Homework #3
ME 4470/ESE 4470/ME 5475-02
Wind and Tidal Energy

J. W. Naughton **Assigned: 10/07/15** **Due: 10/16/15**

This homework is worth 33 points

1. (5) Provide reference from reading the Executive Summary from "Western Wind and Solar Integration Study" (May 2010 report) to support your answers below (page number and line number).

   (a) What changes to balancing areas in Western Electricity Coordinating Council (WECC) are expected?

   (b) Describe the three scenarios studied. Under what scenario does Wyoming have the largest wind generation installed capacity? Which scenario costs the least?

   (c) Describe the effect of wind on other generation sources. Why are nuclear and coal fired generation challenging from a load management perspective when renewables are incorporated into the system?

   (d) Under what conditions does wind primarily displace coal in comparison to the scenario where no renewables are developed? What is the effect on emissions in this case?

   (e) Under what scenario does pumped-hydro energy storage become a economically viable?

2. (5) Provide a short answer to the questions below, and provide a reference from reading the Executive Summary section ES.4 (The Wind Vision Roadmap: A Pathway Forward) from Wind Vision to support your claims (page number and line number).

   (a) List 5 areas that are a focus for increasing development of wind energy.?

   (b) Who are the primary stakeholders in the continued improvement of wind energy technologies? What is a stakeholder?

   (c) What are the action areas for the Economic Value theme?

   (d) Why is it important to continue reduction of wind energy costs?

   (e) What are the potential consequences of not pursuing the proposed roadmap?

3. (20) A wind turbine blade has the following properties

- Blade and chord distribution:

r (m)	c (m)	θ_p(deg)	Shape
4	1.5	26.0	DU-97-W-300
6	1.4	16.0	DU-97-W-300
8	1.3	10.0	DU-97-W-300
10	1.2	5.7	DU-97-W-250
12	1.0	3.7	DU-95-W-250
14	0.8	2.5	DU-95-W-250
16	0.6	2.0	DU-95-W-180
18	0.4	1.5	DU-95-W-180
20	0.2	1.0	DU-95-W-180

- Blade minimum radius: 3 m
- Blade tip radius: 21 m
- Rotational speed: 30 rpm
- Number of blades: 3

Files containing lift and drag data for these airfoils are provided on the web site as are plots of the data. The data files contain a nonsense number (-9.999) for angles where data does not exist.

Using the blade element momentum approach (with and without the Prandtl correction) and dividing the blade into nine 2m segments as suggested above, consider the turbine operating at sea level (ρ=1.23 kg/m^3) with a 10 m/s wind.

(a) Plot the local angle of attack α in degrees as a function of distance from the hub. Plot with and without the Prandtl tip correction.

(b) Plot the local Normal and Tangential Force Coefficients as a function of distance from the hub. Plot the Forces using the Prandtl correction and without it. Where does the correction have the most effect?

(c) Determine the total thrust, torque, and power experienced by the turbine blades from the results determined using the Prandtl tip correction. Since these quantities require integration over the blade, make sure you explain how you evaluate each quantity.

Hints: Use interpolation to determine the values of lift and drag coefficient at the angles where your program needs them. Note that you may need to extrapolate the data (particularly the drag data) beyond where it is given so your program can converge on the correct lift/drag value.

Follow a presentation of your work identifying what is given, what you are asked to find, the data provided, assumptions, etc. Include plots and tables as requested above, but e-mail your programs to me rather than including the printed version. Please spend time discussing your approach (complete with equations and how they

were implemented) and discussing the results - just don't hand in plots with no explanation. A simple rule for the level of detail requires is that you should be able to understand completely what you did if you picked this assignment up 3 years from now.