SUMMARY IN ENGLISH

Lemnhult wind farm is located about 20 kilometers south of the city of Vetlanda in Jönköping County. The wind farm consisted of 32 wind turbines, of the same type and height. On 24 December, 2015, one of the turbines collapsed. The wind turbine that fell, tower 15, was 129 meters tall, and had a turbine diameter of 112 meters. The wind turbine had been in operation for almost three years.

The tower structure consisted of six sections that on the top and bottom part were fitted with flanges. The sections were held together with bolted joints. The joint in the first flange, i.e. between the first and the second section, failed and the upper part of the tower (five sections) fell. The bottom section, which was anchored to a concrete foundation, was still standing after the collapse. The bolts that had held together the joint had suffered from a fatigue process and the bolts could no longer withstand the loads of normal operation. The flange surfaces in the main wind direction showed signs of corrosion, which most likely originated from the bolts.

The cause of the fatigue in the bolts was that the pre-tension force in the joint was too low. The reason for not achieving the specified pre-tension force was due to the bolts, tower sections and tools not being protected from rain and snow during the installation. Water affected the lubricant of the nuts, which lead to increased friction in the contact surfaces of the joint. The tools used in the installation had not been maintained according to the standard or the tool manufacturer's recommendations to ensure that the proper torque force was applied. The assembler who performed the final torqueing of the bolts had no previous experience from such work, and had not received the manufacturer's internal training course to that end. Settlement had not been taken into account, either in the joint or in the softer materials, which always affect the pre-tension force. The manufacturer had not verified that the specified pretension force could be achieved or tested the weather's impact on the ability to achieve the specified pre-tension force.

During different time periods the wind turbine was exposed to vibrations and additional loads due to the software used in the control unit of the wind turbine. The manufacture has stated that these additional loads, under the condition that the specified pretension was achieved, were within the design limitations of the wind turbine. In a bolted joint with low pre-tension force these additional loads may lead to a decrease in lifetime.

The authorities who inspected the wind turbine from a safety perspective did not request the technical documentation for the tower construction. The municipality and the control manager limited the inspections to the foundations.

Lemnhult wind farm had had problems with loose and broken bolts prior to the accident. These problems were not reported by the operator to the supervisory authority, Jönköping County Administrative Board.

Safety Recommendations

Vestas Wind Systems A/S is recommended to:

- Follow up on the compliance of instructions and manuals on installation sites. *(RO 2017:01 R1)*

The National Board of Housing, Building and Planning is recommended to:

- In a suitable way inform municipalities of the relevant findings in this investigation, such as the Planning and Building Act's (2010:900) requirements on load bearing capacity. *(RO 2017:01 R2)*

Jönköping County Administrative Board is recommended to:

- Ensure that the operator has clear procedures for the reporting of events that may lead to an inconvenience to people's health and the environment according to the Ordinance (1998:901) of Owner's Own Control, see section 2.5. *(RO 2017:01 R3)*

The Work Environment Authority is recommended to:

- Together with suitable competency in the fields of wind power plants, assembly and construction, develop a checklist specifically aimed at inspections of the machine type wind power plant, see section 2.5. *(RO 2017:01 R4)*

- Strengthen the inspections regarding the fulfillment of the machine directive for the machine type wind power plant to ensure that the machine is compliant with the requirements for safety, including e.g. design, assembly, operations and disassembly, during the full life span of the machine, see section 2.5. *(RO 2017:01 R5)*