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Effect of Damping on Tower Deflection and Design

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ASTRACT

For a given tower height and turbine size the only system property that can be varied to change the dynamic response is stiffness. In order to avoid the resonance range caused by the rotating blades, un-damped towers must be either very soft or very stiff. Increasing tower stiffness requires an increase in weight or an increase in tower diameter or both. Because damping reduces the tower deflection due to resonance, a damped tower can operate closer to the resonance range. This means that a damped tower can have a smaller tower diameter and/or a lower tower weight vs. an un-damped tower of the same height and turbine size.

A wind turbine generator system (WTG) is highly dynamic in nature. While the turbine is operating the tower is subject to continuous cyclic loading due to the rotating blades and the turbulent nature of the wind. To avoid the negative effects of resonance, traditional tubular steel towers are designed to be very stiff, with a natural frequency far removed from the rotor rotational frequency. This added stiffness results in a tower that is very heavy and impossible to erect without the largest crane equipment.

An open frame, or space frame tower can be significantly lighter than a tubular tower, but in order to achieve the stiffness required to avoid resonance they must have large base diameters.

Another way to avoid the problems of resonance is to add damping to the tower structure rather than stiffness. Damping absorbs or dissipates the energy associated with harmonic motion. Therefore, adding damping to a wind turbine tower enables it to be softer, with a natural frequency closer to the rotor rotational frequency. The result is a structure that is lighter weight than a traditional tubular tower and has a smaller base diameter than a traditional open frame tower. The effects of adding damping in a wind turbine tower structure can be understood by using a single degree of freedom approximation as shown in Fig. 1 below.

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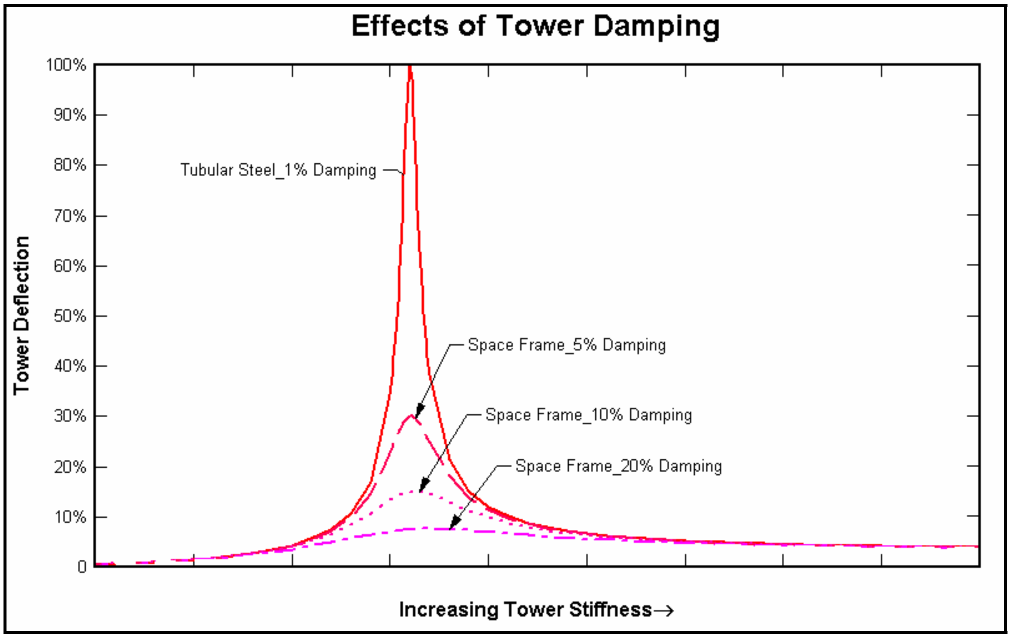

Figure 1: Single Degree Freedom Damping Effects on Tower

Without damping the tower would experience larger deflections which cause higher stresses and increased fatigue rates in the tower members. Figure 2 is the simulation time history of an operating 2.5MW turbine mounted on top of a space frame tower. Note the harmonic nature of the tower top deflection and note that the larger deflections are reduced as much as 30% by including damping.

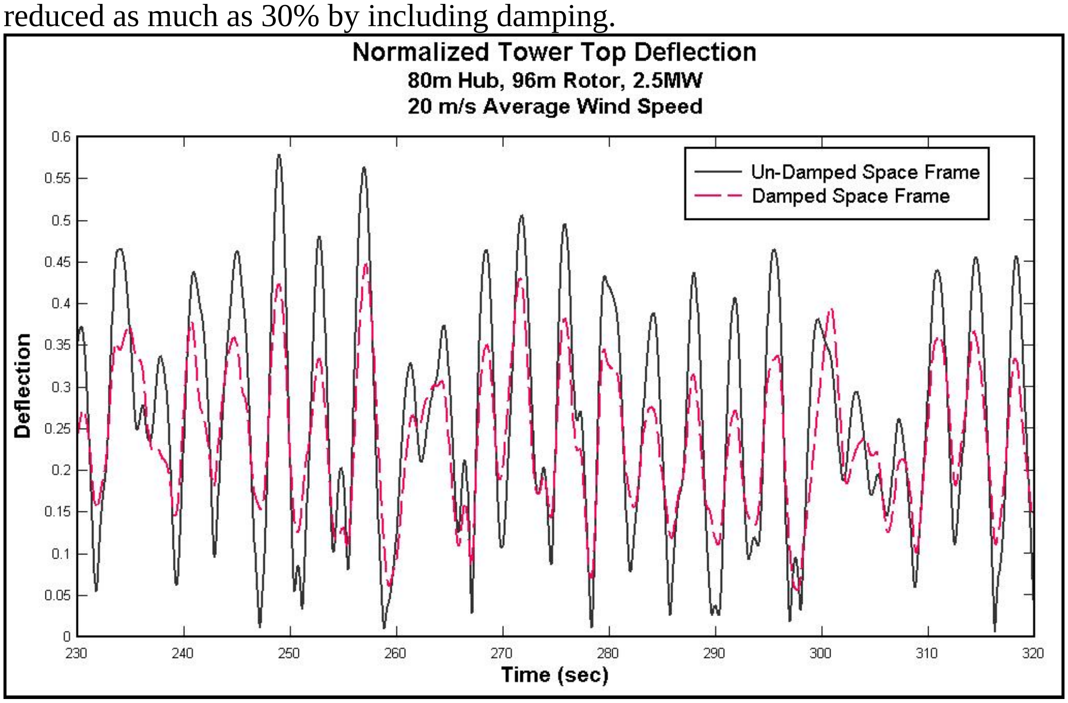

Figure 2: Simulation time history comparing space frames with and without damping.

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Wasatch Wind has developed an innovative damped strut that can be installed in the space frame tower. The struts replace normal structural members already in the tower to provide damping and response attenuation such as shown in Figure 2. The resulting tower design is a lighter weight smaller diameter space frame tower that enables the use of a gin pole erection method which can save money vs. a typical large crane installation.