Active vibration-based SHM system: demonstration on an operating Vestas V27 wind turbine

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Abstract:
Blades of modern wind turbines are designed for 20-25 year service under extremely severe weather conditions, where their damage is unavoidable. With a high probability, a small blade defect will develop into a bigger defect, and if no countermeasures are taken, become critical, which may cause catastrophic consequences unless the damaged blade is replaced. Repair of a small defect is significantly cheaper than repair of a bigger one or entire blade replacement, therefore wind turbine operator companies pay a serious attention to structural health monitoring of the blades. Today this is done by periodical visual inspections conducted every one-two years but everyone in the industry realizes that a better approach is needed.

The suggested study presents a system, which is able to detect defects like cracks, leading/trailing edge opening or delamination of about 15 cm, remotely, without stopping the wind turbine. The system is vibration-based: mechanical energy is artificially introduced by means of an electro-mechanical actuator, whose plunger periodically hits the blade. The induced vibrations propagate along the blade and being picked up by an array of accelerometers. The vibrations in mid-range frequencies are utilized: this range is above the frequencies excited by blade-wind interaction, ensuring a good signal-to-noise ratio. At the same time, the corresponding wavelength is short enough to deliver required damage detection resolution and long enough to be able to propagate the entire blade length.

The paper demonstrates the system on a 225kW Vestas V27 wind turbine. One blade of the wind turbine was equipped with the system and a four-month monitoring campaign was conducted, while the turbine was operating normally. During the campaign, a defect – a trailing edge opening – was artificially introduced into the blade and its size was gradually increased from the original 15 cm to 45 cm.

Using an unsupervised learning algorithm, we were able to detect even the smallest amount of damage while the wind turbine was operating under different weather conditions. The paper provides the detailed information about the instrumentation and the measurement campaign and explains the damage detection algorithm.