Chapter 12
An Implementation of a Complete Methodology for Wind Energy Structures Health Monitoring

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ABSTRACT
In this chapter a complete methodology for a SHM damage detection solution is explained, and how this is validated in a laboratory tower model. Several methodologies are proposed for the typical process of SHM. Starting with sensor placement (the best possible sensor locations are found), selecting the more representative data, classifying the different environmental and operational conditions, applying a damage detection methodology, including sensor fault detection. The paradigm of damage detection can be tackled as a pattern recognition problem (comparison between the data collected from the structure without damages and the current structure in order to determine if there are any changes). There are lots of techniques that can handle the problem. In this work, accelerometer data is used to develop statistical data driven approaches for the detection of damages in structures. As the methodology is designed for wind turbines, only the output data is used to detect damage; the excitation of the wind turbine is provided by the wind itself or by the sea waves, being those unknown and unpredictable.

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INTRODUCTION

Motivation

The world energy crisis has made the humanity find new energy sources. The development of renewable energy sources is a key research driver as the greenhouse effect is affecting the global warming problem. Among the renewable energy technologies, the wind energy is thought to be a cheap and clean energy source. Wind turbines are doing the job of creating energy from wind, and the maturity, and cost competitiveness makes the wind energy one of the best clean energy sources nowadays.

In order to harvest more energy through higher efficiencies and due to cost-effective considerations, the size of the wind turbine has increased over the years. The size is not the only thing that has changed, nowadays the wind farms are moving towards the sea. Taking into account the height of the turbine and the rough sea conditions, the wind industry is now facing new problems. Among these new problems, we can find:

1. It is difficult to perform inspection and maintenance work considering the height and location of the turbine. This can be difficult for the maintenance worker, and quite risky.
2. The marine sea conditions and the durability of the structure in the water, and specially the substructure.
3. How to transport the energy to the shore.

To improve safety considerations, to minimize down time, to reduce the frequency of sudden break-downs and associated huge maintenance and logistic costs and to provide reliable power generation, the wind turbines must be continuously monitored to ensure that they are in good condition. Among all the monitoring systems, a Structural Health Monitoring (SHM) system is of primary importance because structural damage may induce catastrophic damage to the integrity of the system. A reliable SHM system, low cost and integrated into the wind turbine system may reduce wind turbine costs and make wind energy more affordable. The SHM information gathered could be used in a condition-based maintenance program to minimize the time needed for inspection of components, prevent unnecessary replacement of components, prevent failures and it allows utility companies to be confident of power availability.

Wind Energy Structures Health Monitoring Solutions

SHM and damage detection has been widely studied in the last two decades. The more complex the structures are, the more complex damage detection systems are needed. Vibrational methods are highly used in wind energy SHM solutions. Some global methodologies have been developed to determine the integrity of wind turbines. For example, Rolfes et al. proposed an integrated approach by using wireless sensors (eight biaxial accelerometers and two strain gauges) to detect all the possible vibrations on the structure. For the undamaged condition: dynamic stress, measured by strain gauges, is proportional to dynamic velocity, which can be derived from measured acceleration signals. This relation is valid when sensor locations are in line with the eigenform occurring. The sensor locations have to be chosen according to the maximum eigenform amplitudes and the maximum stress locations. If damage occurs, the
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