Efficiency Improvement in Wind Farms

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Overall Objective

Within this review I focus primarily on wind farm efficiency analysis; its importance, factors that impact efficiency, methods to optimise/increase efficiency, companies that address the efficiency market and the role that Mouli Engineering Inc could play in this arena.

Wind farms energy is going to grow at significant rate. Most wind farms will require, planning to understand efficiency, reliability, safety, risk assessment (insurance) and operational assistance. Wind farms are those that have more than one wind turbine. Hence, there are two factors that determine efficiency, turbine availability and turbine yield (power out).

A turbine that is 99% available but has very low yield (lower power output) is not functioning at optimum needs. Similarly, a turbine that has 10% availability and 99% yield (close to ideal power output), is not performing at optimum needs.

Overall, it is clear that analyses of wind farms are critical for accountability of the wind farm designers, turbine manufacturers, operators, and maintenance and erection companies. There needs to be an impartial, informed and auditing outside organization that will be able to monitor and present actions for improvement of wind farm efficiencies.

With nearly 20000MW of wind farm installations the need to understand the efficiency is vital to reducing capital and increasing revenue. For each 1MW of energy the equivalent is $1M a year in lost revenue. I will discuss the factors that will be needed to be monitored and controlled in order to improve wind farm efficiencies.

Wind Farm Geographies & Market

Market Characteristics

The penetration of wind farm energy in the overall energy market is fairly shallow at about 1 to 2% of all US energy. The anticipated growth is from 20GW of generated energy to 300GW of energy by year 2025. This is a 15 fold increase. At $1M/MW, the total installation cost is $300B. These projections are from the AWEA database of conservative projections.

The Wind Energy Generation market is split into two type – (1) owner/operator type and (2) Utility. Due to many tax incentives, renewable energy subsidies and freely available capital owner / operator type of companies promoted the wind energy generation business. However, due to the freezing of credit, such companies have not been able to generate the capital needed to satisfy the growth needed for the 300GW wind energy.

The Utility companies which are the second type purchased the wind energy from the owner / operator type companies and sold it to the customers at retail rates. However, since Utility companies have higher level of credit they are starting to see the potential for Wind Energy Farm development. Also as they have experience in the management of conventional power plants, transmission and distribution lines, some economy of scale can be anticipated to improve the cost distribution to the end user.

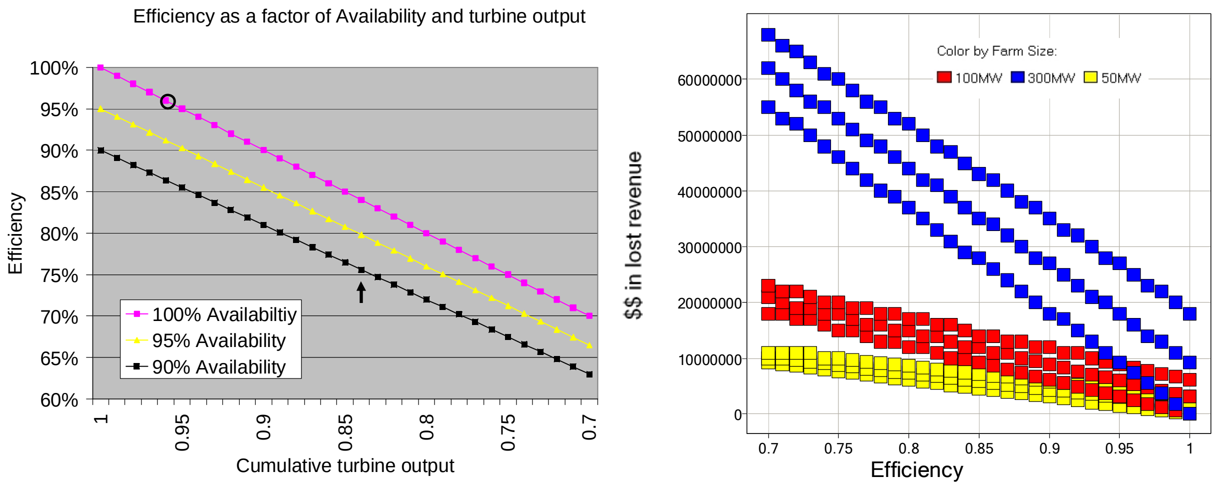
The table below (source: www.awea.org/publications/reports/2Q08.pdf) gives an idea of the most current projects that have been commissioned.

State	Project Name	Cap (MW)	# of turbines	Turbine rating	Turbine Mfg	Owner/ Equity Partner	Power Purchaser
IN	Goodland I	130.5	87	1.5	GE Energy	Orion Energy Group, LLC	Duke Energy Indiana/Vectren Power Supply Inc.
IO	Charles City (2Q08)	18	12	1.5	GE Energy	MidAmerican Energy	MidAmerican Energy
IO	Endeavor (2Q08)	62.5	25	2.5	Clipper	FPL Energy	FPL Energy
MA	Forbes Peak	0.6	1	0.6		Forbes Park	
MN	Cisco	8.4	4	2.1	Suzlon	community/John Deere Wind	Northern States Power
MN	Ewington	20	10	2	Suzlon	community/John Deere Wind	Northern States Power
MN	Marshall	18	9	2	Suzlon	community/John Deere Wind	Missouri River Energy Services (MRES)
MN	Odin	20	10	2	Suzlon	Edison Mission Group/Rahn Group	Missouri River Energy Services (MRES)
NY	Noble Bliss	100.5	67	1.5	GE Energy	Noble Environmental	n/a
NY	Noble Clinton	100.5	67	1.5	GE Energy	Noble Environmental	n/a
NY	Noble Ellenburg	81	54	1.5	GE Energy	Noble Environmental	n/a
OR	Klondike IIIA	76.5	51	1.5	GE Energy	Iberdrola Renewables	n/a
TX	Capricorn Ridge expansion	156	104	1.5	GE Energy	FPL Energy	n/a
TX	Lone Star II (2Q08)	52	26	2	Gamesa	Horizon	JAron
TX	Goat Mountain Phase I	80	80	1	Mitsubishi	Cielo/Edison Mission Group	
WA	Goodnoe Hills	94	47	2	REpower	NW Windpower (enXco/Power Holdings)	PacificCorp
WI	Blue Sky - Green Field	145.2	88	1.65	Vestas	We Energies	We Energies
WI	Forward Expansion	30	20	1.5	GE Energy	Invenergy	Wisconsin Public Services, Alliant energy, Madison Gas & Electric
		1193.7	762	29.85			

Importance of Farm Efficiency in a Competitive Market

Wind farm efficiency, simply stated, is the product of turbine availability to turbine power output. In an ideal situation where there are “n” turbines in a farm and they are available 100% of the time and are producing the rated capacity of the turbine.

Figure 1 gives the relationship between availability and turbine output. For a 90% availability and 84% turbine output the efficiency is 75.6% (arrow). Similarly for a 100% availability and 95% turbine output, the efficiency is 96% (circle).



(a) (b)

Figure 1: (a) Availability and turbine output as it effects efficiency and (b) Lost yearly revenues in dollars due to efficiency loss.

We can now calculate the cost for efficiency decrease depending on the size of the farm. A 300MW farm operating at 95% efficiency is loosing $9.2M in revenue every year. As the farm size increases the importance for efficiency is clearly evident as well. The larger the farm size the efficiency loss is quite dramatic.

The opportunity for efficiency improvement occurs between the initial start and final operation of the wind farm. While safety systems of the wind turbine and farm are being checked, efficiency gauges and instrumentations can be placed to begin the process of improving revenues.

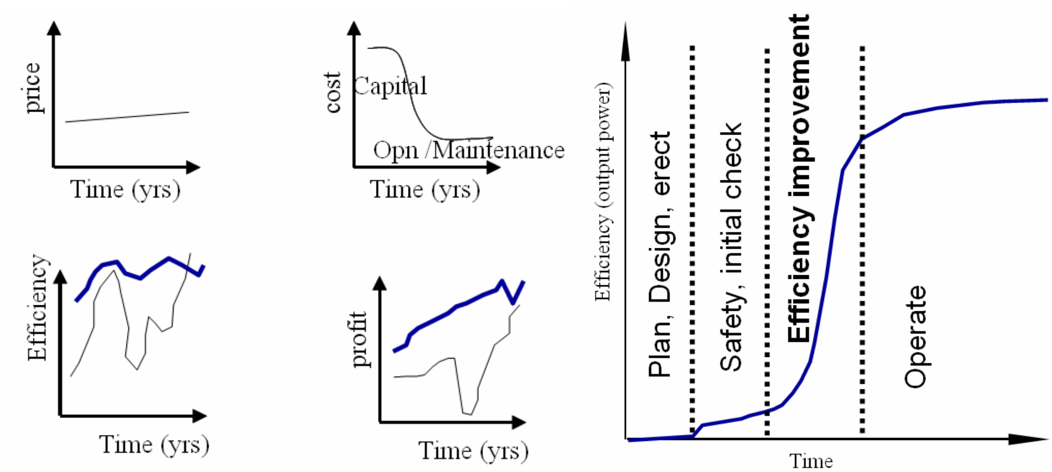


Figure 2: (a) Price, cost, efficiency and profit. (b) Efficiency improvement opportunity.

The opportunity to improve efficiency is immediately after the safety systems, turbine qualifications and release to production have been submitted. At which point efficiency Improvement team performs monitoring and analysis of the wind farm to obtain clear parameters that will help production in improving the efficiency.

It is anticipated that this period of efficiency improvement is somewhere between 1 and 3 years depending on the size and capacity of the farm. After this efficiency period, the farm can then handed over to the production team that will use the parameters as determined by the efficiency team to monitor and improve the efficiency of the farm.

Key Requirements of Data Analysis to improve Wind Farm Efficiency:

A step before analysis is the instrumentation and measurement. Accurate instrumentation where there is statistically insignificant variation due to instrumentation is necessary in order to make accurate and precise decision.

Some of the main instrumentations and measurements required are

- Wind velocity measurement in X, Y and Z (shear) direction.
- Rotational speed of the rotor and hub.
- Vibration of nacelle.
- Temperature of the nacelle, gear box lubricant and ambient (outside).
- Electrical output (Voltage and Watts).

Large Volumes of Data

The nature of the data collection can be different. The data for each turbine and the entire farm have to be correlated. If 1000bytes of data is collected every minute, this will generate 1.5MB of data in one for each turbine. Hence the volume of information is fairly large.

Some points about the data are:

- There are large volumes of data generated.
- Typical wind farm can have more than 10 wind turbines.
- Each turbine can have similar turbine capacity or it can vary
- Turbine data can be collected continuously, hourly, daily, weekly, monthly, etc.
- The data has to be rapidly accessed from the equipment.
- File formats are fairly standardized for the key parameters.
- Movement of data across the network can also pose problems when the volumes are large.
- Data Management - the challenges of data storage, archival and retrieval are faced on a routine basis.

Data Processing

Data coming out has to be post processed in order for clear translation from data to information. Some characteristics of the data are:

- Data needs to be cleaned.

- Data filtering is critical. The ability to process the data for product that meet certain user-defined criteria enable the engineers to identify root causes.
- Data needs to be processed fast. Fast algorithms ensure timely implementation of corrective measures.
- There are standard analysis techniques that are commonly used.
- In addition, applications should allow the user to design custom analysis routines. These custom routines are typically derived from standard building blocks.
- All data analysis can be broadly categorised into Production or Engineering analysis. Production analysis is typically conducted in the background. While engineering analysis is conducted in the interactively by an engineer.
- Background analysis typically runs on all products that are manufactured and generates automatic alarms and reports. Interactive or drill down analysis is typically run when the engineer needs more information than that provided by the background analysis.
- The ability to write scripts that run analyses in the background is essential.
- The management of background processes.
- Drill down analysis is extremely valuable. The ability to move from one analysis to the next seamlessly, i.e. the data is available, the tool can be launched, etc.
- Exploratory analysis that answers what if scenarios is also useful.
- Data processing --- elimination of outliers, removal of spatial data. Data filtering based on analysis --- eliminate lots with yield less than 50%, etc.
- Automation of analysis routines
- Workflows that are designed for specific types of analysis.

Reporting

The output of the data analysis has to be easily understandable reports, charts or alarms.
A chart that can be read and understood in 5 seconds is far more useful than a table.
The ability to annotate reports or charts is useful.
Alarms that are sent to pagers, phones, email or directly to the equipment are another important aspect of reporting.

Types of Data Available for Analysis

A key requirement to data analysis is the ability to quickly translate data to information. The information should enable action to be taken. This action could include inaction in the vent all turbine (all farms) are performing per intended use.

There are several types of data necessary for monitoring wind farm efficiency. But the most essential data required for monitoring and control of wind farm data individual turbine data and entire farm data.

The individual turbine data such as temperatures at different locations, wind velocities, downtime and power output can be taken continuously. This information can then be taken real time and understood for the entire farm.

A very important efficiency parameter is the power output. By plotting power output as a function of wind speed for each turbine in real time the potential outlier turbine that is under performing can be isolated, detected, corrected and brought back to high efficiency.

The following charts are descriptive examples of such phenomenon.

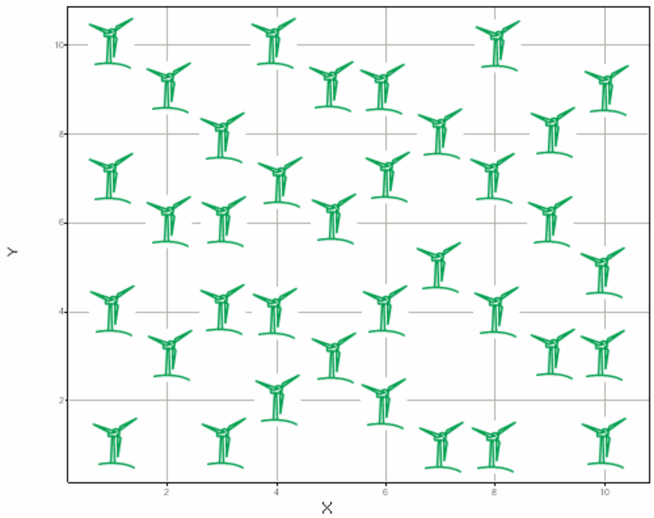


Figure 3: 2D pictorial view of a wind farm with 36 turbines. Spacing between turbines can be adjusted.

The above Figure 3 is a pictorial view of a wind farm. A grid can be drawn and in that grid wind turbines placed. While this gives only a two dimensional view, the topography of the land that is also needed can be superimposed on this chart.

A chart of importance is the plot of wind velocity to turbine power output. A nonperforming wind turbine can be detected instantly by reviewing real time data as follows.

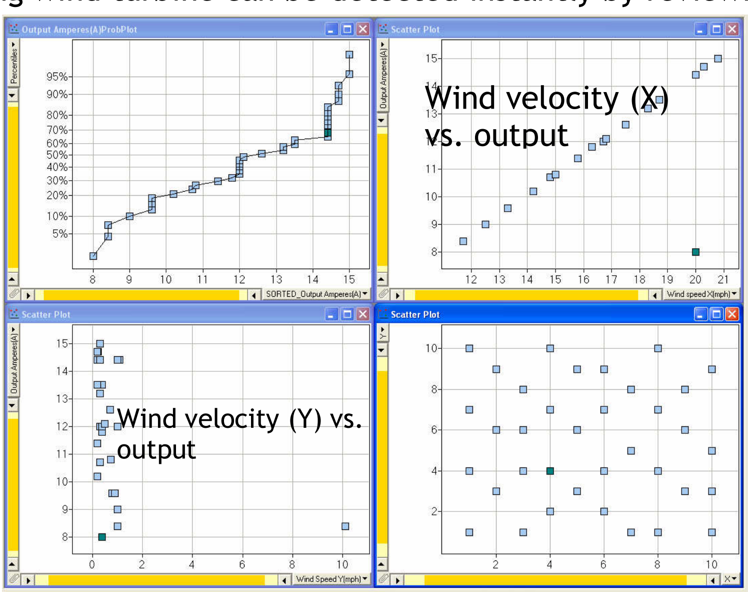


Figure 4. There is a clear relationship between wind velocity and turbine output.

Figure 4 illustrates the point that underperforming turbines can be detected. A turbine with nearly 20mph wind speed is giving an output current of only 8A. The location of this turbine with reference to the wind farm grid is (4,4). Figure 4 shows how an underperforming turbine can be detected instantly by doing real time monitoring.

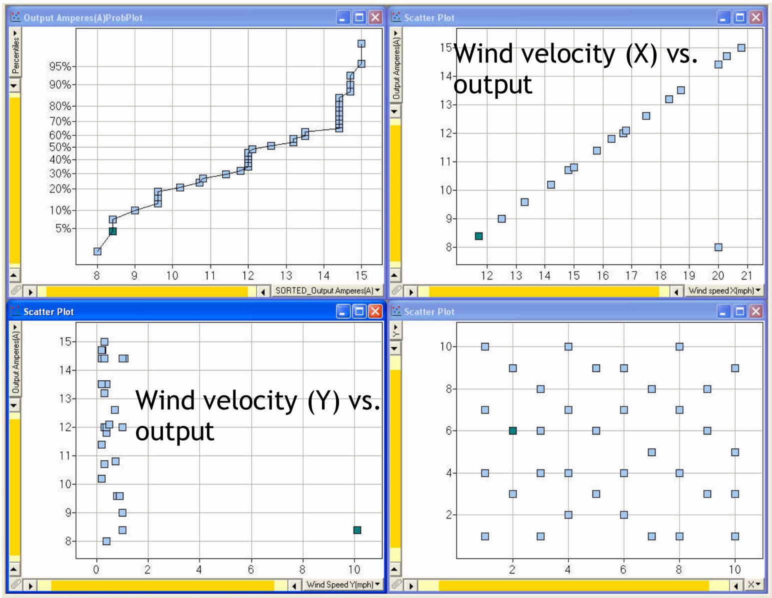


Figure 5: A turbine (2,6) is indicating 10mph wind speed in the Y direction and 11.75mph in the X direction. This indicates the blades are tilted towards the direction of the wind hence will under perform.

A careful review of charting and monitoring techniques is essential to the overall performance improvement of the wind farm.

Key characteristics that needs to be incorporated in wind farms is the notion about availability and efficiency. Since both of these have to be optimized it is critical to obtain and visual information regarding the two at the same time.

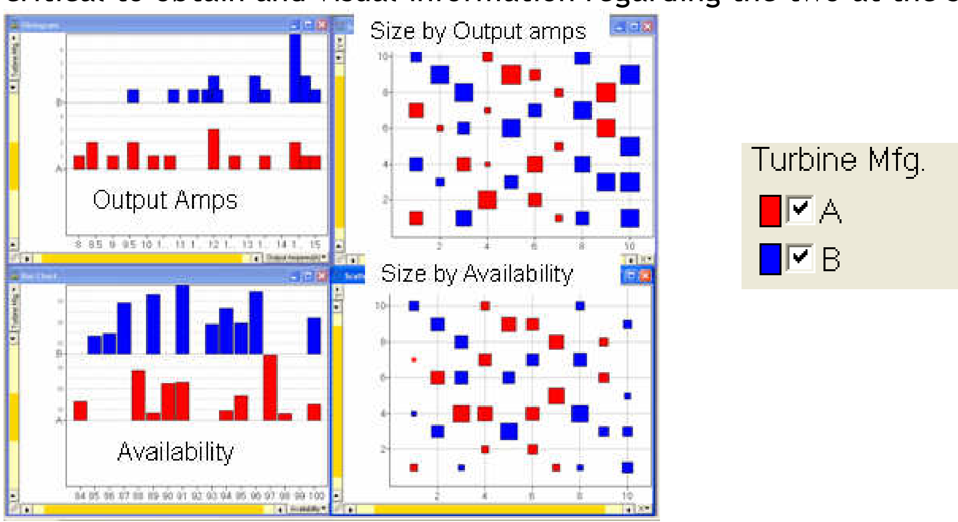


Figure 6: Incorporating availability, turbine manufacturer and efficiency.

From Figure 6 several observations can be inferred, such as,

- Turbine manufacturer A has marginally higher efficiency than turbine manufacturer B.

- There no significant difference in availability between turbine manufacturer A and B.
- The farm centre has higher availability than towards the edge.

While visually the efficiency of the two turbines (A & B) indicate turbine A to be better than turbine B, a more thorough T Statistic evaluation performed confirms the hypothesis that the two populations (A & B) have different means.

The performance of the farm depends on both availability and efficiency. With either availability or efficiency being low can significantly reduce the performance of the wind farm.

Summary

Wind Farms are relatively new to the industry. There are significant improvements in availability, efficiency and reliability to be made. For this to happen improved instrumentation, monitoring, control, data analysis and information loop need to be developed.

The product of availability and efficiency is critical for highest wind farm output. The efficiency improvement can be more dramatic as the size of the farm increases.

Through a few small examples given in this presentation the importance for instrumentation, monitoring, control and analysis has been illustrated.
It is the objective of Mouli Engineering Inc. to supply these services with no increased capital to our customers.

References:
1. AWEA: http://www.awea.org/
2. NREL: http://www.nrel.gov/