TU Delft

Offshore & Dredging Engineering

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Limiting mechanisms for the torque density of wind turbine drivetrains

As wind turbines continue to increase in size, so do the loads acting on the drivetrain. To handle the higher loads the mass of the drivetrain needs to increase. A better understanding of this mass increase can result in lighter drivetrain design and provide an insight in which drivetrain design has the lowest mass potential for large rotor diameters. In this thesis the limiting mechanisms, mass and torque density of three offshore wind turbine drivetrains are investigated for an increasing rotor diameter. The limiting mechanisms in this thesis provide a theoretical limit to the minimum required mass of a drivetrain for increased loading. Through an extensive literature study the limiting mechanisms are found and three scaling models are developed to calculate the torque density of the drivetrains. The drivetrains that are being considered in this thesis are the drivetrain with gearbox and high-speed generator, the direct drivetrain and the hydraulic drivetrain. The following research questions are answered in this thesis:

- What are the limiting mechanisms of the three investigated drivetrain types?
- What are the achievable torque densities of the three investigated drivetrain configurations for increasing rotor diameters?

For the drivetrain with gearbox and high-speed generator, a planetary gearbox with two planetary stages and one parallel stage has been selected (see Figure 1). In this setup, a high speed permanent magnet generator is included in the design. For the direct drivetrain configuration, the radial flux permanent magnet synchronous generator (RFPMSG) has been selected. For the hydraulic drivetrain, an internal radial piston pump is used to pressurize hydraulic fluid.

Two limiting mechanisms are found for the drivetrain with gearbox and high-speed generator: Tooth flank stress (**1.72 GPa)** and Root bending stress (**0.24 GPa)**. The Tooth flank stress is found to be governed by the Hertzian contact strength while the root bending stress is governed by the flexural strength. Two limiting mechanisms for the RFPMSG are found for the airgap flux density (**1 T)** and the current loading (**30 - 200 kA/m)** in the generator windings. The airgap flux density is limited by the saturation of the stator teeth material in the generator whereas the current loading is limited by the heat dissipation of the windings and stator laminations. For the hydraulic pump, the limiting mechanism is found at the interaction of the camring and the cam roller.
As for the gearbox, the maximum stress that is allowed at this point is determined by the Hertzian contact strength of the material and is again found to be (**1.72 GPa)**. Using the limiting mechanisms of the three drivetrain configurations, scaling models for the mass and torque density of the three drivetrains have been developed.

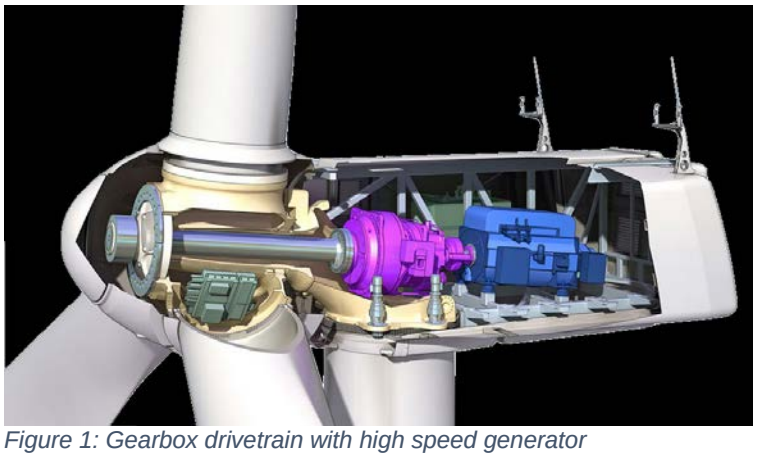

Figure 1: Gearbox drivetrain with high speed generator

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