Gaining Ten Percent

How Vindicator™ Can Improve Wind Turbine Performance by 10%

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How Vindicator Can Improve Wind Turbine Performance by 10%

There are two important sources for the Catch The Wind, Inc. (CTW) estimate that Vindicator can provide a 10% improvement in performance for those wind turbines that have modern control systems. A modern control system is defined as one that can translate real time and accurately predicted wind data into yaw motor control inputs that effectively "catch the wind." This capability will reduce the amount of time that a wind turbine generator (WTG) spends yawed, or misaligned, with the direct component of the wind.

The first source is a Light Detection And Ranging (LIDAR) For Turbine Control study, *"Technical Report NREL / TP-500-39154"* dated January 2006, that was conducted by the National Renewable Energy Laboratory (NREL) in 2005. That study examined LIDAR's potential for remotely sensing the wind speed and direction. NREL reported stated that using LIDAR for the measurement of changes in the wind flow approaching the large WTGs had the advantages of "increased turbine energy output and reduced turbine fatigue damage." (Page iii – Executive Summary)

In order to understand the quantitative effects of WTG efficiency and the relative improvement in energy output or power production that could be expected, CTW utilized the expertise of Dr. J. Gordon Leishman the Minta Martin Chair of Engineering and Professor of Aerospace Engineering at the University of Maryland who dedicated an entire chapter on the "Aerodynamics of Wind Turbines" in his book, *"The Principles of Helicopter Aerodynamics."* Dr. Leishman goes into exhaustive analytical detail about the power loss effects of the WTG being "yawed" or more accurately "misaligned with the wind." The resultant effect of yaw on power output is reflected on page 727:

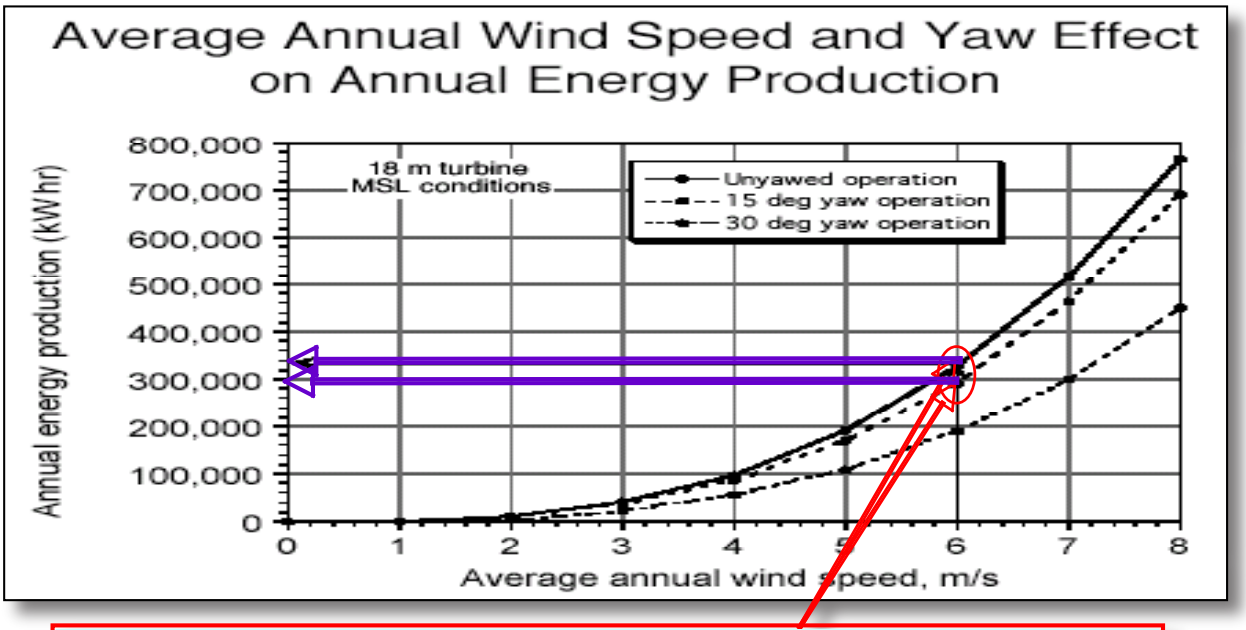
> "the power output drops by $\cos^3 \lambda$ <yaw angle> and so the importance of accurately controlling the orientation of the turbine relative to the wind direction becomes immediately clear. This must be done by design or by some sort of mechanical control device that senses wind direction and automatically points the turbine accurately into the wind."

Indeed, page 96 of the *"Wind Energy Handbook,"* 2001, John Wiley & Sons, Ltd., describes the changing nature of the wind environments in which wind turbines normally operate:

> "The rotor axis of a wind turbine rotor is usually not aligned with the wind because the wind is continuously changing direction; the rotor is not capable of following this variability and so spends most of its time in a yawed condition. The yawed rotor is less efficient than the non-yawed rotor and so it is vital to assess the efficiency for purposes of energy production estimation."

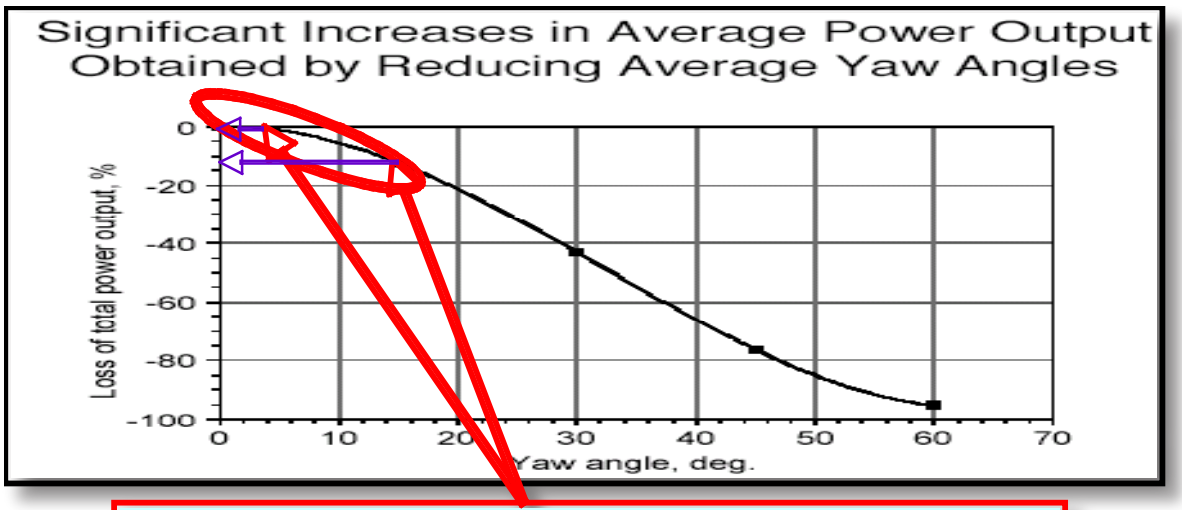
Dr. Leishman provided CTW with some graphic examples quantifying how much power loss could be expected because of annual average yaw effects. From the charts below, one can see the significance of yaw effects on a wind turbine. Three cases were considered: unyawed operations, 15 degrees yaw operations and 30 degrees yaw operations. This data was calculated for an 18 meter wind turbine at mean sea level with average annual wind speed from zero to 8 meters per second. A large wind turbine with a rotor diameter of 100 meters would exhibit similar yaw effect characteristics. According to Dr. Leishman, the effects are scalable to large wind turbines.

From the chart below, it can be seen that the yaw effect at a moderate wind speed of 6 meters per second results in a power loss of approximately 13 percent for an average annual yaw operation of 15 degrees.



At an average annual wind speed of 6 m/s,
An average 15 degree yaw results in
~13% of annual energy production

By reducing the average annual yaw angle from 15 degrees to 5 degrees, the power output loss can be reduced from 13 percent to 3 percent. Thus a 10 percent improvement in efficiency can be gained if the annual average yaw effect for a large wind turbine is reduced by 10 degrees. This increase in average power output is illustrated on the chart below:



~ 10% more power output obtained by reducing yaw angle from 15 degrees to 5 degrees