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Q1. For Darrieus H turbine

$U = 6\ m/s$ @ $10\ m$. $P = 1.01\ atm = 102338.3\ Pa$

$T = 16^\circ C = 289\ K$ $Z_2 = 20m$

a). Air Density:

$$\rho = \frac{PM}{RT} = \frac{102338.3\ Pa \cdot 29\ kg/kmol}{8314\ Nm/kmol\,K \cdot 289\ K} = \boxed{1.235\ kg/m^3}$$

b). Wind speed at $Z=16$, $Z=20$, $Z=24m$. w/ $\alpha = 1/7$

$$\frac{U(Z_1)}{U(Z_2)} = \left(\frac{Z_1}{Z_2}\right)^\alpha \quad \text{let } Z_2 = 10\ m.$$

$U(Z_2) = 6\ m/s$.

$Z_1 = 16\ m$

when. $U(Z_1) = 6\ m/s \left(\frac{16}{10}\right)^{1/7}$

$U(16) = 6.417\ m/s$.

When $Z_1 = 24\ m$.

$U(24) = 6\left(\frac{24}{10}\right)^{1/7}$

$U(24) = 6.799\ m/s$.

when. $Z_1 = 20\ m$.

$U(20) = 6\ m/s \left(\frac{20}{10}\right)^{1/7}$

$U(20) = 6.625\ m/s$.

c). Wind power density @ $U(20m)$.

At $z = 20$ m.

$U(20) = 6.625$ m/s.

$$\frac{P_w}{A} = \frac{\rho U^3}{2} = \frac{1.235 \cdot 6.625}{2} \boxed{= 179.55\ W/m^2}$$

d). Maximum Power output.

$C_{p,Betz} = 0.593$. $A_R = \pi \left(\frac{D}{2}\right)^2$

$U(24) = 6.799$ m/s.

$$P_{Betz} = C_{p,Betz}\, \rho \frac{\cancel{AU^3} AU^3}{2}.$$

$$= 0.593 \cdot 1.235 \cdot \left(\frac{3}{2}\right)^2 \pi \cancel{7} \cdot 6.799$$

$\cancel{P}$ $\boxed{= 3.259\ MW}$.

e). $\cancel{A}$ $C_{p,Actual} = 0.31$ Online Source.

$$P_{real} = 0.31 \cancel{=} \cdot 1.235 \cdot \frac{\pi}{2} \cdot 3^2 \cdot 6.799$$

$\boxed{P_{real} = 1.701\ MW}$. $\boxed{TSR = 2.6}$.

f). $TSR = \frac{wR}{u}$ $\Rightarrow$ $w = \frac{TSR \cdot u}{R} = \frac{2.6 \cdot 6.779}{3} = 5.89$ rad/s $\boxed{= 56.24\ RPM}$

$t = \frac{60}{56.24} = \boxed{1.067\ sec}$

2) Weibull Parameter: c, K.

Q2

$\bar{U}_{avg} = 8\ m/s$. $SD_w = 3.7\ m/s$ $\sigma_v = 3.7\ m/s$.

$Z = 20m$ $\sigma^2 = 13.69$.

~~As~~ Solve. c & K in MATLAB.

① $K = 2.2922$, $c = 7.1759$. at $Z = 100m$.

② $K = 2.2921$, $c = 9.0306$ at $Z = 20m$.

at ①

$$\bar{P}_{Betz} = \frac{A\bar{\rho}\eta C_{p,Betz}\, c^3\, \Gamma(1 + 3/K)}{2}$$

$$\frac{\bar{U}(Z_1)}{\bar{U}(Z_2)} = \left(\frac{Z_1}{Z_2}\right)^{\alpha}$$

$$\bar{U}_{(100)} = \bar{u}(20m)\left(\frac{20m}{100m}\right)^{1/4}$$

$$= 8\ m/s\left(\frac{20}{100}\right)^{1/7}$$

$$\boxed{\bar{u}(100) = 6.357\ m/s}$$

$$\frac{\sigma(Z_1)}{\sigma(Z_2)} = \left(\frac{Z_1}{Z_2}\right)^{\alpha}$$

$$\sigma_{(100)} = 3.7\left(\frac{20}{100}\right)^{1/7}$$

$$\boxed{\sigma = 2.94\ m/s}$$

at 2

$$\bar{P}_{Betz} = \frac{A \bar{\rho} \eta C_{p,Betz} C^3 \Gamma(1+3/K)}{2}, \quad \rho = \bar{\rho} = 1.225 \ kg/m^3$$

$C_{p,Betz} = 0.593$. $\eta = 0.9$. $C = 7.1759$.

$K = 2.2922$.

$$\boxed{\bar{P}_{Betz} = \cancel{1.117} \ 1.1127 \ MW}$$

Q3

$$\frac{U(z_1)}{U(z_2)} = \left(\frac{z_1}{z_2}\right)^{\alpha} \qquad z_1 = 30$$

$$z_2 = 10.$$

$$U(z_1) = U(z_2)\left(\frac{30}{10}\right)^{\cancel{?}\,\alpha}$$

Linear fit U_1 & U_2 $\rightarrow$ $y = 1.2x + 0.0031$.

$\cancel{\rightarrow 3^{\alpha} = 1.2}$ $\cancel{\alpha =}$ $\rightarrow 3^{\alpha} = 1.2x + 0.0031.$

$$\boxed{\alpha = 0.167}$$