Energy Storage for Wind Power Not Possible

By

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Introduction

Some 10 years ago, when the intermittent and variable nature of wind power was mentioned as an impediment to the advancement of wind energy on the grid, proponents were quick to point out that the grid has plenty of flexible power generators to address the normal variability of load, and until wind energy reaches some 20% of supply, its variability can be handled along with that of load. Now, with much less than 10% of a grid's power coming from wind, the added variability is being blamed as the primary cause of blackouts in California and elsewhere. It has become obvious that small amounts of wind power can disrupt grid operations. Advocates point to the addition of grid scale energy storage (batteries) as the preferred solution to the problem. Of primary importance is the maximum amount of wind energy that must be stored to avoid rolling blackouts in a fossil fuel free grid. To get a handle on this need, the daily energy output from a local 1.5 MW wind turbine was downloaded for a period of almost two years to a spreadsheet where various amounts of energy storage can be assumed to find just how much storage is necessary to stabilize this one turbine. The answer turned out to be so large that, on the assumption that a grid scale application will require some multiple of this one turbine experiment, a conclusion can be reached, that a 100% clean energy grid is next to impossible.

Proposed Theory

In theory, if the extra wind energy during periods of strong wind can be saved for when winds are light, the combination of wind and storage can be configured to supply a steady amount of power matching that of fossil fuel. Figure 1 is a simple configuration of a single wind turbine feeding all its energy into a storage device (battery) while the battery drives an average load of about 360 KW, about a quarter of the wind turbine's maximum power rating. The load value, 360 KW, is derived through experimentation by finding the value of cell D3 of the spreadsheet model. The value 8640 KWh was found to just avoid any power shortage for the almost two year period of the dataset. The 360 KW load is calculated by dividing the 8640 KWh by 24, the number of hours in a day.

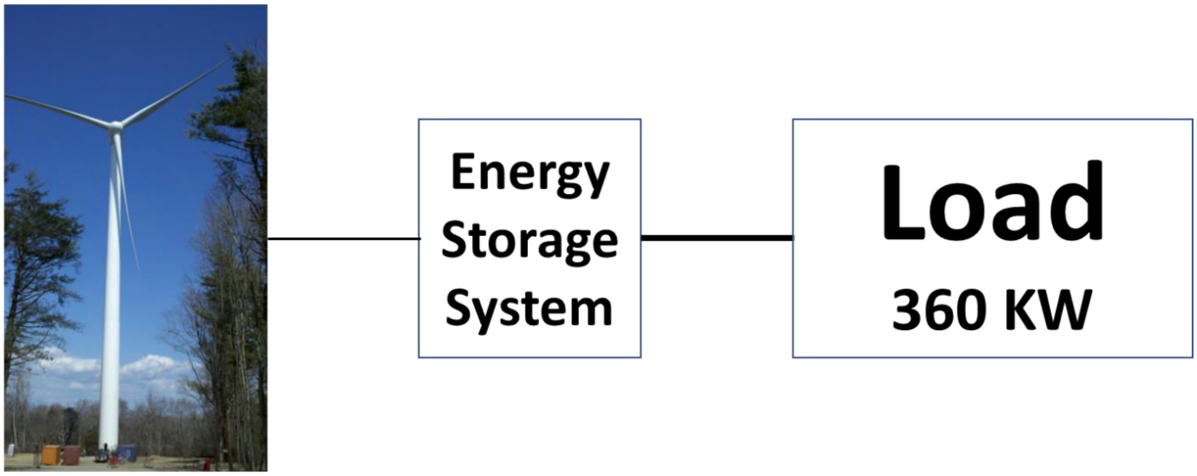

Figure 1

Spreadsheet Model

To put this theory to the test, close to two years of daily power output was downloaded from a local 1.5 MW wind turbine in Fairhaven, MA. The data were entered into an Excel spreadsheet where different scenarios can be tested to determine just how much energy storage one needs to guarantee that the combination can supply power, uninterrupted by blackouts, over the almost two-year period of operation.

Figure 2 is a plot of the turbine power output (Column B) over the test period modeled on the spreadsheet.

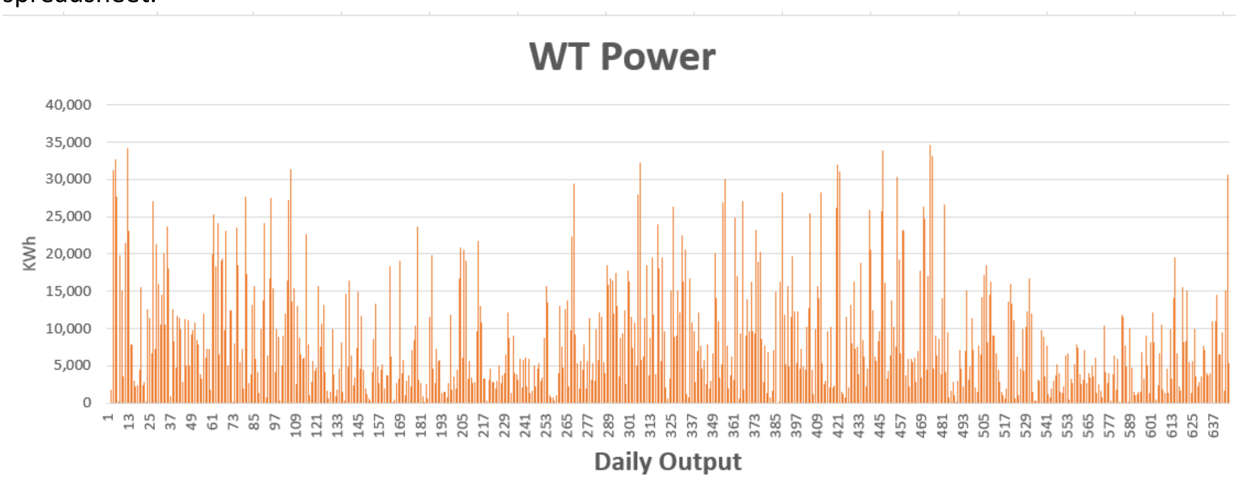

Figure 2

The plot shows the high variability of the daily output wind turbines generate. From day to day the output can go from the highest, 36,000 KWh maximum, all the way down to zero. In order to smooth out this variability, energy storage (battery) is proposed to store the excess energy from windy days and provide it on days with light or no wind. To get a handle on the size of the battery needed to provide a firm power level from this one turbine, the spreadsheet in figure 3 was developed to determine just how much storage is needed over the almost two-year period of output data.

	A	B	C	D	E
1		Fairhaven South Wind Turbine Energy Output			
2		Mwh	Max Energy Kwh	StorePoint	Storage
3		1.5	36,000	8640	Start
4		Production	Charge/Discharge		102000
5	1	0	-8640	Jan	93360
6	2	0	-8640		84720
7	3	1769	-6871		77849
8	4	31247	22607		100456
9	5	32747	24107		124563
10	6	27617	18977		143540
11	7	9	-8631		134909
12	8	19862	11222		146131
13	9	15111	6471		152602
14	10	3587	-5053		147549
15	11	21499	12859		160408
16	12	34201	25561		185969
17	13	23150	14510		200479
18	14	7790	-850		199629
19	15	7829	-811		198818
20	16	3016	-5624		193194
21	17	2268	-6372		186822
22	18	2442	-6198		180624
23	19	4514	-4126		176498
24	20	15608	6968		183466
25	21	2427	-6213		177253
26	22	2871	-5769		171484
27	23	73	-8567		162917
28	24	12556	3916		166833
29	25	11360	2720		169553
30	26	6638	-2002		167551
31	27	27032	18392		185943
32	28	7266	-1374		184569

Figure 3

The spreadsheet segment, Figure 3, column B, starting with cell B5, contains the wind turbine daily output, downloaded from the wind turbine, and used to plot figure 2. While the segment shows 32 rows, the actual spreadsheet is some 650 rows long, one row for each day’s output. Cell D3 contains the daily output energy supplied to the load on a steady basis. By entering different values for this cell, the overall performance of the system can be determined and, by observation, the value 8640 is the maximum average daily value that the wind turbine can provide without running short over the two year period of the test. This will become clear later when a plot of the storage data is shown for the period in question.

Each cell of column B, the daily output, is compared to cell D3 (8640). The difference is displayed on the same row in column C. It is then added to the cell on the previous row of column E. Column E is the running total of stored energy.

To initialize the running total, column E, the value 102,000 KWh is entered into cell E4, representing stored energy from previous generation. To illustrate the process, starting at row 5, cell B5 shows the 1st day's output which is zero. As a result, the day's energy has to come from storage, this is indicated by the negative value (-8640) of cell C5. The negative value of C5 is then subtracted from the running total of the previous row cell E4, the result displayed on the current row cell E5.

Row 8 illustrates how excess energy is stored. B8 shows the day's energy generation (31247 KWh). This exceeds the daily system output of 8640 KWh. The difference (C8, 22607) is added to the running total and displayed in cell E8 (100486), the running total of stored energy. The daily output from the wind turbine is handled the same way for the 649 days of power generated by the turbine.

Energy Storage Requirement

Figure 4 is a plot of column E, the running total of stored energy.

Notice that energy needs to be increasingly stored from about November to May, and available to supplement the low producing months from June to October.

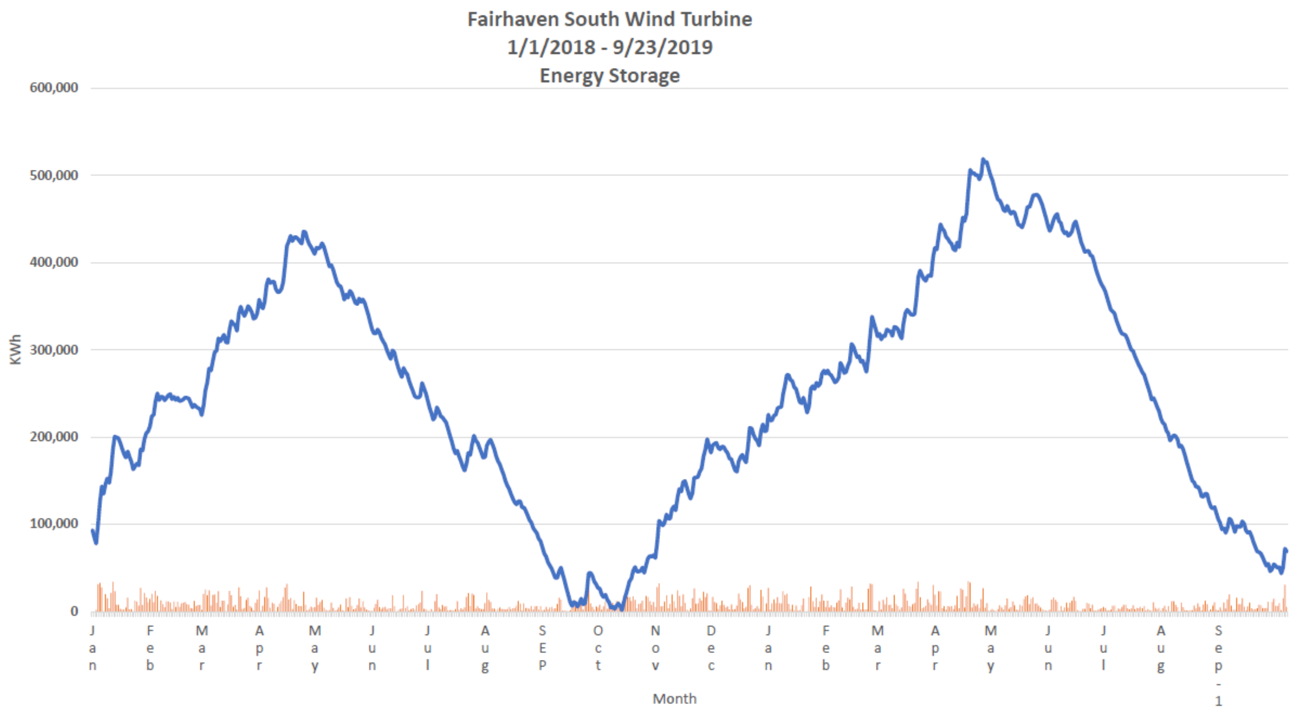

Figure 4

Using the trial and error method, the value of 8640 KWh produced the plot of figure 4, the running total of energy stored. The Plot indicates that sometime around October, the level of stored energy runs the risk of becoming depleted forcing the system to shutdown (blackout). From November to March the turbine generates excess energy that must be stored to avoid running short in October.

Of prime interest, figure 4 shows that the storage capacity needed for firming the output of this single wind turbine is 500,000 Kilowatt hours or 500 Megawatt-hours.

To illustrate the accuracy needed in setting the daily power output of a system dependent on wind power, Figure 5 shows the result of increasing the daily power output by just 5 KW, an increase of just 1.4%. Notice that sometime in the middle of September the output drops below the 8640 KWh needed to sustain continuous power and does not recover until past the middle of October. What this indicates is that a very small error in estimating the system's daily wind power generation would result in very serious blackout conditions that can only be addressed with a full complement of fossil fuel power.

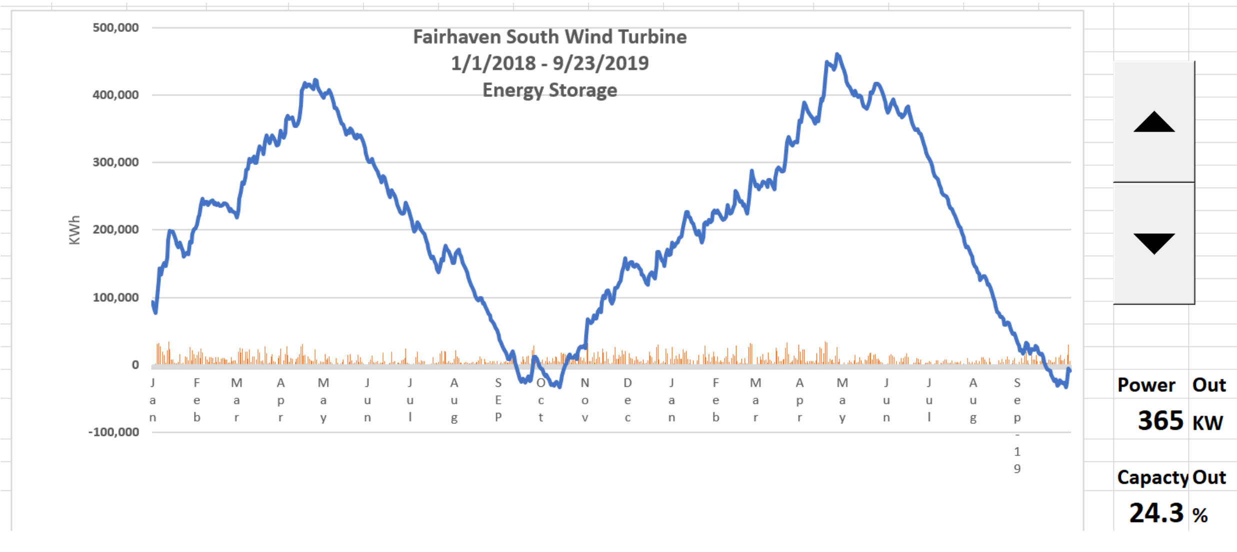

Figure 5

Figure 6 shows a picture of the world's largest battery installed at Hornsdale, South Australia. This battery can only store 129 megawatt-hours, which is about a quarter of the storage needed for just one small wind turbine.

Hornsdale Power Reserve

Figure 6

Conclusion

The test period is relatively small, less than two years. It is unlikely that this represents the worst case scenario. Given the fact that it would take some four to five times the size of the largest battery on earth to balance this one small wind turbine, it is an inescapable conclusion that the scenario of 100% renewables, primarily based on wind, and solar balanced by energy storage, is not possible. This small experiment with a single wind turbine shows clearly that little to no amount of the present conventional power sources can be eliminated. Furthermore, even if by some miracle, energy storage becomes feasible, the data show that even the slightest error in estimating how much energy to save on windy Winter-Spring days can result in catastrophic blackouts in the Fall. As a result, most of the existing power plants will have to be maintained to avoid blackouts.

From a common sense point of view, the fact that wind and solar cannot eliminate the need for the existing fossil fuel power plants, without a substantial risk of periodic long lasting blackouts, it is doubtful that even with storage, wind and solar can only provide no more than 10% of a well-managed grid system.