sensors

MDPI

Review

Non-Destructive Techniques for the Condition and Structural Health Monitoring of Wind Turbines: A Literature Review of the Last 20 Years

Marco Civera * and Cecilia Surace

Department of Structural, Geotechnical and Building Engineering (DISEG), Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Turin, Italy; cecilia.surace@polito.it

* Correspondence: marco.civera@polito.it

Abstract: A complete surveillance strategy for wind turbines requires both the condition monitoring (CM) of their mechanical components and the structural health monitoring (SHM) of their load-bearing structural elements (foundations, tower, and blades). Therefore, it spans both the civil and mechanical engineering fields. Several traditional and advanced non-destructive techniques (NDTs) have been proposed for both areas of application throughout the last years. These include visual inspection (VI), acoustic emissions (AEs), ultrasonic testing (UT), infrared thermography (IRT), radiographic testing (RT), electromagnetic testing (ET), oil monitoring, and many other methods. These NDTs can be performed by human personnel, robots, or unmanned aerial vehicles (UAVs); they can also be applied both for isolated wind turbines or systematically for whole onshore or offshore wind farms. These non-destructive approaches have been extensively reviewed here; more than 300 scientific articles, technical reports, and other documents are included in this review, encompassing all the main aspects of these survey strategies. Particular attention was dedicated to the latest developments in the last two decades (2000–2021). Highly influential research works, which received major attention from the scientific community, are highlighted and commented upon. Furthermore, for each strategy, a selection of relevant applications is reported by way of example, including newer and less developed strategies as well.

Keywords: structural health monitoring; condition monitoring; damage detection; fault diagnostics; non-destructive testing; artificial intelligence; wind turbine; wind farm; blade monitoring

Citation: Civera, M.; Surace, C. Non-Destructive Techniques for the Condition and Structural Health Monitoring of Wind Turbines: A Literature Review of the Last 20 Years. *Sensors* **2022**, *22*, 1627. https://doi.org/10.3390/s22041627

Academic Editors: Adam Glowacz, Jose A Antonino-Daviu and Wahyu Caesarendra

Received: 29 December 2021
Accepted: 15 February 2022
Published: 18 February 2022

1. Introduction

There is a general consensus from technicians, political leaders, and public opinion alike that the worldwide energy sector should shift to more sustainable sources.

Wind power is widely considered one of the best options in this sense. As for any energy source, it has its own advantages and limitations; for instance, it is an intermittent source, not dispatchable on demand but rather subject to the fluctuating nature of meteorological conditions. Nevertheless, it is fully renewable and highly sustainable, with minimal environmental impact when compared to traditional fuel power. However, wind turbines (WTs) come with both worker and public safety concerns.

In case of mechanical faults, turbine nacelle fires may erupt. Due to their height, these can be dangerous to extinguish, while releasing toxic flumes and potentially causing secondary fires in their immediate surroundings.

The risks are even more evident for structural collapses. These can be due to global or local failure mechanisms. The first case can be caused by a failure at any point along the tower height or its complete toppling due to foundation issues. In this instance, not only the wind turbine but also nearby structures can be damaged in the collision.

Even in the case of local failures, the consequences may be particularly severe, especially for turbines located near highly-populated areas. These failures include the detach-