CAI335 SOLAR AND WIND ENERGY SYSTEM

UNIT III NOTES

3.9 Aero foil

3.9.1 Terms and Definitions

1.Aerodynamics. It is the branch of science which deals with air and gases in motion and their mechanical effects.

2. Airfoil or aerofoil. A streamlined air surface designed for air to flow around it in order to produce low drag and high lift forces.

3. Angle of attack. It is the angle between the relative air flow and the closed of the air foil .

Blade. An important part of a wind turbine that extracts wind energy.

5. Leading edge. It is the front edge of the blade that faces towards the direction of flow

6. Trailing edge. It is the rear edge of the blade that faces away from the direction of wind flow

7. Mean line. A line that is equidistant from the upper and lower surfaces of the air Foil.

8. Camber. It is the maximum distance between the mean line and the chord line, which measures the curvature of the airfoil.

9. Rotor. It is the primary part of the wind turbine that extracts energy from the wind. It constitutes the blade-and-hub assembly.

10. Hubs. Blades are fixed to a hubs which is a central solid part of the turbine.

11. Pitch angle. It is the angle between the direction of wind and the direction perpendicular to the planes of blades

12.Pitch control. It is the control of pitch angle by turning the blades or blade tips

13. Yaw control. It is the control for orienting (steering) the axis of wind turbine in the direction of wind

14. Teethering. It is see-saw like swinging motion with hesitation between two

alternatives. The plane of wind turbine wheel is swung in inclined position at higher wind speeds by teethering control

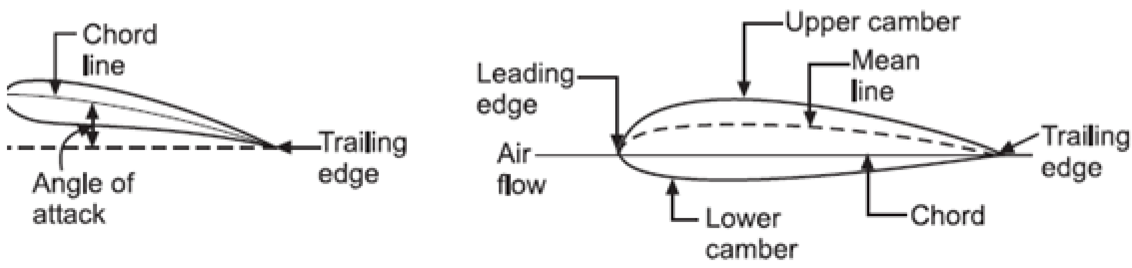

Figure:Air foil with description

15.Solidity. It is ratio of blade area to the swept area (area covered by the rotating rotor).

16. Drag force. It is the force component which is in line with the velocity of wind.

17. Lift force. It is the force component perpendicular to drag force.

18. Windmill. It is the machinery driven by the wind acting upon sails used chiefly in flat districts for grinding of corn, pumping of water etc.

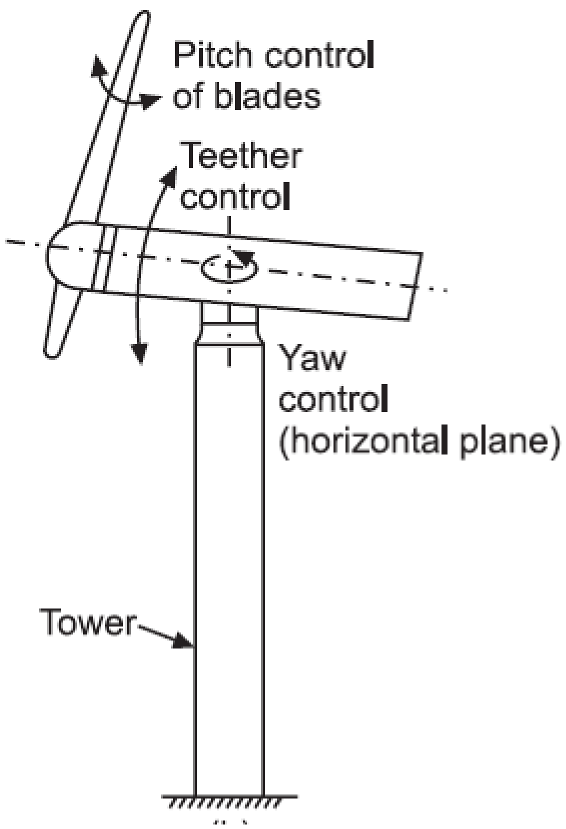

Figure: Pitch control; Yaw control; Teether control.

3.9.2 Lift and Drag

The extraction of power, and hence energy, from the wind depends on creating certain forces and applying them to rotate (or to translate) a mechanism.

Following are the two primary mechanisms for producing forces from the wind.

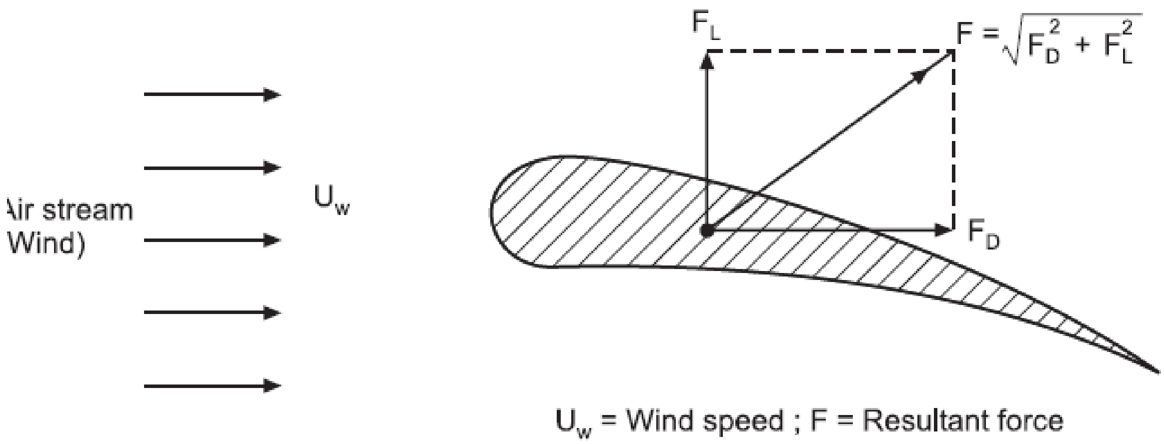

Figure: Lift and Drag on airfoil

Lift force. The component of force at right angles to the direction of air stream on the airfoil is called the lift force (FL) .

Drag force. The component of force in the direction of stream is called drag force (FD).

When air stream approaches the airfoil along the axis of symmetry, the force acting on the body is only the drag force, in the direction of flow and there is no lift force. The production of lift force requires asymmetry of flow while drag force exists always. It is possible to create drag without lift but impossible to create lift without drag.

'Lift forces' are produced by changing the velocity of air stream flowing over either side of the lifting surface–speeding up the air flow causes the pressure to drop, while slowing the air stream down leads to increase in pressure. In other words, any change in velocity generates a pressure difference across the lifting surface.The pressure difference produces a force that begins to act on the high pressure side and moves towards the low pressure side of the lifting surface which is called an airfoil.

A good airfoil has high lift/drag ratio (LDR); in some cases it can generate lift forces perpendicular to air stream direction, 30 times as great as the drag force parallel to the flow. The lift increases as the angle formed at the junction of the airfoil and the air stream (the angle of attack) becomes less and less acute, upto the point where the angle of the air flow on low pressure side becomes excessive. When this happens, the air flow breaks away from the low pressure side, a lot of the turbulence ensues, the lift decreases and the drag increases quite substantially this phenomenon is known as stalling.

3.10 Tip speed Ratio

TSR refers to the ratio between the wind speed and the speed of the tips of the wind turbine blades. The Tip Speed Ratio (often known as the TSR) is of vital importance in the design of wind turbine generators. If the rotor of the wind turbine turns too slowly, most of the wind will pass undisturbed through the gap between the rotor blades. Alternatively if the rotor turns too quickly, the blurring blades will appear like a solid wall to the wind. Therefore, wind turbines are designed with optimal tip speed ratios to extract as much power out of the wind as possible.

When a rotor blade passes through the air it leaves turbulence in its wake. If the next blade on the spinning rotor arrives at this point while the air is still turbulent, it will not be able to extract power efficiently from the wind. However if the rotor span a little more slowly the air hitting each turbine blade would no longer be turbulent. Therefore the tip speed ratio is also chosen so that the blades do not pass through too much turbulent air.

3.11 Betz Coefficient

The Betz Limit, or Betz Law, calculated by German physicist Albert Betz nearly a century ago, states that no wind turbine generator can convert more than about 60% of the kinetic energy of the wind into mechanical (or electrical) energy simply be turning the blades of a rotor.

$$P_{\text{total}} = \frac{1}{2}\rho \times \frac{\pi}{4} D^2 \times U_w^3 = \frac{1}{8}\rho\pi D^2 U_w^3$$

All this power cannot be extracted because, for this, wind velocity would have to be reduced to zero which means that the wind mill would accumulate static air around it which would prevent the wind mill operation. Theoretically, a fraction 16 27 j 0.593 (59.3%) of the power in the wind is 'recoverable'. This is called "Gilbert's limit" or "Betz coefficient". Aerodynamically, efficiency for converting wind energy to mechanical energy can be reasonably assumed to be 70%. So the mechanical energy available at the rotating shaft is limited to 40% or at the most 45% of wind energy.