Active Monitoring of Blades Pitch Misalignment for Wind Turbines

S. Milani, J. Leoni, S. Cacciola, M. Tanelli and A. Croce
Politecnico di Milano

Wind turbines are complex mechanical systems that convert kinetic energy from the wind into electrical power. To better exploit wind power, they are often located offshore or in remote environments, which makes their maintenance costly in terms of time and money thereby going to increase the Cost of Energy. Continuous vibrations during operation can cause mechanical degradation of components such as gearboxes, motors, sensors, and blades, leading to system failure. To date, the reduction in energy production due to system faults has been a significant limitation, leading to periodic maintenance interventions to inspect component status. However, periodic maintenance is inefficient overall, as failures can occur between interventions if intervals are too long, while unnecessary and costly inspections can be planned and executed if intervals are too short.

Practical and automatic diagnostic and prognostic algorithms are necessary to transition from a "time-based" to a "condition-based" maintenance scheduling approach. These algorithms should be able to track wind turbines' actual health and usage status continuously, identifying anomalous behavior related to incipient faults. Early detection of failures allows for prompt maintenance and prevents irreversible damage to the system. Given the recent successes of machine learning and signal processing in many industrial health and usage monitoring applications, we propose a diagnostic framework for wind turbines that combines these techniques with the initial aim of detecting blades pitch misalignment. On the one hand, our approach leverages signal processing techniques to extract effective time and frequency domain features from the continuously measured variables of the system, leveraging measures that are actually available in commercial machines.
On the other hand, it leverages machine learning capabilities to associate the values of these features with the health and usage status of the wind turbine components of interest. Combining time and frequency domain features is particularly promising in this scenario, due to the intrinsic periodicity of the system. When a component experiences a failure, its vibrational signature changes, and the deviation from the expected behavior varies with the severity of the damage.

Our health and usage monitoring system has the potential to extend the life cycle of wind turbines, schedule maintenance interventions more effectively, and maintain a constant level of energy production. By continuously tracking the system's status, in fact, one can avoid unnecessary operations and identify potential issues before they result in costly failures. The idea proposed here for pitch misalignment, will later be extended to other wind turbine sub-components.