Most efficient wind generator design

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Wind turbine design is the process of defining the form and configuration of a wind turbine to extract energy from the wind.[1] An installation consists of the systems needed to capture the wind''s energy, point the turbine into the wind, convert mechanical rotation into electrical power, and other systems to start, stop, and control the turbine.

In 1919, German physicist Albert Betz showed that for a hypothetical ideal wind-energy extraction machine, the fundamental laws of conservation of mass and energy allowed no more than 16/27 (59.3%) of the wind''s kinetic energy to be captured. This Betz'' law limit can be approached by modern turbine designs which reach 70 to 80% of this theoretical limit.

In addition to the blades, design of a complete wind power system must also address the hub, controls, generator, supporting structure and foundation. Turbines must also be integrated into power grids.

Blade shape and dimension are determined by the aerodynamic performance required to efficiently extract energy, and by the strength required to resist forces on the blade.

The aerodynamics of a horizontal-axis wind turbine are not straightforward. The air flow at the blades is not the same as that away from the turbine. The way that energy is extracted from the air also causes air to be deflected by the turbine. Wind turbine aerodynamics at the rotor surface exhibit phenomena that are rarely seen in other aerodynamic fields.

Rotation speed must be controlled for efficient power generation and to keep the turbine components within speed and torque limits. The centrifugal force on the blades increases as the square of the rotation speed, which makes this structure sensitive to overspeed. Because power increases as the cube of the wind speed, turbines have must survive much higher wind loads (such as gusts of wind) than those loads from which they generate power.

A wind turbine must produce power over a range of wind speeds. The cut-in speed is around 3-4 m/s for most turbines, and cut-out at 25 m/s.[2] If the rated wind speed is exceeded the power has to be limited.

A control system involves three basic elements: sensors to measure process variables, actuators to manipulate energy capture and component loading, and control algorithms that apply information gathered by the sensors to coordinate the actuators.[3]

Any wind blowing above the survival speed damages the turbine. The survival speed of commercial wind turbines ranges from 40 m/s (144 km/h, 89 MPH) to 72 m/s (259 km/h, 161

MPH), typically around 60 m/s (216 km/h, 134 MPH). Some turbines can survive 80 metres per second (290 km/h; 180 mph).[4]

A stall on an airfoil occurs when air passes over it in such a way that the generation of lift rapidly decreases. Usually this is due to a high angle of attack (AOA), but can also result from dynamic effects. The blades of a fixed pitch turbine can be designed to stall in high wind speeds, slowing rotation.[5] This is a simple fail-safe mechanism to help prevent damage. However, other than systems with dynamically controlled pitch, it cannot produce a constant power output over a large range of wind speeds, which makes it less suitable for large scale, power grid applications.[6]

A fixed-speed HAWT (Horizontal Axis Wind Turbine) inherently increases its angle of attack at higher wind speed as the blades speed up. A natural strategy, then, is to allow the blade to stall when the wind speed increases. This technique was successfully used on many early HAWTs. However, the degree of blade pitch tended to increase noise levels.

Vortex generators may be used to control blade lift characteristics. VGs are placed on the airfoil to enhance the lift if they are placed on the lower (flatter) surface or limit the maximum lift if placed on the upper (higher camber) surface.[7]