Why Are Wind Farms Never Able to Produce at Full Power?

Wind farms don't seem to be able to produce at their rated full power capacity, nor reach their planned average yearly capacity factor. There is always a little 5% to 10% of their production missing at all facilities. Those losses are typically blamed on the first culprit that comes to mind, that is the wind itself. To explain the phenomenon, promoters generate laconic statements like: "*Reduced Production Resulted From Wind Resource Being Lower Than Expected During The Period*".

After tens of Billions of investments in this new technology, somebody has to figure out why there is missing production even when plenty of wind is available. Wind turbine manufacturers have spent fortunes testing their machinery in wind tunnels to come up with what is called a *Wind Production Curve*.

Those curves all have the same basis shape. Figure 1 shows such a typical curve for a common model, the GE 1.5 MW. Production starts at around 4 meter per second (m/s) [9 miles/hr], reach full power at about 12 m/s [27 miles/hr], keep on producing at full power up to a turbine shutoff at 24 or 25 m/s [54 or 56 miles/hr] or a similar number depending on model. This production curve is obtained in a wind tunnel testing facility for steady state airflow and provides a reliable description of the expected instantaneous production for laboratory conditions. Does this mean that the operator will have the same production in the field when the wind averages the laboratory winds peed? Well, not really. Let's see why things may be different in the field, remembering that wind speed may easily vary by plus or minus 30% or more over a few minutes.

Let's first see what happens at <u>Operating Point A</u> of Figure 2. This zone is the cut off point where we should first reach 100% power production when the wind blows steadily at 12 m/s [27 miles/hr]. Are we going to really produce at full power at a real wind farm? The answer is unfortunately NO. Although the average wind speed is indeed 12 m/s [27 miles/hr], the wind varies somewhat around the average. When the wind speed is higher, no problem, the turbine will produce at full power, but when the wind decreases to 10, 9 or 8 m per second, the production drops significantly, resulting in an average power at 12 m/s [27 miles/hr] that will be less than 100% about half of the time. Perhaps the actual production at this wind speed will drop at 90%, depending of the wind variability, but it will not be 100%.

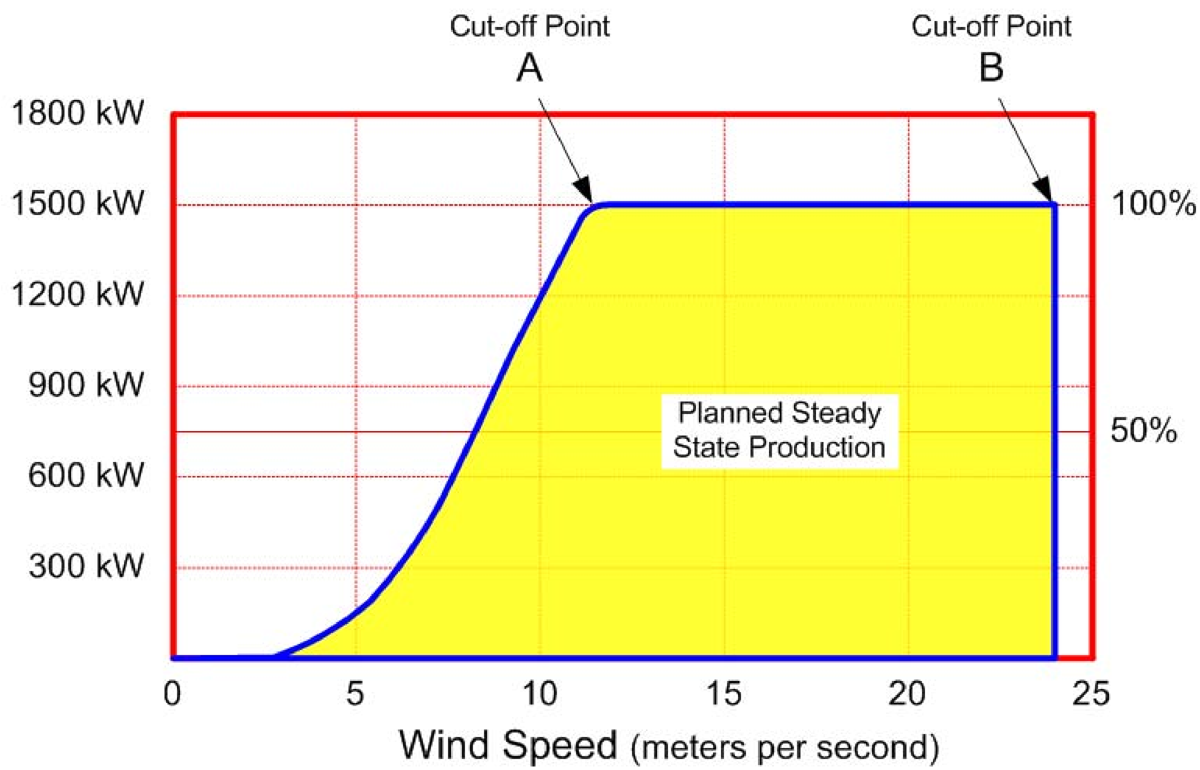
Let's see what happens at <u>Operating Point B</u> where we should also have 100% power production when the wind blows at 24 m/s [54 miles/hr]. Are we really going to produce at full power? Again, the answer is simply NO. Here a different phenomenon occurs. At higher than 24 m/s [54 miles/hr] the turbine must shut off to prevent too high vibrations and stresses in the blades, turbine machinery and tower. When the wind speed exceeds this value over a few tens of seconds, it shuts off. To restart, lower than 24 m/s [54 miles/hr] wind speed has to be measured over a short period. At the B cut-off point, at best, the turbine would operate half of the time at full power and half of the time shutdown. Thus at a 24 m/s [54 miles/hr] wind speed, on average, it can only produce at a maximum power of 50% power. However, due to the cut-off restart logic, production will be even lower, perhaps 40% power or less depending on wind variability. One positive effect is that some production may still occur above an average 24 m/s [54 miles/hr] wind speed, as some production will occur from short-term operation at lower wind speed. When the wind speed average falls below 24 m/s [54 miles/hr], the capacity factor will increase back from about 40% towards 100%. Will it finally reach 100% power? Well, we are still out of luck; it will only come close to full power most likely without ever reaching it over a sustained period. The maximum capacity factor would occur around Operating Point C, when the turbine is less affected by the turbine production cut-offs at 24 m/s [54 miles/hr] wind speed, while still not being too affected by the lower capacity factor from operation temporarily below 12 m/s [27 miles/hr]. A site with more wind variability will see a reduced production at point C.

Most wind sites have a yearly average wind speed of 7 m/s to 9 m/s [16 to 20 miles/hr] at best. High velocity winds in the range of 12 to 24 m/s [27 to 54 miles/hr] are less frequent than winds in the 4 m/s to 12 m/s [9 to 27 miles/hr] range when the wind blows most of the time. A wind turbine produces most of its electricity when the wind is blowing in the range of 6 m/s to 15 m/s [13 to 34 miles/hr]. The losses incurred in this range thus most likely represent the largest portion of the missing production reported by the land based wind farms. The extra production from operation at a wind speed above 24 m/s [54 miles/hr] occurs rarely and will result in a negligible extra production, unable to compensate for other losses. Offshore wind farms generally experience more steady wind conditions and direction that most likely makes them less susceptible to large production losses from dynamic wind conditions. This review covers only wind speed variation. Some supplementary losses would occur from variations in the wind direction resulting in the wind turbine not always being best aligned to capture the energy, resulting in further losses.

It is surprising that a multi billion dollars industry with money pumped from several governmental organizations still does not reportedly seem to have comprehended why the actual production rarely meets the planned or contracted production. May be nobody wants to know, as it makes bad press and would reduce subsidies.

The specific experience in Québec is noteworthy. The first large scale *Le Nordais* wind farm was supposed to produce at an average yearly capacity factor of 26.5%. The wind resource was carefully measured before implementation but the facility finally obtains a meagre 18% capacity factor from actual production. The next large facility at Miller Mountain was planned at a whooping 41.2% but is getting about a 33% production, still quite good but significantly short of the planned production. And the list goes on for the *Pubnico Point, Copper Mountain*, *Baie des Sables* wind farms that also do not get the planned production. Many investors are lured to invest in wind energy based on optimistic projections of power production that that are too frequently never achieved.

There must be some scientists in the industry that most likely know about the production losses from dynamic wind conditions compared to laboratory data. However, due to contractual commitments to production, it is always easier to blame the wind than it is to blame its own the predictions. Wind farm promoters may be at risk, should investors take court actions to demonstrate that those production shortcomings do not come from the wind as typically quoted, but simply from an biased technical assessment that is the responsibility of the promoter to calculate properly.



Theoretical Steady State Production of GE 1.5 Wind Turbine

Figure 1

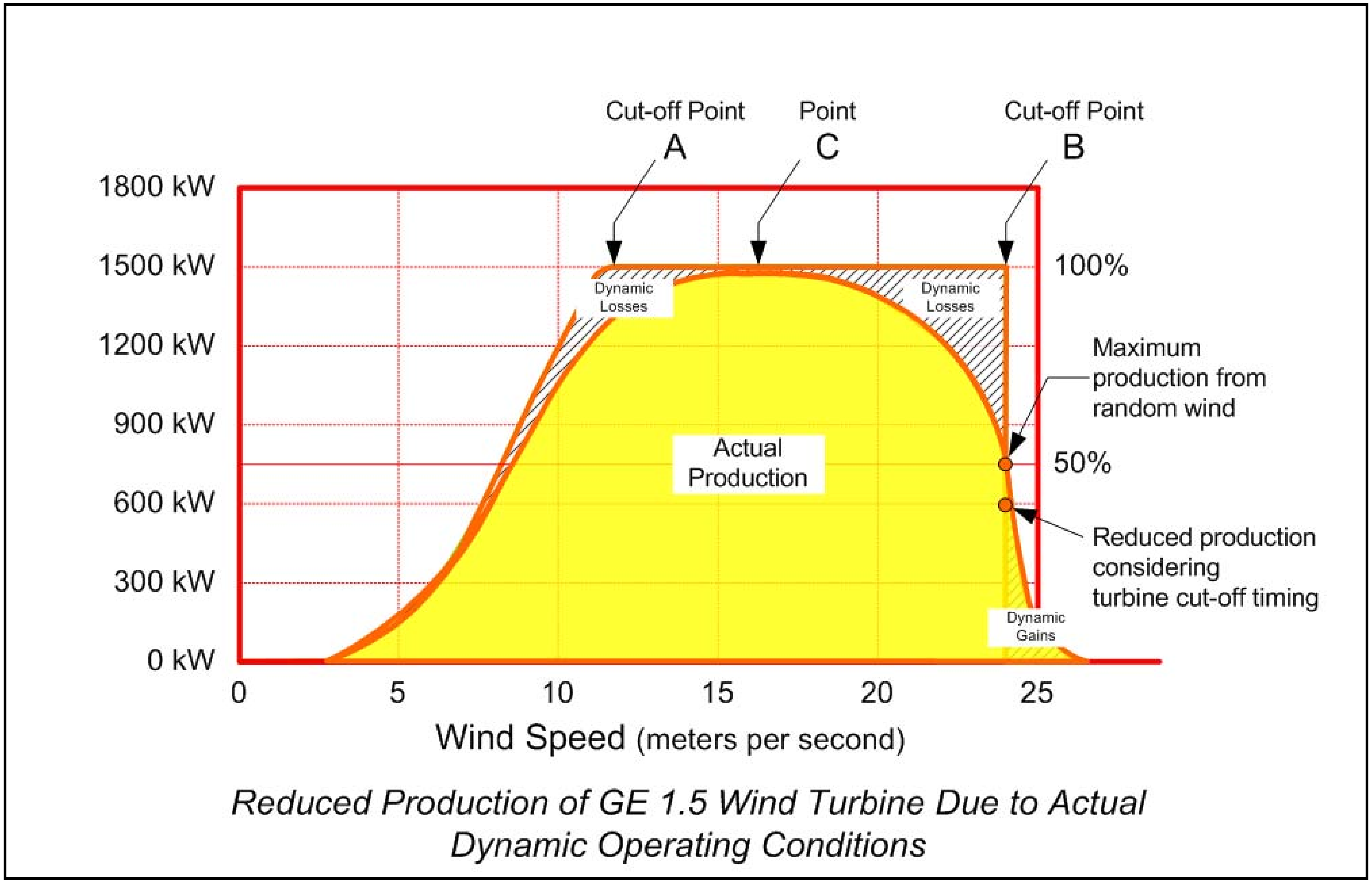

Cut-off Point
A
Point
C
Cut-off Point
B
1800 kW
1500 kW
1200 kW
900 kW
600 kW
300 kW
0 kW
100%
50%
Dynamic
Losses
Dynamic
Losses
Actual
Production
Maximum
production from
random wind
Reduced production
considering
turbine cut-off timing
Dynamic
Gains
0
5
10
15
20
25
Wind Speed (meters per second)
Reduced Production of GE 1.5 Wind Turbine Due to Actual
Dynamic Operating Conditions

Figure 2