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

by
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Introduction

This report should be read in conjunction with SWIEP reports R#41, R#42 and R#43. If you have not seen these reports you can download them from SWIEP at http://www.ualberta.ca/~mtyree/SWIEP/Publications.html

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 probability distribution function of wind speeds at my location in Ellenburg Depot, NY This statement encouraged me to monitor power output on the GridTek10's LED by taking a webcam photo once per minute during a wind storm.

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 initial report applies to data for 1 Sept to 10 Nov 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 furled from Dec 6 (day 97) until Dec 29 (day 110).

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.

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 plan to keep the turbine unfurled for the next 30 days. I will use that period to compare actual power production to that estimated by the model described in R#45 Appendix 2. If corrections are needed I will retroactively apply the correction in my third interim report, which will be submitted on or about March 1, 2009.

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).

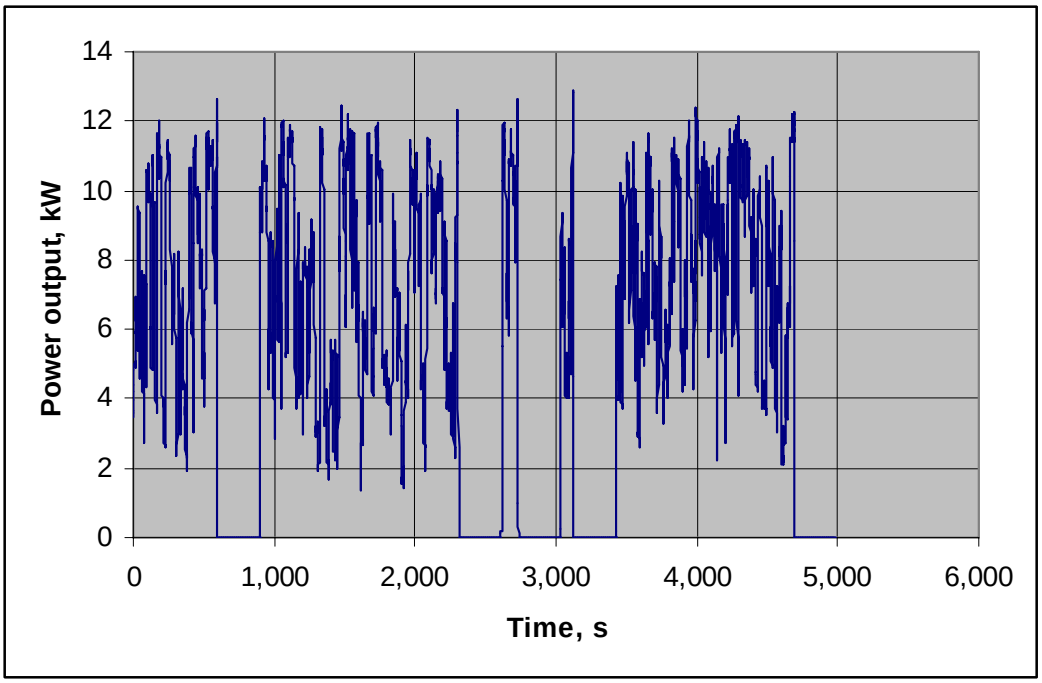

Figure 1: One second readings of power output from a GridTek10 inverter and Bergey 10 kW Excel turbine starting at 10:23 PM 28 Oct 2008. The inverter went off-line for four 5-min periods due to power overload at times = 600, 2307, 2733 and 3119 s and returned to production after a 300 s delay each time. 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 6 more wind events causing power loss on days (76, 100, 103, 113, 116 and 118). 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 33% after 121 days of measurements. This is early in the season and windy events are likely to be more frequent later.

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.

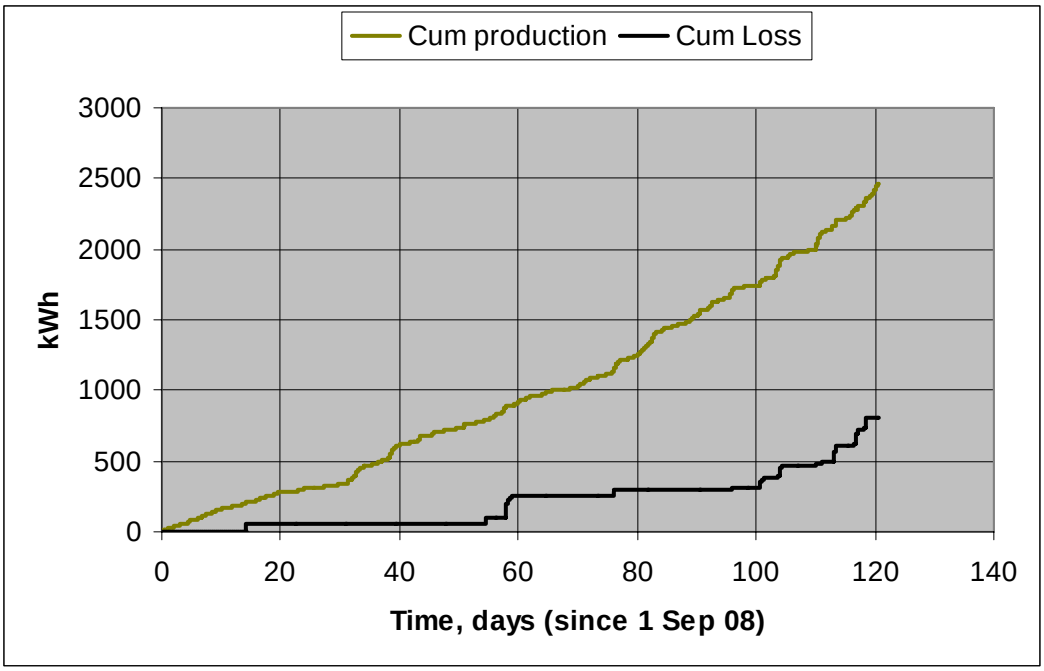

Figure 2. Cumulate total energy produced in kWh and energy lost versus time in days since 1 September 2008.

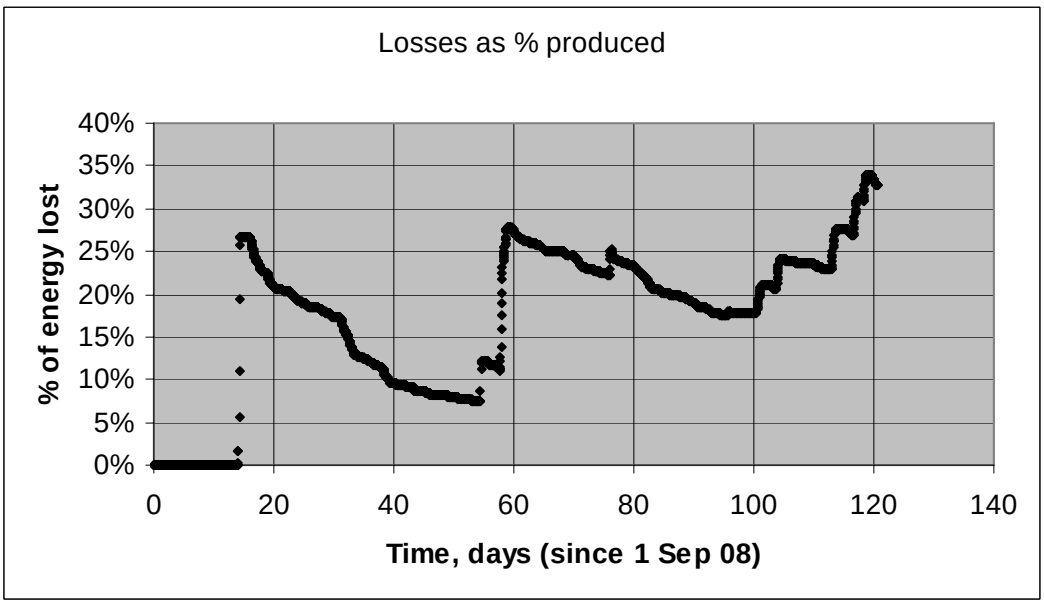

Figure 3: Energy lost as a percentage of energy produced. As data collection continues the variation in % energy lost will become more gradual (stable) with time. The rapid drop between day 14 and day 55 is a mathematical consequence of a short sampling period, i.e., low amount of cumulate energy production.

Conclusions

I have no general conclusions yet because this is an interim report. I will update this report every two months until April 2009 and then draw more general conclusions. We must await the end of the study to get a final estimate of % energy lost due to poor design of the turbine/inverter in this study.

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.

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