Grand Ridge notes / grid-connected wind turbines
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First, look to see whether the wind turbines are turning at exactly the same rate. This tells you something about their generator and electronics design.

Older style wind turbines are forced to turn together because they're all connected to the grid when they're making power, and the grid essentially regulates what they do. The grid is just a big tangle of wires – there's no intelligence to it, or one-way valves and gates. It's just a bunch of wires that the turbogenerators (turbines + generators) all connect to, and that the people receiving power all connect to. So when a turbogenerator connects to the grid, it can't just make whatever frequency power it wants – it is connected to all the other thousands of turbogenerators all oscillating in unison. In all the problem sets to date you've considered the case of an isolated turbogenerator driving loads, but never a whole network of turbogenerators connected together. So these ideas are all new to you, and we haven't discussed them in class.

Think through a thought-experiment: First, imagine that you hook up a generator to the grid but you don't apply any force to it at all. But then it's just a motor! The situation is exactly like plugging an AC motor into your wall power. It will begin rotating all by itself at the grid frequency (modulated by its own gears and number of poles).

Then, imagine that you grabbed the rotor and started trying to turn the generator at a different frequency. You brace yourself and push as hard as you can to try to force it to turn at a different frequency –but you're fighting the collective power of all the other generators that are driving the 60Hz oscillation of your wall power. If you did manage to get your generator to turn at the different frequency you want, you'd be setting the voltage at your generator wires to be a different frequency than 60 Hz… but those wires are connected to all the wires in the grid. So the only way you could do that would be if you forced the whole grid to rotate at that frequency. And you can't do that, you're just one person. All you'd get would be sore hands and a hot motor.

Only if you can turn the motor/generator at *just* the right frequency AND somehow put work into it will you be able to act like a generator and contribute more power to the grid than you draw from it.

The idea of "putting work into the generator" that is hooked up to other generators is an odd idea, but maybe one that benefits from analogy. A single turbo-generator is like a cyclist. His body is the turbine, and if his load doesn't change, then the more mechanical work he puts out, the faster his legs go around. This is exactly like the single-generator problem set you did. If the load was constant but you upped the turbine power, the generator would spin faster.

Now, connect two turbogenerators / cyclists together, in such a way that they're constrained to rotate at the same rate. Again assume a constant load (the road stays at the same slope, the headwind is constant). If one of the two slacks off, the whole system will rotate more slowly. If one of the two starts to pound on the pedals energetically, the rotation will speed up noticeably.

With three cyclists, any one starts to make less of a fractional difference, but still, if one of the three cyclists gets lazy, the pedals will revolve noticeably more slowly and the bike will slow down.

With four cyclists, maybe it doesn't matter so much whether one particular member is contributing to a whole… (especially if that one was a small power producers to begin with). The rotation rate is relatively constant but the small turbogenerator / cyclist and contribute or not – his power contribution can go from zero to full on without affecting the whole too much.

The more cyclists / turbogenerators you have connected together, the less each individual one matters. That means that connecting or disconnecting an individual wind turbine doesn't alter the whole grid much (it does by a tiny tiny amount), BUT that individual wind turbine can contribute either a lot, or nothing, or it can even draw power FROM the grid … all while turning always at the same rate. The rate is determined by the collective whole, but the power the turbine can put into that whole is set by its local wind conditions. More wind and it can lend an extra push – but it's never so much push as to skew the grid frequency, because the number of generators connected together is so large.

Many newer wind turbines take advantage of power electronics to free themselves from this constraint, however. Because the wind is variable, they don't want to be tied to one rotation rate. This is not a concern that matters to fossil-fueled steam- or gas-fired turbogenerators, or even hydro turbines - this strategy is something you find only in wind turbines. Grand Ridge will let you look at the electronics, but you should be able to tell what type of turbogenerators they are just by watching them rotate from a distance.

Note that if a generator of either type is electrically disconnected from the grid, it's once again free to spin on its own at whatever rate it wants to. Or, as a flip side, if you want to stop a turbine, you HAVE to disconnect it from the grid to do so. If you're lucky, the operators at Grand Ridge will actually stop a turbine for you so you can go inside (they won't let you inside the tower while it's turning). You can see what happens – first the turbine is disconnected from the grid to permit it to slow down. Then the operator feathers the blades of the turbine, turning them into the wind so that the blades get no lift anymore – he or she makes them into terrible airfoils. The turbine then starts to slow down – it's getting no more power, so it gradually comes to a stop. Once it's stopped, the operator can set the brake and allow you to go inside the tower.

Grand Ridge operator were very generous in the past with talking about finances of wind turbines. You can do some pre-calculation – if the generator is e.g. 1.5 MW rated, then assuming the site is a reasonable one the turbine will produce something like 0.5 MW of power on average. Over the course of a year that's 0.5*365*24 ~ 4400 MWh. At a wholesale cost of ~ 3.5 cents/kWh then each turbine is grossing 4400 MWh x $35/MWh = $150,000 ! Compare that to how much Grand Ridge says they e.g. pay farmers in rent, or neighbors in nuisance payments, and you can see those payments are pretty small in comparison.

Or course, turbines aren't functioning all the time. Last time I believe we were told that Grand Ridge had one repair guy per 10 turbines, which implies a fair amount of down time. They seemed quite willing to talk about operational issues as well.