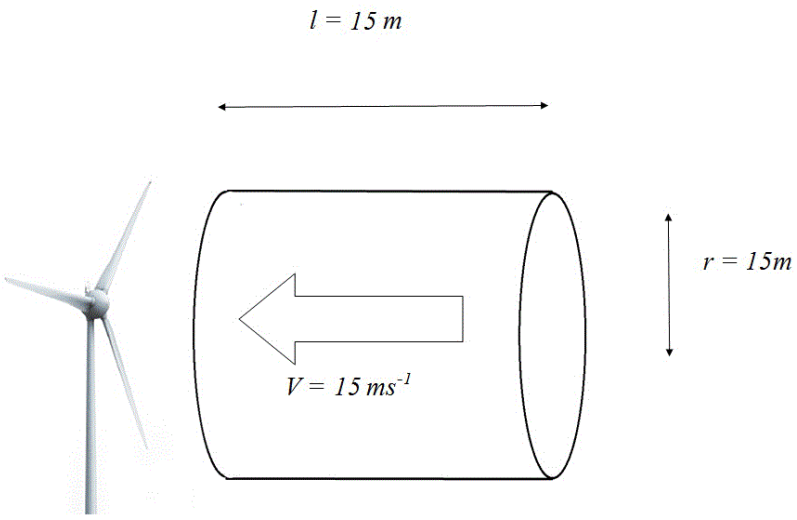
Copper in Wind Power 2

Turning the generator is the job of the turbine blades. This page shows that it is quite easy to calculate the available power using simple physics equations.

Calculating Energy and Power

Imagine a cylindrical volume of air approaching a wind turbine. If we can work out how much kinetic energy it has, then we can calculate how much energy is available. The amount of energy available per second gives us the power.



These questions will guide you to the solution

What is the volume of air in the imaginary cylinder?

The density of air is 1.2 kg m^{-3}. What is the mass of the air?

If the length of the cylinder is 15 metres and the wind speed is 15 ms^{-1} then the whole cylinder passes through the turbine in 1 second. What is the mass of air passing through the cylinder in 1 second?

Kinetic energy = 1/2 mv^2. What is the kinetic energy of the air in the cylinder that passes through the turbine?

If all that kinetic energy is transferred to the turbine in 1 second, what is the power of the turbine?

Did You Know?

The copper content per installed wind turbine is 2.5–6.4 tonnes per megawatt, as follows:

Generator: 0.7–4.0 tonnes of copper
Cabling: 0.7–1.0 tonnes of copper
Transformers: 0.7–1.4 tonnes of copper.

Figure 1: Modern offshore turbines are very large. (Courtesy of Alstom.)

Do you think that all the energy will be transferred? See **Figure 2** (right).

If all the energy was extracted from the wind, the air would stop behind the turbine. It turns out that you can never convert more than 59% of the wind energy into rotational energy in the turbine.

Will altitude make any difference to available power?

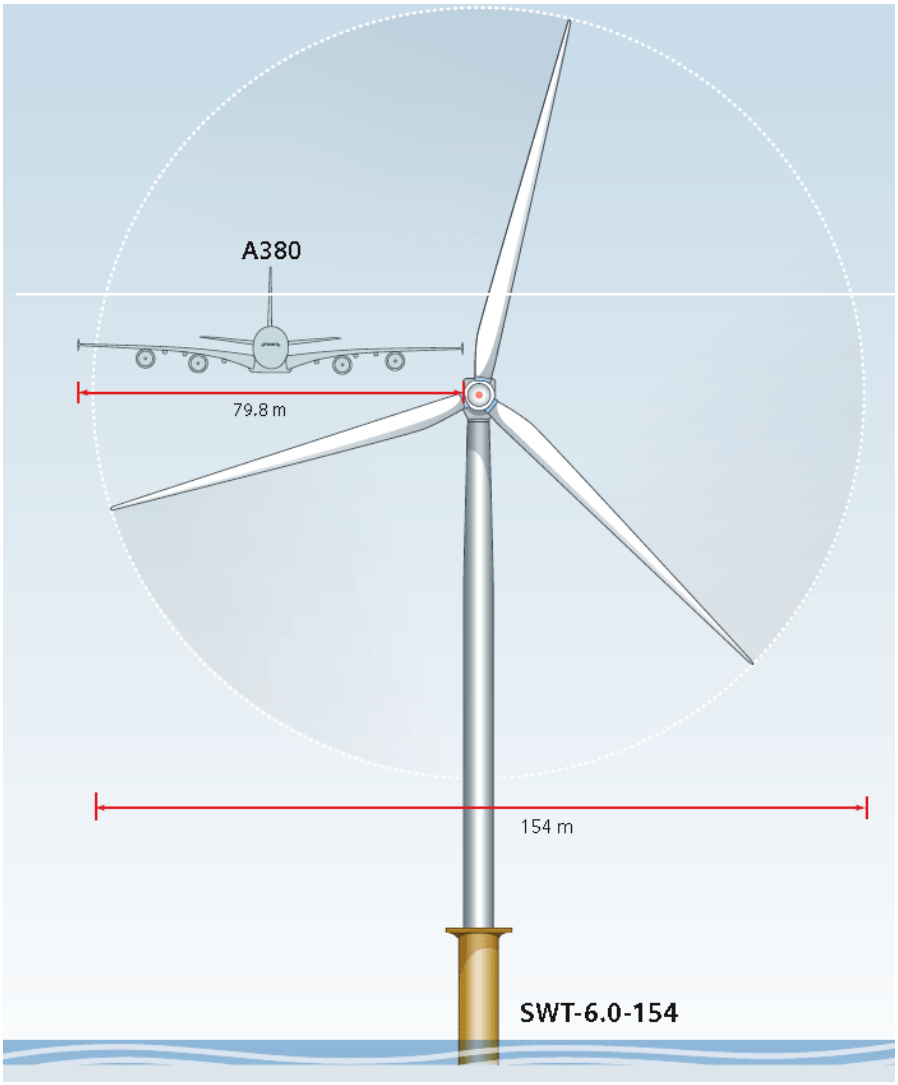


Figure 3: This Siemens 6 MW turbine has a 77 m radius. The swept area is 18,629 m² and a maximum rotation speed of 11 revolutions per minute. (Courtesy of Siemens.)

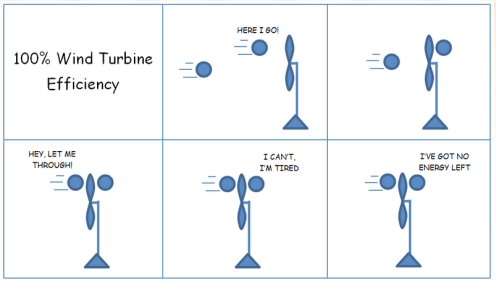


Figure 2: Diagram showing why 100% energy capture by the wind turbine is not possible. (Wikimedia)

Figure 4: The insulated copper cables running down from the generator carry huge currents. (Courtesy of Enercon.)

Tidal Flow Turbines

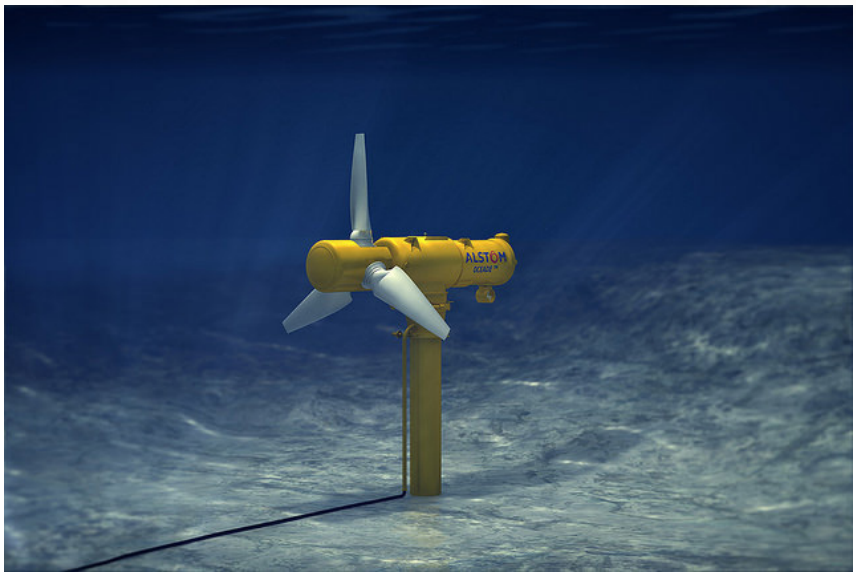


Figure 6: This turbine works under water. The blades are shorter because flowing water exerts huge forces that would destroy longer blades. Electricity and water do not mix, so the casing round the generator and the rotor shaft bearings have to be completely watertight. If maintenance is needed the whole unit has to be lifted onto a ship. (Courtesy of Alstom.)

Figure 7: A tidal flow turbine being installed. (Courtesy of Alstom.)

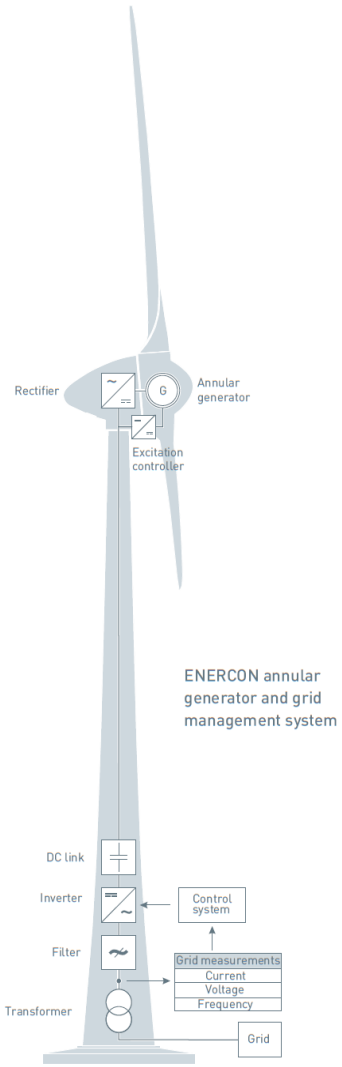


Figure 5: The electricity generated by the turbine has to match the electricity grid it is feeding. This requires transformers and control systems that all rely on copper to work efficiently. The base of the tower is clad with copper nickel alloy to prevent biofouling (growth of microorganisms, plants, algae or animals), which would otherwise make getting onto the tower from a ship very dangerous. (Courtesy of Enercon.)

Questions and Activities

1. **What is the mathematical relationship between wind speed and power output?**

2. **What is the mathematical relationship between blade length and power output?**

3. **For the turbine in Figure 3, what is the maximum speed of the blade tips in km per hour?**

4. **The equation for calculating electrical power is Power (in watts) = Volts x Amps (P=VI). If the generator is developing a voltage of 690 V and the power output is 6 MW, what is the current in amps running down the copper cables to the grid connection at the base of the tower?**

5. **The tidal flow turbine uses the energy of flowing water. Find out the density of water and compare it to the density of air. How many times more kinetic energy is in flowing water compared to wind blowing at the same speed?**

Click here for answers

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Copper Development Association is a non-profit organisation that provides information on copper's properties and applications, its essentiality for health, quality of life and its role in technology. It supports education through a collection of resources spanning biology, chemistry and physics. These materials have been developed in conjunction with the Association for Science Education, and reviewed by teachers.

For more resources, visit www.copperalliance.org.uk/education.