Wind Energy

(Questions 41-42)

<u>Turbine & Location Details</u>

- Blade length, l = 22 meters
- Number of blades = 3
- Average Island Wind speed, v = 10 m/sec
- Air Density, ρ = 1.23 kg/m^3
- C_t = 40% (Turbine efficiency rating)
- C_a = 65% (Alternator/Generator efficiency rating)

**Use Site 1 to answer these questions*

Question #41:

Using the provided conditions, determine the *maximum* possible power (in megawatts), taking into account Betz Law, that could be produced by the wind turbine proposed to power the convenience store.

Solution:

P = .5 * ρ * A * V^3

P = .5*1.23 kg/m^3*(π*22^2)*(10m/sec)^3 * (16/27)

P = 554149 watts = .55 *MW*

Question #42:

Determine a realistic (taking into account mechanical inefficiencies) power output (in megawatts) for your client that could be produced by the wind turbine.

Solution:

$P = .5 * \rho * A * V^3 * C_t * C_a$

$P = .5 * 1.23\ kg/m^3 * (\pi * 22^2) * (10m/sec)^3 * .4 * .65$

P = .24 *MW*

(Questions 43-44)

An important concept in the construction of any building (e.g., the small convenience store) is wind load (the force enacted on the building by the wind). Wind engineers who install wind turbines are also involved in calculating wind load. Dolphin Cruise Lines is interested in the "wind load" on the small convenience store and the tower holding up the wind turbine.

**Use Site 1 to answer these questions*

Question #43:

Calculate the wind load on the wind-facing wall of the building using the following details: The convenience store wind-facing wall dimensions are: 12' tall, 20' long. How much force (in lbs) will be exerted on the wind-facing wall of the building by the wind?

Solution:

F = A * Pr * Cd

F = 12 * 20 * .00256 x V^2 * 2.05

F = (12'*20') * ($.00256 *$ 32.81 ft/s$)^2$ * 2 .05

F = 1355.87 lbs

Question #44

Calculate the wind load on the turbine tower using the following details: The tower for the turbine has a radius of 48 inches and a height of 260 feet (assume a uniform cylindrical shape for the tower). How much force (in lbs) will be exerted on the tower by the wind?

Solution:

F = A * Pr * Cd

F = ($2\pi rh$) * ($.00256 * (10\text{m/s})^2$ * 1.17

F = ((2 * π * *4'* * *260'*) * [.00256 * $(32.8084)^2$] * 1.17

F = 21067.31 lbs

(Questions 45-47)

<u>Turbine & Location Details</u>

- Blade length, *l* = 22 meters
- Average Island Wind speed, *v* = 10 m/sec
- Air Density, ρ = 1.23 kg/m^3
- C_t = 40% (Turbine efficiency rating)
- C_a = 65% (Alternator/Generator efficiency rating)
- T (time it takes each rotor to make one revolution) = 1.1582 sec

**Use Site 1 to answer these questions*

Question #45:

Calculate the distance traveled (in feet) by the tip of each blade in one revolution and the revolutions per *minute* of the proposed turbine. *Note:* the distance traveled will be the same as the circumference of the circle created by the spinning of the blades.

Solution:

Distance traveled = 2 πr

$2\,\pi * 22$= 326.73 meters

138.23 meters = 453.51 feet

Revolutions per minute = 60 sec / 1.1582 (time for one revolution)

= 51.80 revolutions per minute

Question #46:
Calculate the Tip Speed Ratio for the proposed turbine.

Solution:

TSR = $\frac{Tip\ Speed\ of\ Blade}{Wind\ Speed}$

Tip Speed = $\frac{2\pi r}{T}$

- T = time (sec)

TSR = ((2π*22) / 1.1582 sec) / 10 m/sec

TSR = ((2π*22) / 1.1582 sec) / 10 m/sec

TSR = 11.93

Question #47:

Calculate the difference between the optimum Tip Speed Ratio (for maximum power output) and the Tip Speed Ratio for the proposed turbine (as found in problem 6).

Solution:

TSR (Maximum) = $4\pi / n$

TSR (Maximum) = $4\pi / 3$

TSR (Maximum) = 4.19

Difference = 11.93 – 4.19 = 7.74

Suppose you research wind turbines on an island in close proximity and discover that the average wind speed on nearby islands is 13 m/sec and the average TSR is 4.3.

**Use Site 1 to answer this question*

Question #48:

In this scenario, assume a 3-blade turbine is being use and it takes 1.593 seconds for each blade to make one revolution. What length of blades (in feet) should be purchased for the proposed Dolphin Cruise Lines' turbine in order for it match the TSR obtained on the other islands?

Solution:

TSR = $\frac{Tip\ Speed\ of\ Blade}{Wind\ Speed}$

Tip Speed = $\frac{2\pi r}{T}$

- T = time

4.3 = ((2π * l) / 1.593 sec) / 13 m/sec

4.3 = ((2π * l) / 1.593 sec) / 13 m/sec

55.9 = (2π * l) / 1.593 sec)

89.0487 = (2π * l)

l = 14.1725 meters

***l* = 46.4977 ft.**

(Questions 49-50)

Some of the engineers on the team have proposed choosing a different site for the wind turbine (see scenario picture). The turbine and blade dimensions would be the same, but the site and wind speed would be different.

SITE 1: Turbine & Location Details

- Blade length, l = 22 meters
- Number of blades = 3
- Average Island Wind speed, v = 10 m/sec
- Air Density, ρ = 1.23 kg/m^3
- C_t = 40% (Turbine efficiency rating)
- C_a = 65% (Alternator/Generator efficiency rating)
- T (time it takes each rotor to make one revolution) = 1.1582 sec

SITE 2: Turbine & Location Details

- Blade length, l = 22 meters
- Number of blades = 3
- Average Island Wind speed, v = 12 m/sec
- Air Density, ρ = 1.23 kg/m^3
- C_t = 40% (Turbine efficiency rating)
- C_a = 65% (Alternator/Generator efficiency rating)
- T (time it takes each rotor to make one revolution) = .976 sec

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Question #49

Which site should your team choose to maximize power output and efficiency (select the site that provides the TSR *closest* to the ideal TSR)? What is the calculated TSR for the site you selected?

Solution:

Site 1

TSR = $\frac{Tip\ Speed\ of\ Blade}{Wind\ Speed}$

Tip Speed = $\frac{2\pi r}{T}$

- T = time

TSR = ((2π*22 meters) / 1.1582 sec) / 10 m/sec

Commented [SB1]: Wind speed is 10

TSR = ((2π*22 meters) / 1.1582 sec) / 10 m/sec

TSR = 11.93

Site 2

TSR = $\frac{Tip\ Speed\ of\ Blade}{Wind\ Speed}$

Tip Speed = $\frac{2\pi r}{T}$

- T = time

TSR = ((2π*22 meters) / .976 sec) / 12 m/sec

TSR = ((2π*22 meters) / .976 sec) / 12 m/sec

TSR = 11.80

TSR (Maximum) = 4 π / n

TSR = 4 π / 3

TSR = 4.19

Correct answer is E (Site 2, TSR = 11.80)

Question #50:

If site 2 were chosen what would the calculated wind load be for the proposed turbine in site 2? The tower for the turbine would have the same specifications as the tower outlined for site 1.

Solution:

F = A * P * Cd

F = $(2\pi rh)$ * $(12\text{m/s})^2$ * 1.17

F = ((2 * π * *4'* * *260'*) * [.00256 * $(39.3701)^2$] * 1.17

F = 30336.9 lbs