In wind energy engineering, the **Tip Speed Ratio (TSR)**, often denoted by the Greek letter λ\lambda (lambda), is a dimensionless parameter that describes the relationship between the rotational speed of the wind turbine's rotor and the actual velocity of the wind.

Essentially, it tells you how much faster (or slower) the tip of the turbine blade is moving compared to the wind speed blowing past it.

Definition:

Tip Speed Ratio is the ratio of the speed of the turbine blade tip to the wind speed.

$$\lambda = \frac{\text{Blade tip speed}}{\text{Wind speed}} = \frac{\omega R}{V}$$

Where:

- **ω\omega** =The angular velocity of the rotor (measured in radians per second).
- R=The radius of the rotor (the length of one blade).
- V= The upstream wind velocity (the speed of the wind before it hits the turbine).

Why is TSR Important?

The Tip Speed Ratio is critical for determining the efficiency of a wind turbine. If the rotor turns too slowly, most of the wind passes through the gaps between the blades without transferring much energy. If the rotor turns too quickly, the blades act like a solid wall, creating turbulence and "propeller wash" that reduces power output.

- **Aerodynamic Efficiency:** Every turbine design has an **optimal TSR** where it extracts the maximum possible power from the wind (approaching the Betz Limit).
- **Blade Design:**
  - **High TSR (6–10):** Common in modern 3-blade utility-scale turbines. These use thin, aerodynamic blades designed for high-speed rotation.
  - **Low TSR (1–3):** Common in multi-blade water-pumping windmills. These generate high torque but rotate slowly.

- **Noise and Stress:** Higher TSRs generally lead to more aerodynamic noise and increased centrifugal stress on the turbine structure.