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Lift control of wind turbine blades by using smart composite materials to manipulate aerodynamic rotor properties

The development of offshore wind turbines poses significant engineering challenges that must be addressed before cost effective wind machines can be successfully installed in moderately deep water. When moving turbines offshore, the trend is to increase the rotor diameter to harness a larger amount of wind, ultimately decreasing the cost of energy. The increase in diameter creates design issues for many of the components, with the blade length being the first parameter affected. One of the major challenges for all turbines is designing the blade so that it is robust, low weight, cost effective, and highly efficient. Because the wind speed is ever-changing, the blades must be able to adapt to a variety of loading conditions to remain efficient.

Passive pitch control can save money through improved aerodynamic efficiency and a reduction of loading conditions. The concept refers to the ability of a turbine blade to automatically adapt to the changing wind conditions without the input of external energy. One method for passively controlling the pitch of a wind turbine blade is achieved by utilizing anisometric materials that deform nonuniformly under applied loads. Fiber composites are the leading material choice used in today's industrial turbine blades mainly because of their cost and strength and stiffness to weight ratios. It is possible to tailor the properties of composites so that they become anisometric materials and exhibit bend-extension and bend-twist coupling. By utilizing these couplings, a composite structure can be designed to twist from an applied bending or axial load, thus creating a response not possible with isometric materials.

The aim of this project is to develop a wind turbine blade capable of passive pitch control and suitable for a 10 MW offshore wind turbine. This will be achieved through the design and simulation of blades made of carbon and or glass fiber composite laminae oriented at various angles and stacked in a laminate. The number, thickness, orientation, and fiber material (carbon or glass) will be determined and verified through finite element analysis (FEA). Due to the large size of the 10 MW turbine blades, this project will employ pitching towards feather to reduce the flap bending moment at high wind speeds. Furthermore, the affects of fatigue, buckling, and aerodynamic flutter instabilities on anisometric composites will be studied.