Chapter 6

Tower Structures

I Tower Forces

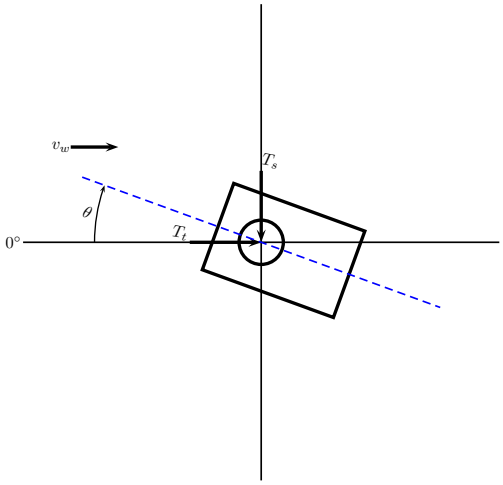

Figure 6.1: Wind turbine thrust and side forces, T_t and T_s, on a vertical tower. Also shown is the yaw angle, θ.

II Experiments

Each experiment will begin with a discussion of the tower structure and how components of the system are intersting to our work. You will then run the wind turbine simulator at various conditions while collecting data that will be processed outside the lab. You will gather data from sensors installed on the machinery, and will collect and analyze it according to the exercise. These exercises will give you an understanding of the static and dynamic nature of wind turbine towers. Insights gained here can lead to more informed structure designs. The concepts experienced here should complement topics discussed in lecture. With rotating machinery involved, it is important that you stay focused and practice safe work habits. Hazards should be discussed prior to each exercise.

Experiment 6.1: Tower Forces

Goals: Identify major components of the wind turbine structure. Measure and understand the forces acting on a wind turbine tower, in both their static and dynamic states. Operate the turbine and observe the structure dynamics.

Procedure:

1. Setup the wind turbine simulator (WTS) trailer in a location conducive to operating the wind turbine with the prime-mover. Setup the control and data acquisition system to measure the tower thrust and side forces and the rotor angle. As a group, discuss the components of the structure and how they interact.

2. Identify the 0° rotor position, and note which blade is aligned with the tower. Also, yaw the turbine so it is aligned with the thrust sensor.

3. Pitch the blades to 10° and run the hub at speeds between 60 and 200 rpm, at increments of 20 rpm. Capture the thrust and side forces, as well as the rotor angle, on the oscilloscope. Be sure to set the oscilloscope to capture all dynamics. Also, observe the forces in time and spectrum using the WindQuest application. Adjust the DAQ settings until a quality spectrum is obtained.

4. For each test condition, identify the frequency components that correspond to the main rotor speed, as well as three-times the rotor speed. Identify other interesting frequencies if present.

5. Run the machine at 100 rpm and 200 rpm, and pitch all three blades to 0°. For both test speeds, pitch one blade (that which is aligned with the tower when the rotor is at 0° to 10°, 20°, and 30°. Capture the time and spectrum of the forces, and the rotor angle. Observe the behavior of the system.

Deliverables:

1. For the case of 200 rpm and 10° pitch, sketch a diagram of the forces acting on the tower structure, and include the average measured values. What is the equivalent force acting on the rotor axis? You will have to measure the height to the nose cone.

2. For each test case, use the oscilloscope data to plot the frequency spectrum. Also quantify the average and peak thrust for each. What is the maximum magnitude of forces exerted on the tower? Is there rotor speed that excites a node of the system, such that an oscillation develops at or around that speed? If so, at what speed does this occur, and how high does the magnitude of the oscillation become?

3. What other frequency components do you observe? Can you identify the contributing component or system?

4. Explain how information gathered in this experiment can be useful in the design of wind turbine structures.