December 2009

Bonneville Power wind-temperature correlations

The Bonneville Power Administration (BPA) provides convincing evidence that wind turbine electricity production is negatively correlated with extreme ambient temperature. That is, extreme temperature, either hot or cold, corresponds to low wind production. A postulated mechanism is that a local high pressure weather system is associated with low wind causing extreme temperatures. To our knowledge this correlation has not been extended to wind-load in part because of weekends disrupt temperature-load correlations.

BPA conducted statistical analysis of wind production in in the Pacific Northwest. BPA wind turbines are located in eastern Oregon and eastern Washington. Fig. 1 shows the probability distribution function for wind power (as % of nameplate capacity) during the years 2001-2006.[i]

The distribution function is the probability that the random variable is less than its value presented on the horizontal x-axis. For example, in Fig. 1 the red circle shows the probability that wind power for "all days" (the heavy solid curve) is less than 17% of nameplate capacity (horizontal axis) is 50% (vertical axis). This is the median (not mean) wind power; half the time the power is greater than 17% half the time it is less.

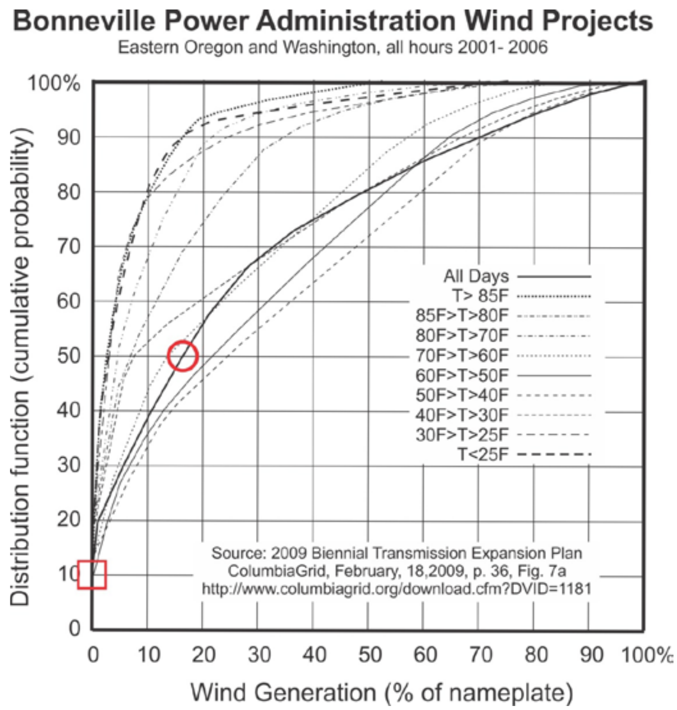

Figure 1 Bonneville power correlations

Each curve on the chart presents the distribution function for different ambient air temperatures. The correlation of wind production with air temperature is quite remarkable. If there was no correlation we would expect all the curves to uniformly fluctuate around the average "all days" curve. Instead, we see two distinct regimes. One regime corresponds to extreme temperatures (both hot and cold); the other regime corresponds to average temperatures. At extreme temperatures, ($T>85^oF$ and $T<25^oF$) the two curves virtually overlap. Remarkably, it does not matter if it is very hot or very cold the wind statistics are similar. Adjacent temperatures ($85^oF>T>80^oF$ and $30^oF>T>25^oF$) cluster around these two extreme curves.

Over a 5 year period the vast volume of wind production data, particularly the high power data, occurs during average temperatures. The number of data points that occur at extreme temperature is small. However, as suggested earlier, extreme temperature can be associated with peak load. The insight behind the Fig. 1 parameterization is that temperature separates extreme (presumably peak load) wind production statistics from the vast bulk of the data. Data sets necessary to generate statistically meaningful information at extreme temperatures need to be large, > 5 years.

Dr. Alex Pavlak, 315 Dunham Ct., Severna Park, MD 21146, (410) 647-7334, (443) 603.3279c, alex@*pavlakt.net*

Fig.1 makes it clear that the statistics associated with “all days” or overall average is not the same as extreme temperature statistics. Expected value, standard deviation, correlations, and probability distributions are substantially different for the two regimes. We cannot use typical or average data to characterize performance at extreme temperature. This temperature correlation significantly changes the traditional view of wind power statistics. To the extent that we believe that extreme temperature and load are correlated (we have no data) the assumption that load and all days wind statistics are independent should not be trusted.

Fig. 1 also suggests large area spatial correlation. The probability of no wind (intersects the y axis, red squre) is greater than 10% for all cases, greater than 20% for extreme temperatures. The fact that wind is lost across the whole region at the same time means that wind farms are functioning as a single large generator.

---

i. ColumbiaGrid, *2009 Biennial Transmission Expansion Plan,* February, 18,2009, p. 36, Fig. 7a

http://www.columbiagrid.org/download.cfm?DVID=1181