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> *"Frankly, when I fly over a number of European countries, the turbines I see do not fill me with envy."*
>
> *– Nicolas Sarkozy, President of France*

Chapter 5: Wind Turbine Power Consumption

That's right folks, wind turbines consume energy. They consume energy when they are operating and even when they are sitting there not turning at all. This is the "P_c" in the previous chapter that has to be subtracted from the gross power generated by a wind turbine, to obtain the net useful power generated by the wind turbine, P_n.

With all the hoopla surrounding wind power, the basic questions concerning its viability must first be asked. Everyone seems to know that wind power is generated with the free fuel of the wind. But few people are aware of the electric power consumed by wind generation facilities. Everyone thinks the electric meter only runs in one direction for wind facilities. The fact is: whether the wind is blowing or not, wind facilities require power.

Normal power plants consume about 10% of the electric energy they produce. Wind facilities require much more power. However, ***since this power is not usually metered***, no one really knows the net generated power from a wind facility. All we ever hear about is the *gross* power generated, but you never hear of the *net* power generated.

It is very difficult to find out what each wind facility generates. If you go to the www.eia.com website, wind generation statistics are lumped together with all the other alternative energies such as biomass, solar, etc.
Besides laziness, there can be only three reasons for lumping these alternative energies together:

(a) convenience
(b) someone has something to hide
(c) what use is there to subdivide an already insignificant number?

The proponents of wind power, will normally quantify the power generated from wind in terms of homes powered, or nameplate capacity, or some other unit of power that is ultimately untraceable or immeasurable. It is frustrating to find out exactly how much net generated power comes from wind farms.

Memories are short. Back in the 1950's, the promise of nuclear power was tantalizing. Claims were being made that power from nuclear plants would be generated so cheaply that it would not even be necessary for it to be metered? Well, the reality of nuclear power showed that it is just another form of power which doesn't have a strangle-hold over any other form of power.

So, without further delay, here are the various systems associated with a wind turbine that require power. For the purposes of discussion, the systems described are associated with a typical HAWT.

a) blade heating. Wind turbine blades have a tendency to accumulate ice in cold, wet weather. This same problem happens to aircraft. It is customary to hear of planes being "de-iced" prior to take off, so they are air worthy and will not crash due to the extra unwanted weight of ice, or ice freezing control surfaces making the plane uncontrollable. Obviously, the turbine blades should be kept free of ice to maintain efficiency. However, they must also be maintained free of ice to prevent the flinging of ice missiles, which could be destructive or deadly. Blade heating can take anywhere from 10-20% of the power supposedly generated by wind turbines.

The number of hours blade heating is required is probably very, very small for areas of traditionally warmer climate, such as, the panhandle of Texas. However, for areas of colder climate like the upper- Midwest and Northeast US States, blade heating could be significant. For arguments-sake let us assume the average loss is 1%.

b) yaw mechanism. This device keeps the wind turbine pointed into the direction of the wind to ensure the maximum power can be generated. On small farm or residence wind turbines this is accomplished with a simple vane at the rear of the turbine. Just like a bomb, the fins keep it going into the direction intended. This device is most visible in Brush's wind turbine. In modern wind turbines, the yaw mechanism is an electric/hydraulic motor assembly located at the top of the pylon and rotates the entire wind turbine assembly from a geared turntable. It is not known how much power this device consumes, but is believed to be about 1% when it is functioning.

Once the yaw mechanism points the wind turbine into the general direction of the wind, only periodic momentary jogging of the yaw mechanism should be needed, since wind direction does not usually change much minute to minute. Let us assume a loss of 0.2%

c) pitch mechanism. This device rotates the turbine blades about their own axes to keep the efficiency of the wind gathering process at a maximum. At lower wind velocities the blades are pitched more, just like aircraft lowering their flaps on landing and takeoff to get a maximum amount of lift. As the wind speed picks up the blade pitch is reduced, as are the flaps raised on aircraft after it takes off and increases speed.

As with the yaw mechanism the blade pitch mechanism should only be needed occasionally. Yet the variation in wind speed is apt always to be much more so than the variation in the wind's direction. With a lot of time-delay averaging techniques, the amount of time the pitch mechanism has to be adjusted can be reduced significantly. Let us be generous and assume this loss is also at 0.2%.

d) hydraulic or mechanical brake. Wind turbines have a speed limit at which they can operate without destroying themselves in the process. A recent You Tube video captured the result of a HAWT exploding during a violent wind storm. HAWT's usually have a cut out speed of around 25 to 30 meters/second.

To ensure they do not operate at high wind speeds, the entire drive-train mechanism including turbine blades are locked hydraulically, just like when you press on the brakes of your car to bring it to a halt. This hydraulic brake consumes a lot of power. To appreciate this level of power, check out the ammeter on the dashboard of a car with air conditioning. When the magnetic clutch is engaged, the dip in amperage, which is most noticeable on older cars, is amazing.

However, the need to apply braking should be very, very small, in that wind speeds are unlikely to be over 20 m/sec. Looking at an average wind histogram, the brake should be on less than 15% of the time. If the braking force must overcome the wind's diving force, then we are talking some significant power here. But this braking force rarely has to be applied. Let us assume a loss of 0.5%.

e) stator energizing. The stator is the fixed wire cage surrounding the rotating armature in a generator. Almost all large HAWTs have electromagnetic rather than permanent magnets as their stator construction. In order for the wind turbine to generate electricity, the stator must be magnetized. No matter what the speed of the wind turbine, the stator must be energized in order for the generator to produce power.

Stator energizing can take up to 10% of the power generated by the wind turbine. Let us assume this power when in operation is 8%. But since wind turbines may operate only about 80% of the time, let us assume a loss of 6.4%.

f) generator cooling. Unlike wind turbine generators which are 1.5 to 5 MW in size, generators in traditional power plants are usually in the 800 to 1,000-MW size. Traditional generators being much larger, reap the benefit of economy of scale with higher efficiencies. They also use hydrogen gas as the medium of removing heat generated. Hydrogen has an extraordinarily high specific heat which allows it to remove the most heat with the smallest quantity of gas, resulting in the least amount of friction or "windage" losses. Wind turbine generators on the other hand are air-only, or air-and-water cooled and are not as efficient as their bigger brothers. Let us assume a loss of 2%.

g) <u>thyristors</u>. These solid state devices slowly throttle the output of the generator onto the grid. These devices are the electric version of a transmission on a car, wherein they permit a smooth conveyance of power from the engine operating at different speeds and power output to the tires on the road operating at constant speed. The thyristors usually take about 1-2% of the power generated by the wind turbine. More modern wind turbines have bypass switches which permit shutting down the thyristors when they are not needed. But the cost of installing the thyristors and bypass switching must still be paid for, whether they are operating, or not. Let us assume a loss of 0.1%.

h) <u>volt amp reactive (var) or power factor correction equipment.</u> Traditional power plants are usually much closer to the points where loads are extracted from the grid by users than is a wind turbine facility. As such, traditional power generation matches closely the load nearby. Wind turbine facilities, however, are almost always more remotely situated from the load they are intend to serve. This is noticeable in neighborhoods with capacitor banks on utility poles. The capacitors correct the phasing of the load with that on the grid. Otherwise, this 'powerless' power would not be metered and lost. This location disparity creates a phase imbalance between the load points and generation points on the grid. With wind turbine facilities, all the generated capacity must be phase corrected before being connected to the grid. This equipment is massive, costly, and has power losses in the range of 1 to 2%. Let us assume a loss of 1.5%.

i) <u>turning gear</u>. Large mechanical drive trains cannot remain stationary for long periods when not in use. Due to their massive weight, they can deform under their own weight. Old Navy ships when in port would "jack the shaft". In traditional power plants, the large turbine generators have the same problem and are put on a 'turning gear'. These devices rotate the entire drive mechanism 1 or 2 revolutions an hour to prevent permanent deformation.

However, there is an alternative to installing and operating a turning gear. Unbelievably, this alternative involves using the wind turbine as a motor rather than a generator. Yes, it's true. Sometimes, when you see a wind turbine turning it may be because it is motoring not generating. So, if the winds appear to be very light, say under 7 meters/second, the reason the turbines are turning may not be because of the wind, but because of the electricity the wind turbine is sucking out of the grid. And remember, the power used by wind turbines is likely not being metered. But let us be reasonable, and assume a loss of 0.2%.

j) speed increaser gear box pumping, cooling or heating. The speed increaser that interfaces the very slowly turning turbine blade shaft with the high speed generator has a gear box which requires cooling in summer and heating in winter. Pumps keep the oil circulating continuousy through heat exchangers, filters, and gear box. On ring type low speed generators, like the Enercons, no gear box is required. Let us assume a loss of 0.2%.

k) main turbine bearing forced lube system. This system furnishes positive forced lubrication of the massive main turbine bearings. This takes power and must be running continuously. Let us assume a loss of 0.2%.

l) nacelle heating and dehumidification. The nacelle is the bus-sized looking enclosure behind and supporting the turbine blades. It houses the generator, speed increaser gear box, main bearings and shaft, lubricating systems, cooling and heating systems, controls, communications, and instrumentation. Many of the components associated with these systems must be maintained within environmentally controlled conditions. This is especially true in areas of high humidity. Almost all electrical equipment is designed to operate between 32 deg-F and 104 deg-F. So, it is necessary to keep all this equipment within this operating temperature range. Let us assume a loss of 1%.

m) aircraft warning lights and site lighting. In all fairness, any generating facility requires warning lights and site lighting. Let us assume a loss of 0.2%.

Granted, not all of the above losses happen all at once, day and night, or in every season. But some of the questions that must be asked are:

- Besides how much ***gross*** power is generated, how much power is ***consumed*** to run all auxiliary devices and systems?
- On a yearly basis, what is the net power produced?

The answers are:

- No one really knows
- they do know and are afraid to tell anyone, or worse, they are getting away with not having to meter the energy used, or ***pay for it!*** All we ever hear about is how many homes will be served, based on nameplate ratings not performance which can be typically expected.

Conclusion

If a wind turbine can only generate 18.4% of the power available in the wind, and uses 13.3% of its rated power to operate its auxiliary supporting equipment, only 5.1% remains available as useful power to be transmitted. In my estimation, the overall efficiency of the wind turbine is 5.1/18.4 = 28%. This means for every 'free' kilowatt of gross power produced by a wind turbine, only 28% of it goes out to the grid. The other 72% is consumed running the wind turbine's own auxiliaries.

The above conclusion may be overstated, because of all the percentage assumptions used for powering various wind turbine auxiliary equipment. In Chapter 8, grid power is documented as 5% of the opera- ting and maintenance cost for the German wind turbine experience. I believe this percentage is vastly understated. The truth, as so often happens, probably lies somewhere in between 5% and 72%.

Summary

a) Power consumed by wind turbines is usually not metered.

b) An estimate of all the auxiliary power used by wind turbines to energize all its supporting equipment may amount to 72% of all the power it produces.