Wind Energy Systems

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Agenda

- Historical Development of WT
- Current Status and Future Prospects of Wind Energy
- Types of Wind Turbine Generators (WT)
- Orientation of WT
- Sizes and Applications of WT
- Components of WT
- Wind Power Calculations

Historical Development

- Wind has been used by people for over 3000 years for grinding grain, sailboats, and pumping water Windmills were an important part of life for many communities beginning around 1200 BC.
- Wind was first used for electricity generation in the late 19th century.

- The Babylonian emperor Hammurabi planned to use wind power for his ambitious irrigation project during seventeenth century B.C.
- The wind wheel of the Greek engineer Heron of Alexandria in the 1st century AD is the earliest known instance of using a wind-driven wheel to power a machine
- Wind-driven wheel was the prayer wheel, which was used in ancient Tibet and China since the 4th century

- The era of wind electric generators began close to 1900’s.
- The first modern wind turbine, specifically designed for electricity generation, was constructed in Denmark in 1890.
- The first utility-scale system was installed in Russia in 1931.
- A significant development in large-scale systems was the 1250 kW turbine fabricated by Palmer C. Putman.

Current status and future prospects

Wind is the world's fastest growing energy source today

The global wind power capacity increases at least 40% every year.

For example, the European Union targets to meet 25 per cent of their demand from renewable by 2012.

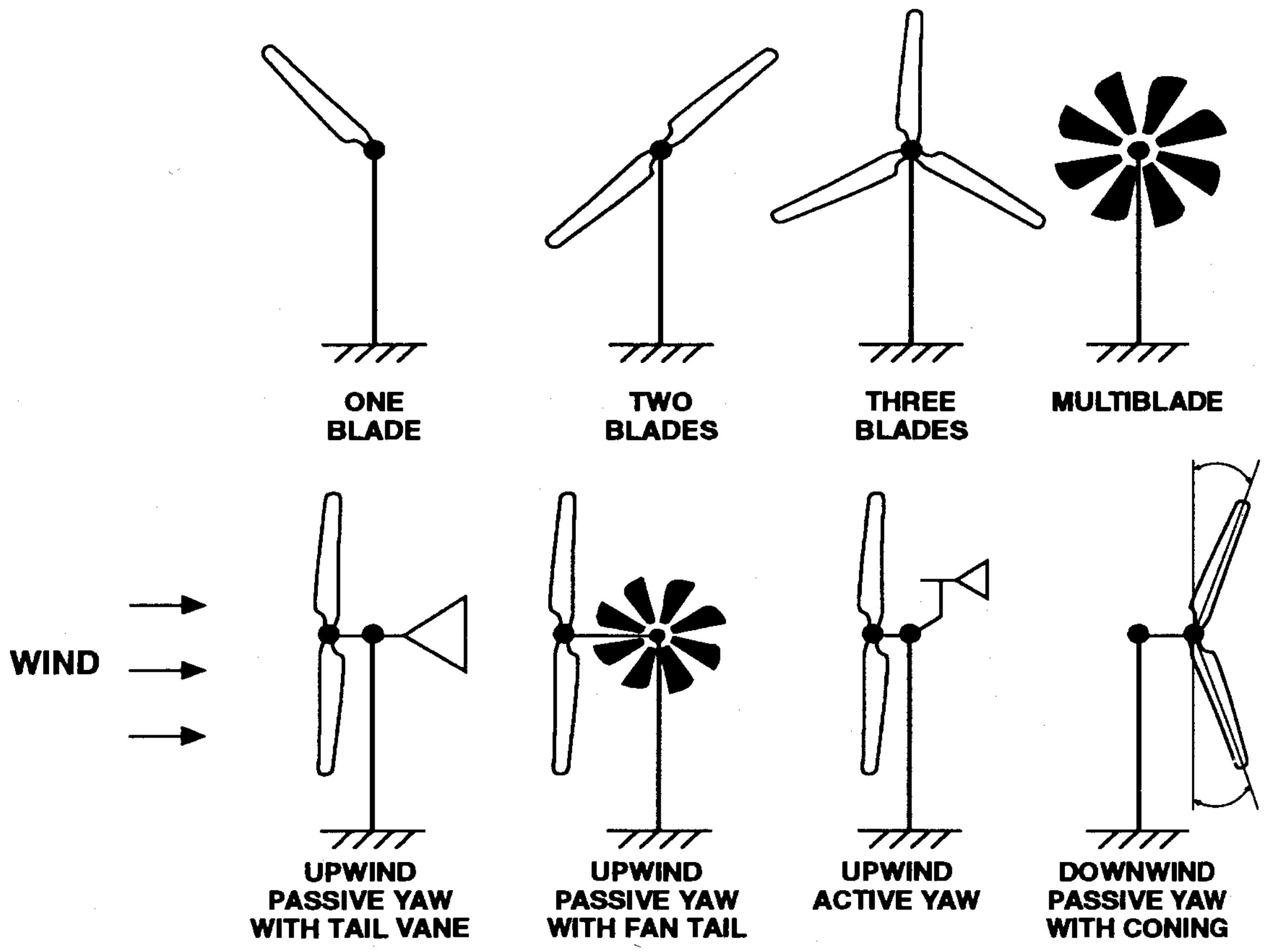
Spain also celebrates in Nov. 10, 2010 when the wind energy resources contribute 53% of the total generation of the electricity.

Over 80 percent of the global installations are in Europe.

Installed capacity may reach a level of 1.2 million MW by 2020

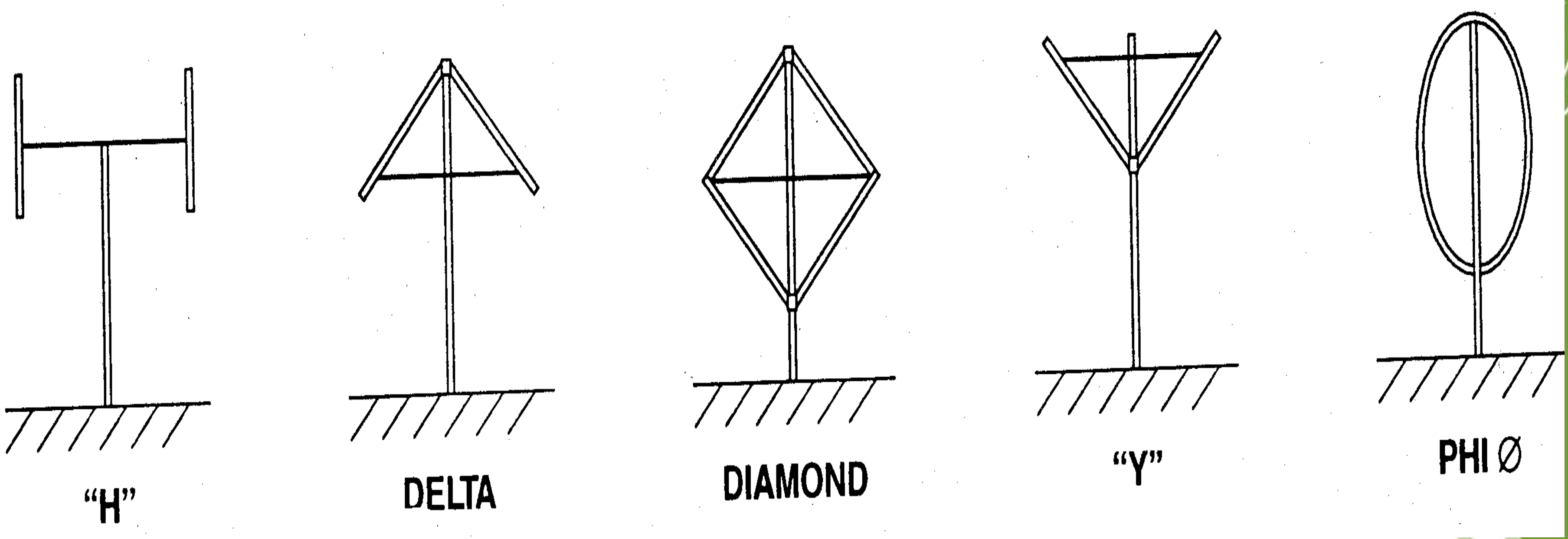
Types of Wind Turbine Generators (WT)

1. Horizontal Axis WTs (HAWTs)



The HAWT configurations

Vertical Axis WTs (VAWTs)



The VA-WTs Configurations

Vertical Axis Turbines

Advantages

- Omnidirectional
  - Accepts wind from any angle
- Components can be mounted at ground level
  - Ease of service
  - Lighter weight towers
- Can theoretically use less materials to capture the same amount of wind

Disadvantages

- Rotors generally near ground where wind poorer
- Centrifugal force stresses blades & components
- Poor self-starting capabilities
- Requires support at top of turbine rotor
- Requires entire rotor to be removed to replace bearings
- Overall poor performance and reliability/less efficient
- Have never been commercially successful (large scale)

Horizontal Axis Wind Turbines

- Rotors are usually Up-wind of tower
- Some machines have down-wind rotors, but only commercially available ones are small turbines
- Proven, viable technology



Wind Power

The power in the wind can be defined as follows,

$$P_w = \frac{1}{2}\rho_a A V^3$$

where ρ_a : Air density, kg/m³.

A: Cross sectional area of wind parcel, m².

V: The wind speed, m/sec.

$$V(Z) = V(Zg) * \left(\frac{Z}{Zg}\right)^{\alpha}$$

where Z : The height above the ground level, m.

Zg : The height of where the wind speed is measured, m.

α : The exponent, which depends on the roughness of the ground surface, its average value, is (1/7) [14].

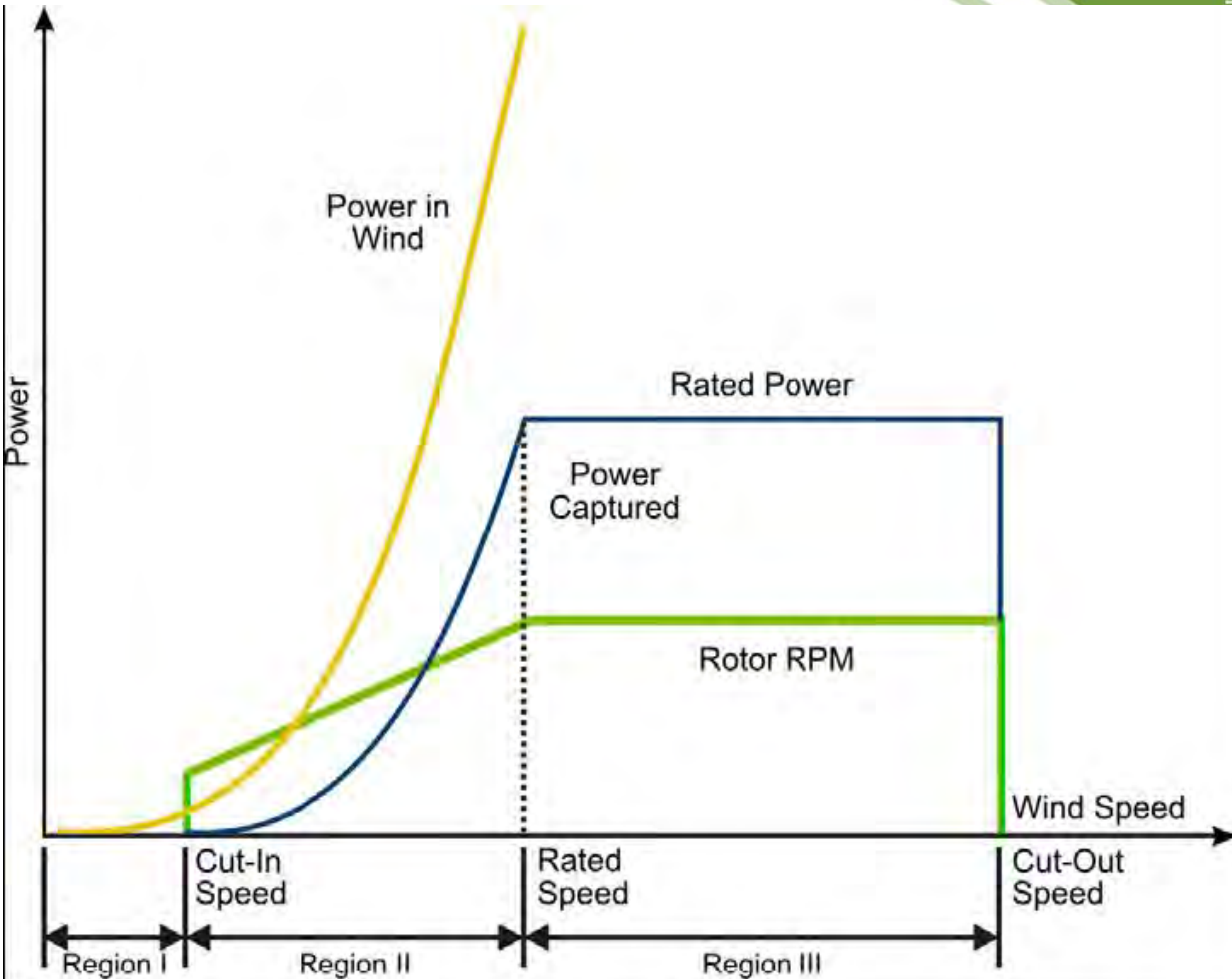
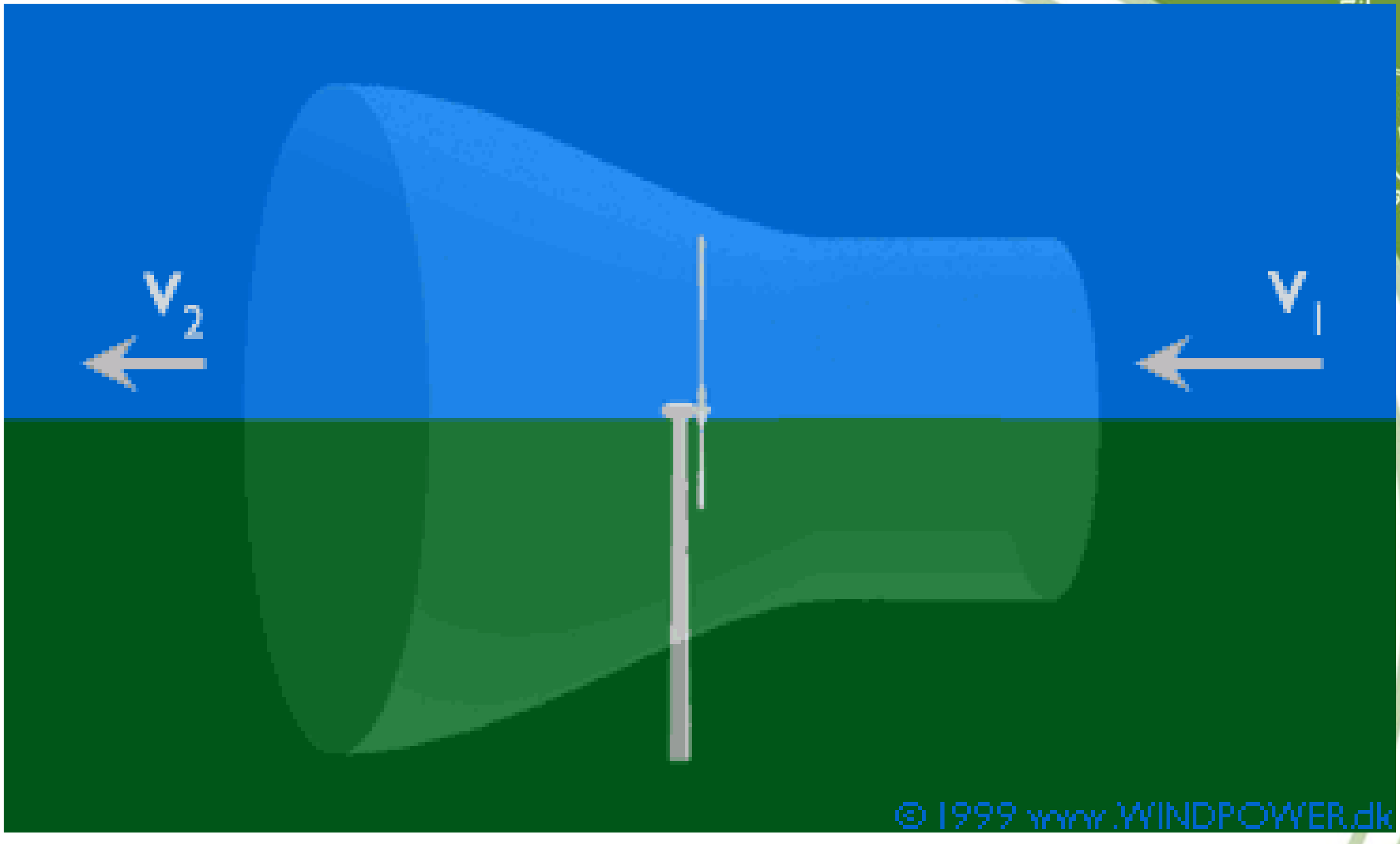


Fig. 1.22 Actual WT output power with the wind speed.

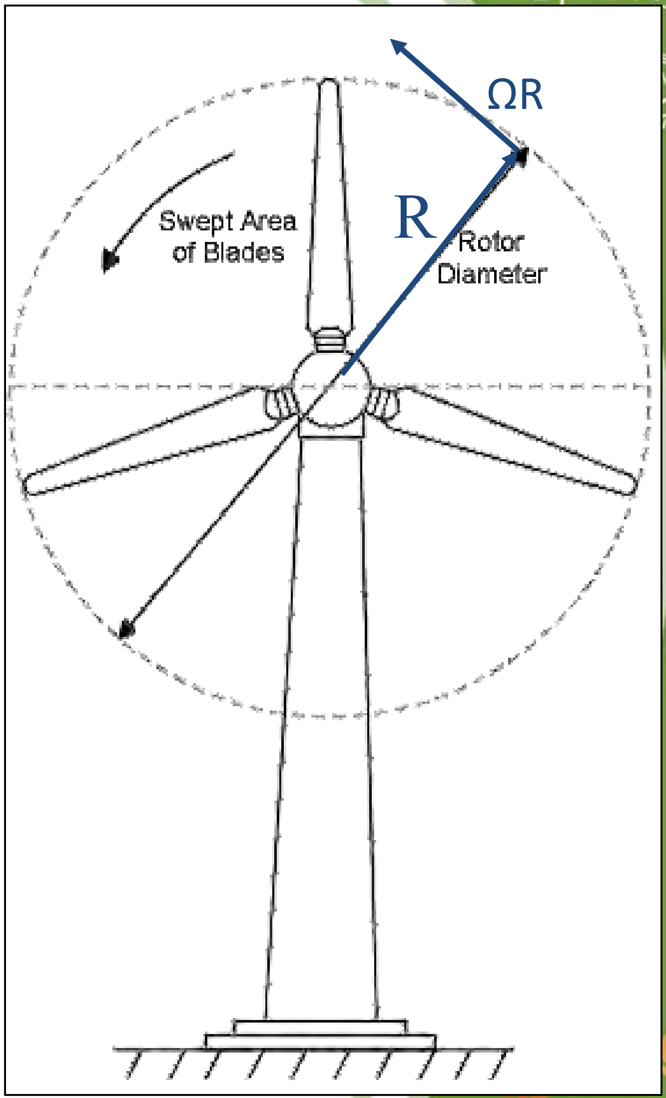


Betz' Law

Betz: law says that you can only convert less than 16/27 (or 59%) of the kinetic energy in the wind to mechanical energy using a wind turbine.

Tip-Speed Ratio

- **Tip-speed ratio is the ratio of the speed of the rotating blade tip to the speed of the free stream wind.**
- **There is an optimum angle of attack which creates the highest lift to drag ratio.**
- **Because angle of attack is dependant on wind speed, there is an optimum tip-speed ratio**



$$TSR = \frac{\Omega R}{V}$$

Where,

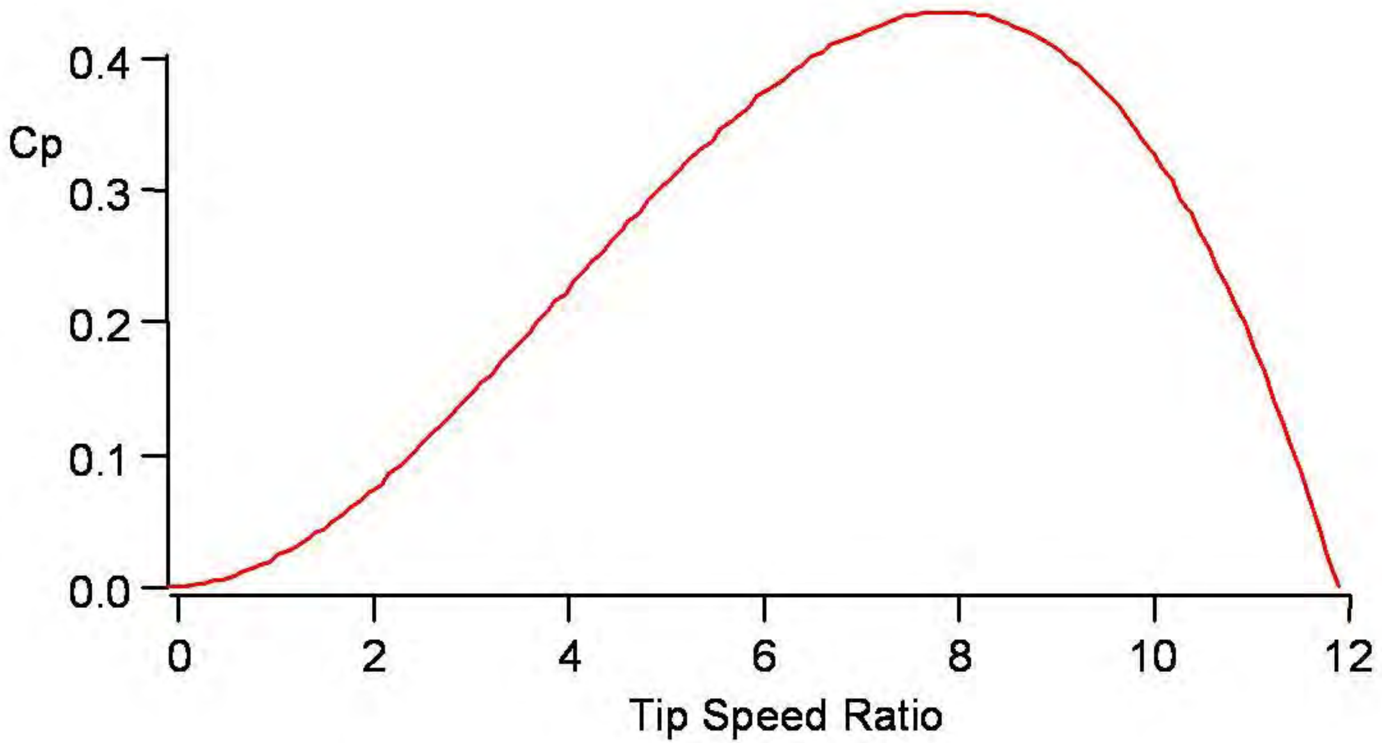
Ω = rotational speed in radians /sec

R = Rotor Radius

V = Wind "Free Stream" Velocity

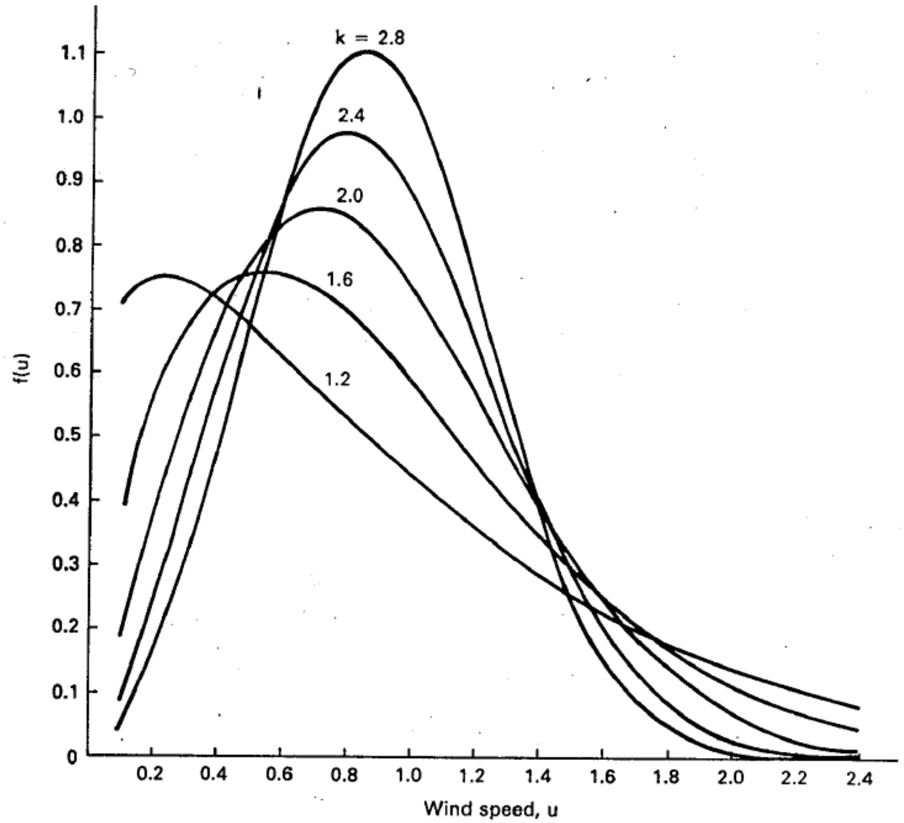
Performance Over Range of Tip Speed Ratios

- Power Coefficient Varies with Tip Speed Ratio
- Characterized by Cp vs Tip Speed Ratio Curve



Weibull Statistics

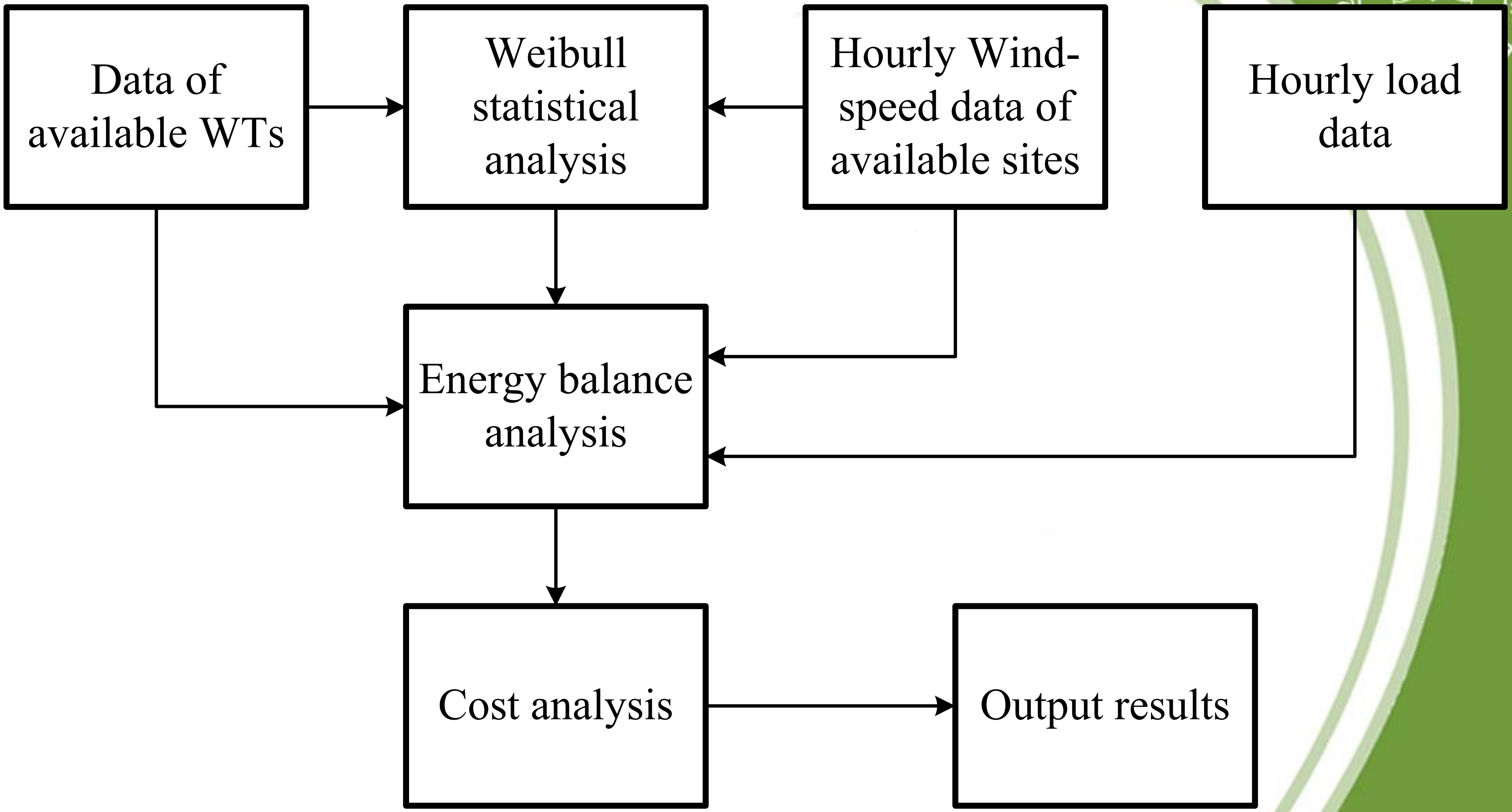
$$f(u)=\frac{k}{c}\left(\frac{u}{c}\right)^{k-1}\exp\left(-\left(\frac{u}{c}\right)^{k}\right),\qquad (k>0, u>0,\ c>1)$$



$$c=1.12\bar{u}\qquad (1.5\le k\le 3.0)$$

Weibull density function *f*(*u*) for scale parameter *c* = 1.

Design of Wind Energy System



Summarized block diagram of the analysis

Project Development

element of wind farm	% of total cost
Wind Turbines	65
Civil Works	13
Wind farm electrical infrastructure	8
Electrical network connection	6
Project development and management costs	8