for greater depths. The diversity of these structural solutions is illustrated in (Figure 1).

D. Tower structures

A tower is a vertical part of the structure that connects the foundation and the rotor. Towers are usually made of steel segments that are assembled on site. The structure must ensure rigidity and withstand both static and dynamic loads.

Hybrid towers, with the lower part made of concrete and the upper part made of steel, reduce the effects of corrosion and manufacturing costs [2].

Fig. 1. Foundation designs for different types of offshore wind turbines [15]

E. Rotor design and aerodynamics

The rotor is one of the most important elements of a wind turbine, directly responsible for converting energy into mechanical power. Its blades are made of lightweight and strong composite materials that are resistant to fatigue. Modern offshore wind turbines can have blades over 100 m long, which makes their design extremely complex.

The aerodynamic design of the blades determines not only the efficiency of energy extraction, but also the transfer of loads to the tower and foundations [12]. An improperly designed rotor can cause vibrations and increase fatigue loads, so aerodynamic design is one of the most important criteria for a reliable structure.

The mechanical chain of a wind turbine consists of the main energy conversion elements–rotor blades, the main bearing, the gearbox, the yaw control system, and the generator. The interaction between these components determines the turbine's efficiency and reliability, and their arrangement is shown in (Figure 2).

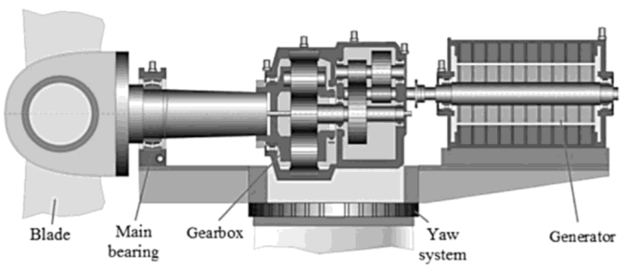


Fig. 2. Structure of a wind turbine mechanical chain, including the blade, main bearing, gearbox, rotation control system, and generator [13]

The type of structure is selected in each case considering the depth of the sea, the type of soil, and economic factors. European practice shows that monopile foundations remain the dominant solution in the North and Baltic Seas, but the importance of floating structures is growing rapidly with the expansion of deeper waters [1].

In summary, the choice of offshore wind turbine structures depends on the depth of the sea and the characteristics of the seabed. Fixed foundations are most used in shallow waters, while floating platforms are used in deeper areas. Hybrid and composite materials are increasingly being used in tower and rotor structures to ensure greater resistance to loads and corrosion. European practice shows that monopile foundations remain dominant, but the importance of floating structures is growing rapidly.

IV. MAIN MECHANICAL CHALLENGES: LOADS, CORROSION, WEAR, VIBRATION, AND NOISE

Offshore wind turbines operate in extremely harsh environmental conditions, where structures are subjected to various types of loads, corrosion, material fatigue, and vibrations. Assessing these factors is essential to ensure system reliability, structural durability, and cost–effective operation [4].

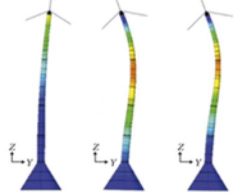
A. Loads

The main loads acting on structures are wind, waves, currents, and the dynamic forces of the rotor. Their interaction causes both static and cyclic deformations, which determine the concentration of stresses in the foundations, tower, and rotor connections. The stability of the structure is determined by the complex interaction of wind and wave loads, which depends on the type of foundation and soil properties [9].

Uneven loads associated with turbulent wind flows cause additional dynamic bending forces, which are particularly dangerous for long rotor blades and tall tower structures. Modern power plants are designed using digital load models that allow the analysis of the combined effects of wind and waves [8].

Due to varying wind and wave loads, an offshore wind turbine is subjected to both aerodynamic and structural deformations, with the highest stress concentrations occurring in the tower and blade regions. The distribution of these loads and the nature of the deformations are illustrated in (Figure 3).

a) Aerodynamic deformation of rotor blades in different wind directions



b) Lateral bending and stresses in the tower;
Fig. 3. Deformation and stress distribution in the wind turbine structure under load [3]

B. Corrosion

The aggressive marine environment–high salinity, oxygen deficiency, and constant moisture–is one of the biggest sources of damage to structures. Salt water accelerates oxidation processes, especially at joints and in underwater areas.

The most important areas of corrosion are those subject to splashing, immersion, and constant contact with water, where multi–layer protection is required: epoxy coatings, advanced polymer systems, and cathodic protection technologies [2].

Recently, multi–layer epoxy and self–healing polymer coatings have been increasingly used, which reduce the frequency of maintenance and extend the service life of structures [6].

C. Fatigue

Fatigue is an inevitable process in marine structures due to constant load changes and long–term operation. The cyclical nature of wave and rotor loads causes microcracks to form, especially in welds and connecting elements. Fatigue damage is one of the main reasons for the need for structural maintenance and early decommissioning [14].

Modern engineering practice uses finite element models (FEM) and digital stress analysis methods to identify the most stressed areas of a structure and optimize their geometry, thereby reducing the risk of fatigue damage [12].

D. Vibrations

Vibration loads arise due to rotor imbalance, oscillation, aerodynamic flows, and structural resonance. If the natural frequency of the power plant coincides with the frequency of the operating forces, resonant vibrations occur, which can accelerate fatigue processes and cause structural deformations.

Modern power plants use active vibration monitoring and suppression systems that allow real–time analysis of vibration intensity and load control through artificial intelligence algorithms [13], [3].

To reduce the dynamic loading of structures and extend the service life of power units, various vibration damping technologies are used–tuned mass dampers and anti–vibration modules that stabilize the tower during operation. The mechanisms of these technologies are shown in (Figure 4).

a) Anti–vibration module for tower stabilization

b) Tower tuned mass damper

Fig. 4. Wind turbine vibration damping technologies [3]

E. Impact of noise

Wind turbines generate two main types of noise: mechanical noise from the operation of gears, generators, and bearings, and aerodynamic noise from the movement of airflow over the surface of the blades. Low–frequency noise and infrasound components can affect not only human health but also marine life, which is why noise reduction has become an important part of wind turbine design [5]. Modern turbines use optimized blade profiles that reduce vortex flows and noise–suppressing materials inside the tower [1].

In summary, offshore wind turbines are subject to complex mechanical stresses caused by variable loads, corrosive environments, material fatigue, vibrations, and noise. These factors directly affect the reliability of structures, so it is necessary to use advanced anti–corrosion coatings, strong materials, digital load models, and vibration monitoring systems. Modern monitoring and analysis solutions reduce the risk of failure and extend the service life of power plants, while properly designed structures ensure safe and efficient operation in challenging marine conditions.

V. INTERNATIONAL EXPERIENCE IN IMPLEMENTING OFFSHORE WIND TURBINES AND REVIEW OF STRUCTURAL SOLUTIONS

A. International development trends

Over the past decade, the development of offshore wind farms has become one of the fastest–growing sectors in the global energy industry. The most significant progress has been achieved by Northern European countries–Denmark, Germany, the United Kingdom, and the Netherlands–which have accumulated long–term experience in designing and operating turbines in harsh offshore environments [4]. The experience of these countries has shown that properly selected structural solutions directly determine system reliability, maintenance costs, and operational lifespan [8].

Early offshore wind farm projects were implemented in shallow waters, where monopile foundations dominated. However, as turbine capacities increased and installations expanded into deeper marine areas, jacket foundations and floating platforms began to be used [11]. This technological advancement enabled the expansion of energy production into deeper offshore zones where wind speeds and stability are higher.

B. Structural solutions and innovations

Current structural improvements focus on hybrid and modular constructions, which allow components to be assembled onshore and later installed offshore. Such solutions reduce installation time, logistics costs, and weather–related risks [2]. Composite materials–such as carbon fiber and glass–fiber–reinforced polymers–are being increasingly applied, reducing weight and increasing resistance to corrosion [6]. The use of composite structures is becoming one of the key design criteria for next–generation offshore turbines, as they help reduce maintenance needs and extend service life.

C. Technological development directions

In modern offshore turbine design, digital modelling and Condition Monitoring Systems (CMS) play an increasingly important role. These technologies enable real–time monitoring of loads, vibrations, and material fatigue, ensuring preventive maintenance and avoiding failures [3]. Additionally, turbine control systems are increasingly enhanced with artificial intelligence algorithms that analyse collected data, predict potential failures, and automatically adjust operational parameters [13]. Such systems reduce failure risk and can extend equipment lifespan by up to 25%.

D. Regional experience and application specifics

Analysis of international solutions reveals that each region applies different structural strategies depending on geological, climatic, and economic conditions. The table below summarises the main technologies used and their outcomes.

Different countries apply various offshore wind turbine structural solutions depending on local conditions, technological capabilities, and environmental requirements. A comparison of these regional solutions is presented in Table 1.

Table I. Practical application of offshore wind turbine structural solutions in different regions.

Region / Country	Applied Structural Solutions	Distinctive Technologies	Key Advantages / Results
Denmark	Monopile and jacket foundations	Hybrid tower structures	Long–term operation, efficient maintenance
Germany	Jacket foundations, modular systems	Digital condition monitoring (CMS)	Reduced failure risk by up to 25%
United Kingdom	Floating platforms (TLP, spar)	Composite blades, AI–based diagnostics	High energy production efficiency
Norway	Spar and semisubmersible structures	AI monitoring, LIDAR systems	Sustainable operation in deep waters
Japan, Portugal	Floating platforms	Self–balancing anchoring systems	Commercial efficiency in serial projects
Baltic States	Monopile and jacket–type foundations	Scandinavian anti–corrosion standards	Environmentally friendly integration into marine ecosystems

E. Baltic Region Application Specifics

The Baltic Sea region, including Lithuania, Latvia, and Estonia, relies heavily on the experience accumulated by Scandinavian countries [1]. In these projects, the main focus is placed on structural durability, corrosion control, and energy efficiency. Environmental protection measures are also increasingly applied to reduce the impact on marine ecosystems [5]. Studies show that advanced installation methods, such as vibratory pile–driving technologies and noise–reduction barriers, make it possible to construct wind turbines while preserving biodiversity.

In summary, international experience in implementing offshore wind turbines reveals clear technological trends: the evolution of structures from monopile foundations in shallow waters to advanced jacket and floating platforms in deeper sea zones. Countries with long–standing offshore energy expertise, such as Denmark, Germany, and the United Kingdom, place significant emphasis on modular structures, composite materials, digital monitoring, and the application of artificial intelligence. These innovations reduce operational costs, extend equipment lifespan, and increase reliability under challenging marine conditions.
The Baltic region adopts the most advanced international solutions, adapting them to local depth, climate, and environmental requirements, thus ensuring sustainable and safe offshore wind energy development.

VI. Lithuania's perspectives and possible technological solutions for offshore wind energy development

A. Lithuania’s offshore energy potential

Lithuania has highly favourable conditions for offshore wind development due to the strong wind potential in the Baltic Sea and its strategically advantageous geographical position [1]. The average annual wind speed at sea reaches 8–9 m/s, enabling efficient energy production from high–capacity turbines. According to the European Commission’s National Energy and Climate Plan (NECP 2030), by 2030 Lithuania plans to install around 1.4 GW of offshore wind capacity in the Baltic Sea, which could generate up to 6 TWh of electricity per year–nearly half of the country’s current electricity demand [5]. As noted in the European Wind Energy Association report, the Baltic Sea region has the potential to become one of Europe’s major offshore energy hubs [7].

B. Structural and engineering solutions

The efficient development of offshore wind in Lithuania depends on selecting appropriate foundation and structural types based on sea depth (35–50 m), seabed characteristics, and hydrodynamic conditions. The most suitable solutions include monopile and jacket foundations, ensuring stability and resistance to dynamic loads [9]. Furthermore, hybrid towers made from a combination of concrete and steel offer increased corrosion resistance and reduced maintenance costs [2]. Composite rotor blades made from lightweight yet durable polymer materials improve aerodynamic efficiency and reduce structural loads [6].

C. Advanced anti–corrosion and material technologies

The Baltic Sea environment is characterised by high salinity and constant temperature fluctuations, making corrosion protection a critical challenge. According to Li, Huang and Wang, the main corrosion–prone zones–the splash, immersion, and continuous seawater contact zones–require complex protection using combinations of coatings, protective paints, and cathodic systems [2]. Applying cathodic protection, epoxy coatings, and self–healing polymer materials can significantly extend the lifespan of offshore structures [6]. Additionally, nanoparticle–based coatings with enhanced resistance to chloride exposure are becoming increasingly common for the protection of marine structures [2].

D. Integration of floating foundations and smart systems

Although the Baltic Sea is considered relatively shallow, floating platform technologies can be beneficial in some deeper zones (>60 m) [10]. Such solutions provide greater flexibility in turbine placement, reduce installation costs, and minimise visual impact on coastal landscapes. Modern floating platforms use tension leg platforms (TLP) and semisubmersible systems, enabling efficient load distribution and high stability even under strong currents [10]. Additionally, intelligent monitoring systems based on artificial intelligence and sensors enable real–time analysis of loads, vibrations, and corrosion levels [3].

E. Economic and regional opportunities

Offshore wind development in Lithuania presents significant economic and regional growth potential. Nowak, Chybowski and Matuszak note that offshore energy expansion in the Baltic Sea significantly contributes to local economic development through job creation, infrastructure improvements, and technological transfer [7]. By expanding ports, logistics bases, cable connections, and maintenance centres, Lithuania could become a major hub for component supply and technical support in the Baltic region [1]. The Port of Klaipėda, due to its geographic location and industrial infrastructure, holds exceptional importance and could become a central construction and logistics hub for offshore wind projects [5].

F. Environmental solutions

Offshore wind farm development must be aligned with environmental protection requirements and biodiversity preservation. During construction, noise, vibrations, and seabed disturbances can affect marine life; therefore, preventive measures are essential. According to the Marine Policy Journal, the most effective methods include vibratory pile–driving technologies, acoustic barriers, and noise–reduction shields, which can reduce construction impact on marine ecosystems by up to 40% [7]. These methods are widely used in German and Danish offshore projects and can be adapted in Lithuania to maintain ecological balance in the Baltic Sea [1].

In summary, Lithuania has highly favourable conditions for offshore wind development and can become an important part of the Baltic region's renewable energy network. Properly selected structural solutions–monopile, jacket, or floating foundations–enable turbine installation across varying depths while improving efficiency. Advanced anti–corrosion coatings, composite materials, and AI–based monitoring systems help reduce maintenance costs and extend equipment lifespan. Economically, offshore wind expansion creates new jobs, promotes port and logistics infrastructure modernisation, and strengthens regional energy independence. However, development must be balanced with environmental protection by applying noise–reduction and ecosystem–impact mitigation techniques. The synergy of these technological and environmental solutions forms a strong foundation for the sustainable growth of Lithuania's offshore wind energy sector.

VII. Discussion

The analysis of 22 scientific publications shows consistent findings regarding the mechanical behavior and reliability of offshore wind turbine structures. Most of the reviewed studies used recognised engineering methods–finite element modelling (FEM), long–term load simulations, corrosion–zone analysis, and probabilistic fatigue assessment. These methods are considered robust because they incorporate variable environmental conditions, nonlinear load interactions, and material property uncertainties, which reduces the risk of misleading or overly simplified results. Therefore, the collected data can be interpreted with high confidence.

Across the reviewed sources, several clear patterns emerged. First, structural reliability is strongly influenced by coupled wind–wave loading, meaning that loads cannot be evaluated independently. This confirms that using simplified linear models would underestimate stress levels, especially in tall towers and large rotor blades. Second, all studies highlight the splash zone as the most critical area for corrosion damage, regardless of coating type. This indicates that corrosion protection strategies must prioritise this region, particularly in the Baltic Sea, where seasonal temperature fluctuations increase coating stress. Third, fatigue analyses show that welds and joints remain the most failure-prone locations, reinforcing the importance of joint optimisation and continuous monitoring.

Digital monitoring technologies, especially AI–supported vibration analysis, also show clear effectiveness. According to several studies, such systems improve early fault detection and can reduce unplanned maintenance by up to one quarter. This suggests that monitoring is not an optional addition but a necessary element of modern offshore turbine design.

Interpreting these findings in the context of Lithuania, the collected data indicate that the recommended structural solutions–monopile or jacket foundations, multilayer coatings, hybrid towers, and sensor-based diagnostics–are fully compatible with Baltic Sea conditions. The results demonstrate that the most reliable offshore systems are those that integrate strong materials, well–selected foundation designs, and continuous digital monitoring from the early design stages.

Overall, the combined analysis shows that offshore wind turbine performance depends on the interaction of mechanical loads, corrosion behavior, fatigue processes, and monitoring technologies. A system–level approach–rather than isolated improvements–offers the most effective way to ensure long–term reliability in Baltic Sea offshore wind projects.

VIII. Conclusion

A. Types of structures and application possibilities

The choice of offshore wind turbine structures is determined by sea depth, soil properties, and the nature of the loads involved. In shallow and medium–depth waters, monopile and jacket foundations are optimal, ensuring stability and economical installation, while floating platforms are more suitable for deeper sea areas. Hybrid towers, combining steel and concrete, and composite blades improve the durability of structures and reduce their weight. A properly selected design reduces the total life cycle costs and operational risks.

B. Key mechanical challenges

The main challenges to structural reliability are combined wind, wave, and current loads, corrosion, material fatigue, vibration, and aerodynamic and mechanical noise. The impact of these factors is mitigated by applying multi–layer anti–corrosion systems, cathodic protection, optimization of joint geometry, and finite element (FEM) analysis. The effects of vibration are effectively reduced by shock absorbers, flexible connections, and optimized blade shapes, while continuous condition monitoring (CMS) and artificial intelligence algorithms enable early detection of damage and preventive maintenance.

C. International experience

The experience of Northern European countries shows that modular construction, serial production, and digital modeling significantly improve the reliability of structures and reduce costs. The monopiles that prevailed in previous projects are gradually being replaced by frame and floating foundations, which are suitable for greater depths. The introduction of composite materials and hybrid towers reduces weight and maintenance costs. Smart monitoring systems (CMS) and AI diagnostics increase reliability, extend operating time by up to 25%, and enable more effective risk management.

D. Lithuania's prospects and technological solutions

The conditions in the Baltic Sea (average depth 35–50 m, wind speed 8–9 m/s) are favorable for the development of offshore wind farms–by 2030, it is planned to install farms with a capacity of 1.4 GW. In the short term, the most rational solutions are monopile and frame foundations, while in the longer term, the installation of floating platforms in niche locations is the most promising. Critical success factors include the modernization of port and logistics infrastructure, the expansion of grid connections, the application of anti–corrosion technologies, and the implementation of condition monitoring systems from the design stage. In the context of sustainable development, it is necessary to integrate vibratory pile driving and noise reduction technologies to protect marine ecosystems and promote the development of engineering competencies and supply chains in Lithuania.

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Conflicts of Interest

The authors declare no conflict of interest.

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BIOGRAPHIES

Ariana Tislenko is currently a second-year student in the Mechanical Engineering study programme at Klaipėdos valstybinė kolegija / Higher Education Institution), Klaipėda, Lithuania. Her studies focus on mechanical engineering fundamentals, including machine elements, materials science, and engineering design. Her academic interests include offshore wind turbine structures, renewable energy technologies, and the application of mechanical engineering methods to sustainable energy systems.

Daiva Stanelytė received the B.Sc. degree in Informatics Engineering in 2010 and the M.Sc. degree in Technical Information Systems in 2012 from Klaipėda University, Klaipėda, Lithuania. From 2010 to 2011, she was an International Projects Administrator at the Faculty of Marine Engineering, Klaipėda University. Since 2011, she has been with Klaipėdos valstybinė kolegija / Higher Education Institution, where she is currently the Head of the Department of Engineering and Informatics and a Lecturer. In this role, she leads a team of 25 academic staff, coordinates study programmes in informatics and engineering, and has overseen the modernisation of laboratory infrastructure, including the implementation of electric vehicle charging stations, a mini wind turbine, a solar power plant, energy storage systems, and a building microgrid monitoring and control system. She is currently pursuing the Ph.D. degree in Energy and Thermal Engineering at the Lithuanian Energy Institute, Kaunas, Lithuania. Her research interests include smart energy management, renewable energy integration in distribution grids, building energy systems, and microgrid monitoring and control. She is the author or coauthor of more than 20 publications and has participated in more than 10 international conferences in the field of energy and building engineering systems.

Nuno Soares Domingues is a PhD candidate in Education – Teacher Training and Supervision at ISPA. He has completed postdoctoral in Information Science and Technology (ISCTE, 2023), Mechanical Engineering (IST, 2022), Science Communication (FCSH-UNL, 2021), and Electrical Engineering and Computer Science (IST, 2020), and holds a PhD in Electrical Engineering and Computer Science (FCT-UNL, 2015). He also earned a master's degree in Electrical Engineering and Computer Science (IST, 2008) and a five-year undergraduate degree in Electrical Engineering (ISEL, 2005).

His research interests cover modelling and simulation, energy systems, SCADA and decision support systems, intelligent optimisation, evolutionary algorithms, machine learning, clean technologies, mobility and transport, sustainable consumption, e-learning, science communication, and education.

He is a Professor at ISEL, holds a UNESCO diploma in Problem-Based Learning and Excellence in Teaching, the international ECDL IT qualification, a Leadership certification from the Military Academy, and is recognised as a trainer in science and engineering by the Scientific-Pedagogical Council for Continuing Education (University of Minho).