Annual Report on Energy Loss During Windy Events:
Apparent design deficiencies in the Bergey Excel 10 kW turbine when combined with the GridTek10 inverter.

by
Mel Tyree
Department of Renewable Resources, University of Alberta
Edmonton, Alberta, Canada T6G 2E3

Introduction

This report should be read in conjunction with SWIEP reports R#41, R#42 and R#43. The first and second reports are R#40 and R#47, respectively. If you have not seen these reports you can download them from SWIEP at

http://www.ualberta.ca/~mtyree/SWIEP/Publications.html

I own a Bergey Windpower Corp (BWC) turbine, a 10 kW Excel-s connected to a GridTek10 inverter. About a year ago, I communicated with Mike Bergey saying that, in my opinion, I might be loosing 10 to 30% of my annual energy production because of the tendency of their inverter to go off-line during windy events. Mike emphatically disagreed with me, because the inverter goes off line only when the wind speeds exceed about 16 m/s and this happens less than 1% of the time based on Weibull probability distribution function of wind speeds at my location in Ellenburg Depot, NY. Mike's arguments are based on a 'simple and compelling' theoretical computation using BWC's WindCad model. I have responded in detail to Mike's simple and compelling argument (R#50) after repeated attempts to talk to him personally failed.

The data in this report are actual measured data. Any experimental physicist will tell you that measured data ALWAYS trumps a theoretical calculation. Hence, if my data disagrees with the WindCad model, then the conclusions drawn from the model are wrong. I have explained in R#50 what I believe has gone wrong. I challenge BWC or Mike Bergey to respond to my many reports. BWC must: (1) defend the WindCad model, i.e., explain what is wrong with my analysis of the model, (2) explain why my measured data is in error. I would much prefer to communicate with them privately and quietly, but they have refused to talk. Hence my options are limited. I could either remain silent even though I think I am correct or I can go public. I think current owners and potential buyers need the facts. Hence I have gone public.

An example of power loss was reported in SWIEP publication R#12, which can be downloaded from www.ualberta.ca/~mtyree/swiep/publications.html . During this 30-hour wind storm my inverter generated 35.3 kWh but lost a total of 110 kWh. So how much does this translate into power loss during the windiest period of the year (Sept to April)? I was encouraged by the results in R#12 to purchase equipment to do more intensive monitoring. This third report applies to data for 1 Sept to 25 Feb 2008.

Methods used to estimate power/energy loss.

Methods used and some objectives have changed since this study started on 1 Sept 2008. Read the first report for details about initial methods used (R#40). Starting about 15 Nov (day 76) I got my NRG cup anemometer working so I could start producing power correlation curves (PCCs). I measured wind-speed at 102 ft (20 ft below the hub) on the same tower as the Bergey Excel-s turbine. The objective here was NOT to measure a power curve at hub height, but to have a correlation between power production and wind speed quite near the hub. At 102 ft the wind speed should be consistently lower than the speed at hub height by 7% or less (depending on wind sheer).

The PCCs can be seen in SWIEP report R#46 for both furled and unfurled states of the Excel-s generator. Doing experiments with a furled turbine was the other major change in protocol of my experiments. The turbine was manually-furled from Dec 6 (day 97) until Dec 29 (day 110) by using the crank provided at the bottom of the turbine tower.

Michael Klemen has expressed concern about the accuracy and resolution of my measurements. In response to that I have also posted reports R#48, R#49 and R#51. Read these for detail. M.K. has implied that his methods are better, but he provided no data to prove his assertion. If M.K. still disagrees then maybe he can provide some proof?

I have established from several pervious studies that that Excel-s turbine is mismatched in size for the GridTek10 inverter. The turbine can overload the inverter causing the inverter to go offline. This causes power loss compared to the ideal behavior and the design objectives of the GridTek10 as explained in detail in R#46. The objective of the furling experiments was to see if a furled turbine would not overload the inverter. I was quite surprised to see that even a furled Excel-s is cable of overloading the inverter. This eliminated some ideas I had of a cheap fix to the problem, i.e., installing a motorized system to partly or fully furl the turbine on windy days. Many folks in windy locations already manually furl the Excel-s when it is too windy, but this procedure clearly does not work as well as it should.

This diversion in protocol required a change in the way that I estimate power loss in this study. In the first 97 days I measured actual power production and then tried to estimate lost production from the generator RPM when the turbine was off line. Now I can estimate lost production from the PCC in R#46 and I consider this method to be more accurate. However the power production of a furled turbine will be less than that of an unfurled turbine at all wind speeds. Also the wind-speed that causes overload of the inverter will be higher when furled than when unfurled. I use a DIRM model to estimate power output from my turbine when the GridTek10 is off-line and the wind is still blowing. See R#49 for detail of this model and a complete error analysis.

The turbine was furled from day 97 to day 114. During this time I measured actual power production of the furled turbine and added to that the difference in power production between the unfurled and furled state based on the measured PCCs. Also during these days I had to estimate the power loss that would occur if the turbine had been unfurled. Details of how this is done are given in R#45 Appendix 2.

I kept the turbine unfurled for the next 30 days. I used that period to compare actual power production to that estimated by the model described in R#45 Appendix 2. I found no reason to make major corrections to my second interim report. Details as to why will be made in a future report.

Results

Figure 1 shows a typical result of GridTek10 power output versus time during a windy event. The time course looks very similar to the NREL results on page 2 of the 1st interim report. On Oct 28 the turbine overloaded the inverter 4 times and the inverter went offline for four 5-minute periods in order to protect the turbine's generator. After this the inverter went offline a fifth time and when it tried going back online it 'saw' a bus voltage overload and ended production with a Fault Code. Recovery from this fault conditions requires human intervention, i.e., a reset button needs to be pressed on the GridTek10 inverter (see R#39).

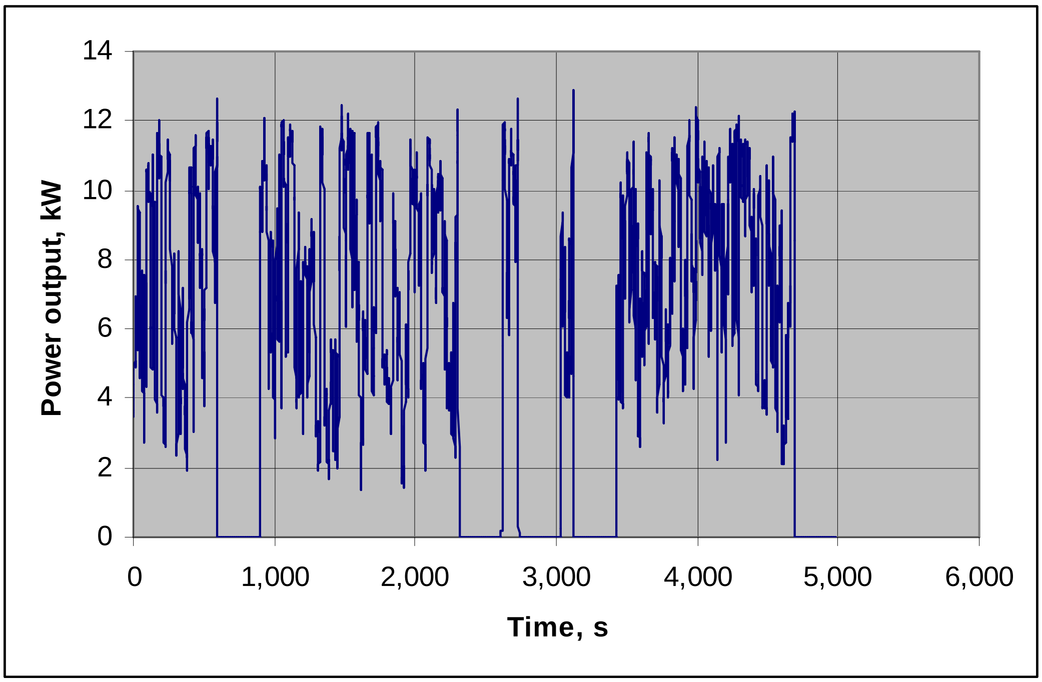

Figure 1: One second readings of power output from a GridTek10 inverter and Bergey 10 kW Excel turbine starting at 10:23 PM 28 Oct 2008. The inverter went off-line for four 5-min periods due to power overload at times = 600, 2307, 2733 and 3119 s and returned to production after a 300 s delay each time. At 4695 the inverter went off-line again but stayed off line because at time = 4995 it attempted to come back on-line during a bus voltage overload condition and went into a fault mode requiring a manual reset.

Figure 2 below shows the cumulative energy production measured since 1 September 2008 versus time (green line). Since my 1st interim report, there have been 8 'major' wind events causing power major loss on days:76, 100, 103, 113, 116, 118, 143 and 158. There have also been many minor events, i.e., wind gusts > 17 m/s causing isolated 5-min periods of down time. See also R#46 for more details.

The cumulative estimated loss of energy expressed as a percentage of the produced energy is shown in the lower graph (Fig. 3) and this value finished at 23% after

200 days of measurements. The last 165 days were less windy so this figure declined to 15% for the year.

The average turbine owner might be less vigilant than I am, i.e., many owners have told me that they check their inverters only once or twice a week. How often the inverter is checked will impact the amount of energy lost. However, I feel the results in Fig. 3 are likely to be representative for my wind regime (5.5 m/s mean annual wind speed). However, in windier locations the % of lost energy is likely to be more.

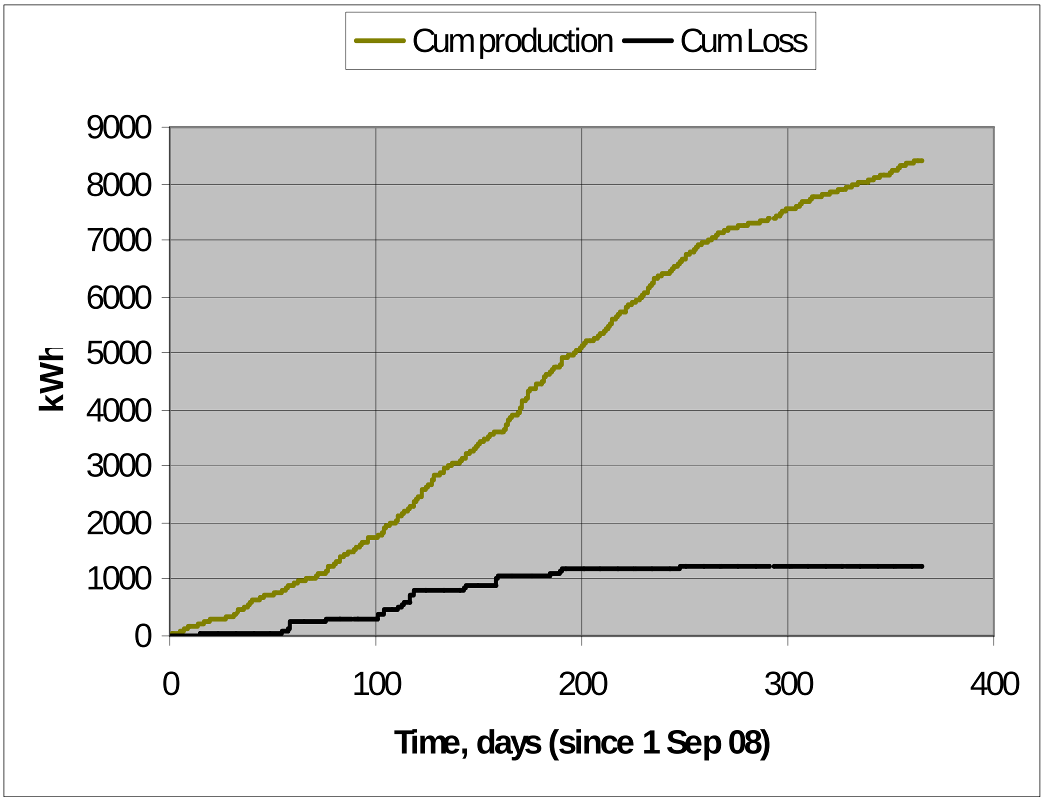

Figure 2. Cumulate total energy produced in kWh and energy lost versus time in days since 1 September 2008.

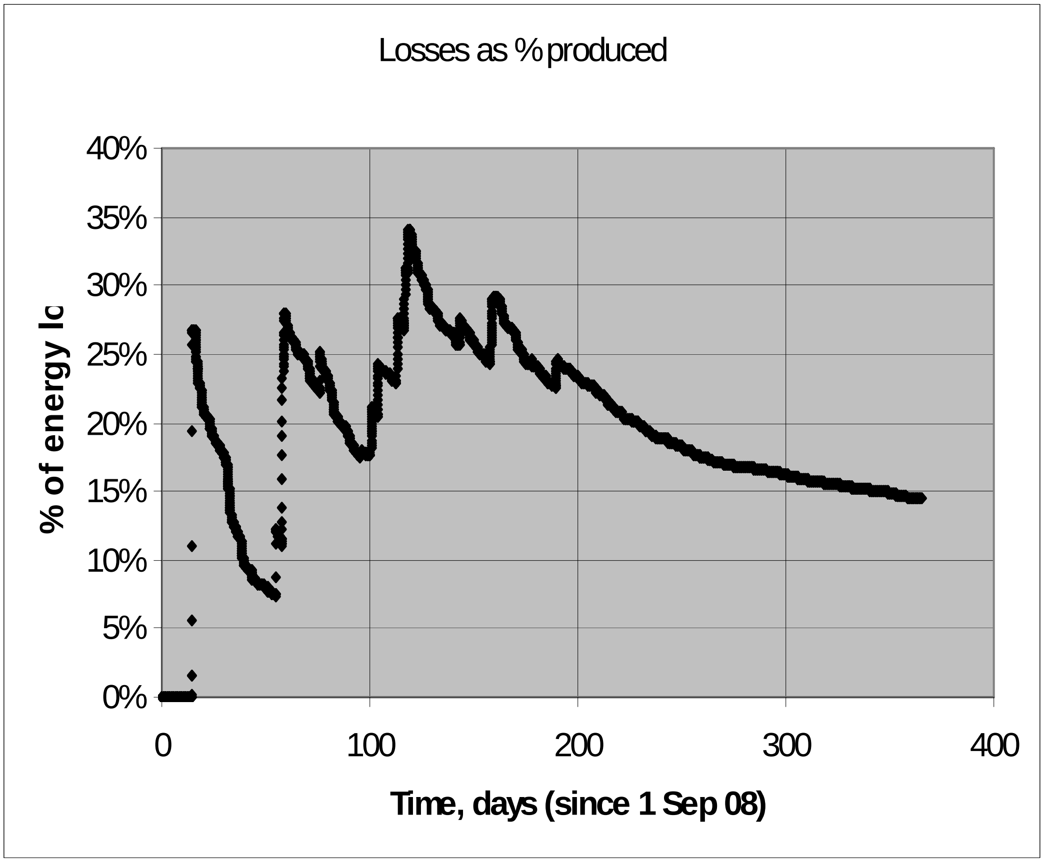

Figure 3: Energy lost as a percentage of power produced. As data collection continues the variation in % energy lost will become more gradual (stable) with time. The rapid drop between day 14 and day 55 is a mathematical consequence of a short sampling period, i.e., low amount of cumulate energy production.

Spontaneous change in autofurling mechanism?

I work out of a home-office in my Ellenburg, NY, and my desk faces a window with a good view of my turbine. I also have a power meter on my desk that gives kW turbine output updated once per second. Hence I tend to spend lots of time looking at my turbine on windy days studying qualitatively how the auto-furling mechanism seems to be working. Generally the machine does not auto-furl until the GridTek10 is offline. When the GridTek10 is offline the RPM increases at any given wind speed because the generator is no longer loaded. I have seen the machine occasionally auto-furl before the inverter is overloaded, but usually it happens only when the GridTek10 is off-line. In a recent wind storm, however, the auto-furling mechanism appeared to act more often. I am beginning to think the effectiveness of the auto-furling mechanism depends on how fast the wind 'gusts-up' in speed. Alternatively the mechanism may have 'spontaneously' changed, which I doubt. Adjusting the mechanical auto-furling mechanism might help avoid overloads, but the best solution is to make the inverter capable of standing the increased voltage at higher wind speeds. BWC now has a new inverter on the market (PowerSync II). I hope they have improved this inverter to take voltages up to 450 V because that should solve the problem. However I fear they may not have bothered because during the R&D of the PowerSync II they were convinced that such improvements are unnecessary. However, I disagree with this very incorrect interpretation.

Conclusions

After one year of data, it is clear that the % power loss is much more than you might expect from an examination of WindCad models in the way done by BWC (see R#50). The percentage of loss is much more during the 6 windy months (Nov to April) than during the low-wind 'summer' season and this is consistent with expectations. I have expanded this study to include three more BWC Excels turbines in central NY State so that I could move towards final outcomes

The final outcomes of this study will be:

(1) A model to predict % energy loss due at other locations were mean annual wind speeds might be more or less than mine
(2) A model to predict the cost-effectiveness to upgrade a system to avoid the energy loss, e.g., if the PowerSync II or an Aurora inverter performs better.

The initial results (3 months of data) were a surprise but have not been fully analyzed, but from the raw data it would appear that the frequency of power losses I see are unique to my site because even at windier sites the events I report above are less frequent. I will start posting these results in the coming months.

I welcome comments from readers and suggestions for improvements of the reports or in methods and analysis. Your suggestions will be acknowledged and incorporated in my next revision.

Prof. Mel Tyree
Department of Renewable Resources
University of Alberta, Edmonton, Canada T6G 0C6
mtyree@ales.ualberta.ca