7 One way to combat climate change is to use renewable energy sources such as wind power. Fig. 7.1 shows a wind turbine that is used to harness wind power for the generation of electric power.

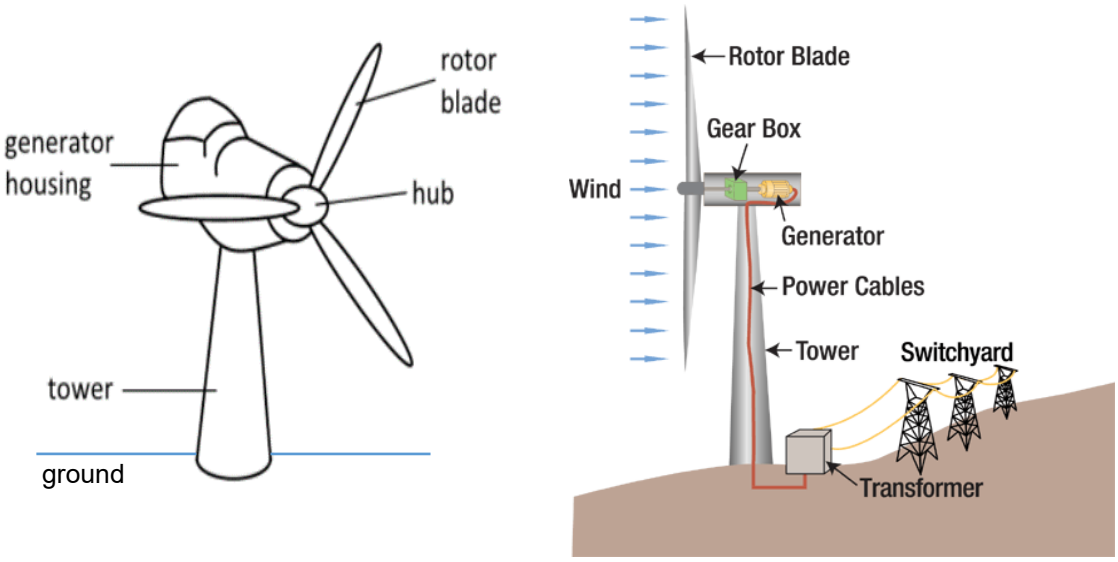

Fig. 7.1

The wind causes the rotor blades to turn and these drive an electric generator. The electric generator is situated in the housing at the top of the tower, as illustrated in Fig. 7.2.

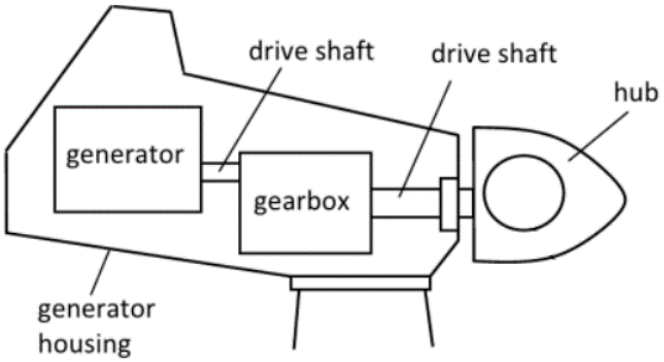

Fig. 7.2

Some information provided by a manufacturer of the wind turbine is given in Fig. 7.3 and Fig. 7.4.

height of tower from ground to hub	80 m
blade length	45 m
number of blades	3
rated power	3 MW

voltage	690 V
frequency	50 Hz

Fig. 7.3

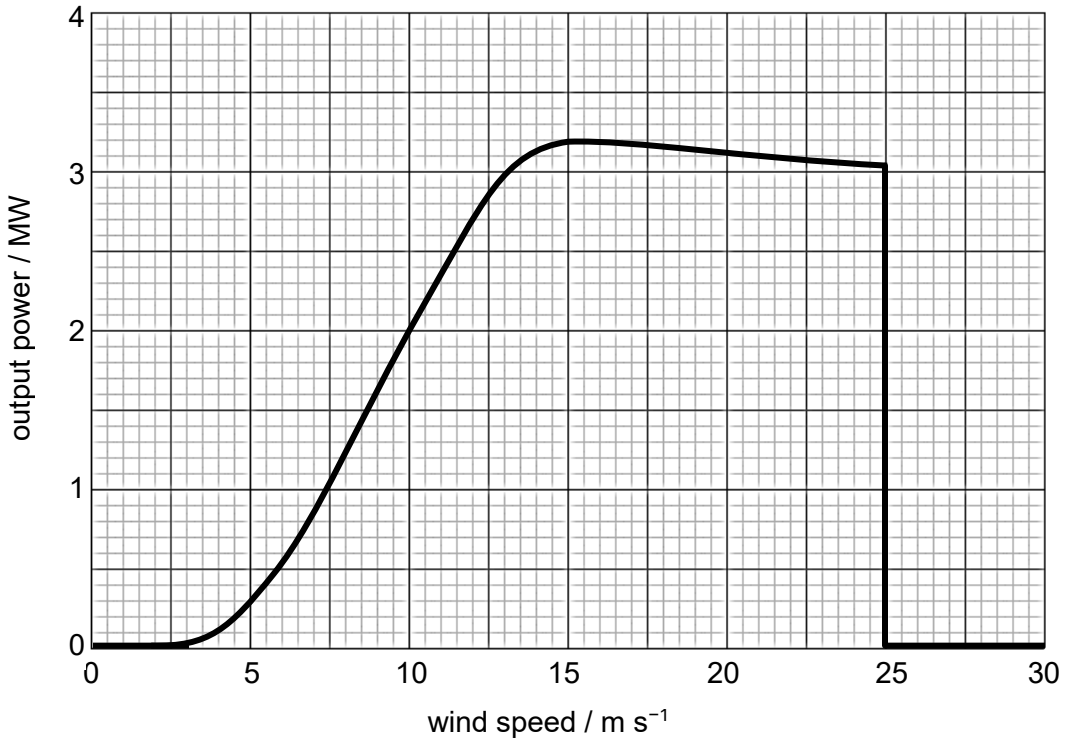

Fig. 7.4

(a) Calculate

(i) the minimum height of the tip of a rotor blade above ground level,

height = ... m [1]

(ii) the area swept by the rotor blades

area = ... m^2 [1]

(iii) the period of revolution of the rotor when the wind speed is 10 m s^{-1}, given that the ratio of the speed of the blade tip to the wind speed is 7.0 .

period = ... s [2]

(b) **(i)** Suggest with reason whether the rated power of 3 MW is a fair value.

.....

.....

.....

.....[1]

(ii) The average monthly electrical energy consumption per household in Singapore is 470 kW h. Calculate the number of homes one wind turbine can serve when operating at the rated power.

number of homes = ... [2]

(c) **(i)** Use the manufacturer's data to give values of

1. the maximum power output,

maximum power = ... MW [1]

2. the wind speed for this maximum power.

wind speed = ... m s^{-1} [1]

(ii) Air of density *p* and speed *v* is incident normally on a rotor of radius *r.* The kinetic energy *E* of the air incident on the rotor per unit time is given by

$$E = \frac{1}{2}\pi r^2 v^3 \rho$$

The air has density 1.25 kg m^{-3}.

Calculate, for the wind turbine operating at maximum output power,

1. the kinetic energy of air incident per second on the rotor (the incident wind power),

incident wind power = ... W [2]

2. the overall efficiency of generation of electric power.

efficiency = ... % [2]

(iii) In addition to the power usefully transformed in the wind turbine, 10% of the incident wind power is lost. Calculate the power of the wind after it has passed through the rotor.

power = ... W [2]

(iv) At high wind speeds, the turbine is 'cut-out', that is, the generator is no longer turned by the blades.

1. Use Fig. 7.4 to determine this cut-out speed.

cut-out speed = ... m s^{-1} [1]

2. Suggest one reason why it is necessary to have a cut-out speed.

.....

.....[1]

(d) The wind turbine must be protected from lightning strike.

(i) Suggest, with a reason, besides the highest point, which part of the wind turbine is most likely to be struck by lightning.

.....

.....

.....[2]

(ii) Suggest how the risk of damage by lightning may be minimised.

.....

.....

.....[1]

End of Paper