The Physics of Wind Generator Collapse

And I looked, and behold, a whirlwind came out of the North...
Ezekiel 1:4

Your wind generator tower just collapsed during the high gusty winds that are prevalent here in Northern Nevada. It was the wind, right?

There's a bigger picture here than what might be outwardly apparent on the surface. Yes, towers collapse during high winds, but is there something else besides high winds involved?

If your tower has collapsed and you are determined to put up a bigger stronger tower, with more supports and guy wires, read this first before you spend a lot of money on a solution that might not work.

I worked in the little known field of reliability engineering and vibration analysis before retiring and moving to Northern Nevada. I had planned to put up a small wind generator system on my property until I had heard from many who had attempted to do so and whose result was a catastrophic failure.

After hearing such warnings, I decided to study the problem first before starting. I went to many places in the county where small wind systems(sws) were installed, and observed them during periods of high gusty winds.

It did not take me long to come to a conclusion and to design a different sws. That system is described roughly in the other section of this presentation called "The Flying Lizard".

For now, I will concentrate on what some owners of conventional sws may need to know to redesign their own systems in order to avoid a potential catastrophe that might cause property damage and injury. The fact is that a windgenerator weighing up to 300 pounds falling from a height of 60 feet has considerable destructive power, and examining the reliability of ones system has merit.

The Upside Down Guitar

Everything in the Universe vibrates. We vibrate, the Earth vibrates, there's no getting around that condition. Under normal circumstances, that vibration is too small to have any effect. In extreme or unusual circumstances, that vibration can become destructive. The point at which

those destructive effects occur is called "resonance".

Every object in the Universe has a resonance point. It is the frequency at which that object can absorb or transfer energy at its maximum rate. The classic case of "Is it live or is it Memorex?"where Ella Fitzgerald breaks the wine glass with her amplified voice is the prime example of the destructive power of resonance.

This is the case with sws structural failure. A classic sws, with the upwind, top mounted generator can be described in terms of being an upside down guitar, where the vortexes coming off the blade tips pluck the string of the supporting tower.

During the right conditions, the combination of wind force and vibration can destroy a perfectly sound support tower within minutes, or over a period of time the effects of vibration caused metal fatigue can weaken a tower at certain locations of maximum vibrational amplitude and cause it to fail during a period of high stress.

There is no way to strengthen a tower to the point where it can withstand the effects of resonance. It has to be designed differently. Its a matter of changing the tune of the upside down guitar.

If you are planning on erecting an upwind, top mounted windgenerator, the best advice is to understand that the relative dimensions of the tower versus the blade length are critical for the structural integrity of the sws.

If there is a priority in designing an sws, it is this: Never, repeat never, put a wind generator on top of a tower whose length is an even multiple of the blade length, and especially grevious, is if that multiple is 4 times the blade length. Disaster is sure to ensue shortly thereafter.

This is because such an arrangement is tuned to absorb the vibration from the passing blade tip in exactly the location of maximum vibrational amplitude on the tower. It is for this reason that the 4 times blade length tower height must be avoided. Use a ratio of blade length to tower height that is a multiple of a prime number greater than two.

Also for reasons related the same principles as the tower height, it is prudent to have the number of blades on your windmill be an prime number. Especially avoid blade assemblies with 2 blades. The reason for this is primarily aerodynamic rather that vibrational.

Calculating blade and tower resonance frequencies

To calculate the frequency of your blades, find the average wind speed for your location. For Silver Springs, Nevada, this is 6 mph. Then somehow measure or interpolate the rpm your windmill will be turning at most of the time from this average speed. Multiply this number by the number of blades on your windmill and divide by 60 to get hz, or cycles per second. This will give you the frequency of the vibrations your tower will be subject to most of the time. This is the average driver frequency

(average rpm x no. of blades)/60 = average driver frequency

It is the frequency at which the blades of the wind generator pass in front of the support tower, sometimes called the blade pass frequency. It represents how many vortexes from the blades hit the support tower per second.

For example, a 5 bladed turbine spinning at 200 rpm will have a blade pass frequency of approximately 17 hz.

Do it again for the maximum sustained wind speed in the area. You can usually get this number from an NOAA wind rose. This is the highest wind speed sustained for 5% of the time in your area, it is usually about 12 mph for the western U.S. but your area can be different.

(Max sustained rpm x no. of blades)/60 = highest driver frequency

Then calculate the resonant frequency of your tower. Divide the length of the tower by the speed of sound in air. This will give you the period of the tower, invert that number and you have the towers natural frequency. The speed of sound is 1000 ft per second and depends on altitude. As air pressure decreases with altitude, the speed of sound decreases

A tower 50 feet high has a resonant frequency of about 20 hz. A 25 ft tower has a resonant frequency of 40 hz.

In fact many windgenerators have blade pass frequencies within this range, and this explains the nature of these failures.

If the resonant frequency of your tower is within the average to highest driver frequency range of your top mounted generator blades, you can expect to have energy transfer between them, and the resultant structural fatique will result in a collapse of the structure at sometime in the future, possibly during periods of high stress. It won't just be the high winds that did your wind generator in, it was a combination of factors.

So there it is, examine your own rig, try out the numbers, and see if you are in the danger zone. One option you may have is to change the height of your tower to get it out of the range of resonance. There may be other options, see if you can come up with alternatives.

Good Luck...

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