Application

Project Title: Dakota Turbines

Applicant: Posilock Puller Inc.

Principal Investigator: Cris Somerville

Date of Application: September 1, 2009

Amount of Request: $178,500

Total Amount of Proposed Project: $497,000

Duration of Project: 1/1/2010 - 7/1/20011
(18 months)

Renewable Energy Program

North Dakota Industrial Commission

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ABSTRACT

Objective:

The primary objective is to create a turbine with efficiencies that provide the consumer a payback period of under 10 years. (Industry norm is 25 years and beyond) To accomplish that, the turbine has to be reliable, with an expected maintenance free period of over 20 years.

Our current turbine has a verified payback of 12 years at .07 per kWhr. The objective of the grant funds would be to incorporate known and unknown improvements on the physical unit, electrical, and software areas, to reach or exceed our goal of a payback period of less than 10 years.

Expected Results:

With already known improvements that will increase efficiencies by over 30 %, we would fully expect to reach our goal of a 10 year payback. We would use the "Small Wind Certification Process" in all testing from here forward, and would expect to achieve Certification of our data by the Small Wind Certification Council. That would provide public documentation of our efficiencies against all other turbines that will go through the same Certification Process.

Duration:

We expect the optimization and certification process to last 18 months. We believe the major physical unit and electrical modifications are known and will be implemented early in the project. The software and certification process will however be ongoing throughout the 18 month period.

Total Project Cost:

The total project cost is expected to be $1,197,000. The total project cost over the duration of the grant period is expected to be $497,000. We would ask for participation of the Renewable Energy Council of $178,500, for 18 month grant period.

Participants:

Energy and Environment Research (EERC) has been involved on a consulting basis. The UND Mechanical Engineering Dept. will be involved in physical plant stress and duration testing. Also involved in the power electronics and software has been Posedg Software of Rogers, MN.

PROJECT DESCRIPTION

Objectives:

To optimize a turbine using our patent pending "Sliding Stator Technology" to create the most reliable and efficient turbine on the market. Install and implement known and to be learned improvements to the physical plant, electrical system, and tighten the parameters of the control software. Run duration and stress tests to prove reliability. And using the new Small Wind Certification Protocols, provide side by side data comparisons of our efficiencies against all other manufactures.

To install our current "bench model" inverter in an industry standard housing, and achieve UL listing to attain marketability of a single phase inverter in the 10 to 100kW size range where none exists.

Methodology:

There are 3 primary task categories we will be addressing within this project. The first, being the duration and stress testing of the existing turbine. The turbine will be periodically lowered and visually inspected for any signs of fatigue, wear or component failure. In addition, we simultaneously collect; wind direction, wind speed, rotor rpm, stator temp., outside temp., yaw direction, stator position, pitch position, and electrical output data from the turbine. On the inverter we collect; temperatures on the, inverter bridge, bridge rectifier, boost diode, and boost IGBT, along with AC output voltage, AC input voltage, DC input from generator, DC output from booster, and AC output current. With the “baseline data” this information provides, we can easily and quickly determine if we have any problems, and narrow the search for the cause. The turbine is presently being run every day in a manual/automatic mode with physical oversight. Although the current turbine is our only source of information in the optimization process, down the road a ways it is more important that it gets run-time, than is itself optimized to the fullest extent possible.

The second task category is the update of major physical components. At this time we only know of two items that fall into this effort. The blades we are now using harvest approximately 63% of the energy available in the wind. Working with blade manufacturers, using the latest blade design and optimization software, we have identified blade designs that would achieve over 85% efficiency, which would be an improvement in electrical output of 35%. Preliminary analysis also leads us to believe we can achieve a similar electrical output from our generator with coils containing half the copper. This would result in significant savings in costs, and would contribute to other electrical efficiencies. We need more testing and information to confirm this option. If a new coil is a viable option, our considerable experience in coil design, as briefly explained in Appendix II, will allow us to determine the size of wire, number of turns, and physical geometry that would be work best.

By far the largest concentration of efforts will be in the software and control hardware configurations. The inverter has 3 micro-processors on “hand-wired boards”. The turbine currently has 6 micro-processors on “hand-wired boards”. The inverter will eventually have three processors on a single printed circuit board. The current thinking is that the turbine will also have only 3 micro-processors, either placed directly on a single printed board, or individually housed on printed boards and attached PCI style to the main board.

Going from hand-wired boards to printed circuits, will in itself solve many of the “cross-talk” and/or “electrical noise” problems that are currently the focus of attention. But as I understand it, that also makes it more difficult to identify the source of problems and to see the results of changes as would be possible on the hand-wired boards. The noise issues now being dealt with can be totally hardware related, software control issues, or a combination of the two. It is our intent to have all the major noise issues solved before the printed boards are made for the next generation turbine to be used for certification purposes.

The software involved controls all things electrical on both the turbine and inverter. However, a second side of the software is the direct control of the pitch-able blades, movable stator, and the yaw system. The parameters of how we control these physical variables can be optimized by the resulting electrical output, but turbine safety, stress, and torque issues must also be addressed. In high to very high wind speeds the control regime will be a compromise between output, and safety and stress considerations.

In North Dakota’s wind regime, the wind blows at 25mph or greater 13% of the time. That 13% in time however, contains 42% of the total electrical output available over a years’ time. From the perspective of the consumer “payback period”, we think it very important that we harvest as much of this potential output as is safely possible. Because these wind speeds are not available a large percentage of the time, and are potentially dangerous when they are, this part of the optimization is a “cautious” process. We believe this can be accomplished within the time frame of the project period.

We will utilize the very stringent Small Wind Certification Protocols though out the entire optimization process. Not only will this provide what is considered to be "best practices" in turbine testing, but will provide data that is consistent and comparable across the whole industry.

Anticipated Results:

We would fully expect to have a turbine certified by the Small Wind Certification Council, and our data published against all other turbine manufactures, for all the world to see on the Small Wind Certification Council web site. www.smallwindcertification.org

We would also expect to have a commercial grade single phase inverter scalable from 10 to 100kW, 96% efficient, to fill a market void where none exists.

Facilities:

Our current model turbine sits on a tower east of Cooperstown, along Hi-way 200. We will soon identify a Certifiable Test Site, upon which to place our next generation turbine. The current turbine and tower location will be utilized to provide duration and stress related information on the physical unit. The certified site will house the new generation turbine with all the improvements now known, and to be learned over the next several months. This facility will provide the certification data SWCC requires.

Resources:

The National Renewable Energy Lab (NREL) and the SWCC will be involved in setting up a certified test site, and in the process for data collection to achieve certification. EERC is available to provide assistance across a wide variety of disciplines. The UND Mechanical Engineering Dept. will be actively involved in the stress and duration testing. Posedg will continue to be involved in the power electronics and software optimization process, as needed.

Techniques to Be Used, Their Availability and Capability:

The Small Wind Certification Protocols to be used in this process are the result of many years of collaborative design by every entity worldwide in the electrical and renewable energy fields. Once adopted later this summer, these protocols will be the universally accepted means of measuring and comparing all small wind turbines, worldwide.

Environmental and Economic Impacts while Project is Underway:

The only environmental impacts during this project will be the creation of wind generated electricity during the optimization process. Direct and indirect economic impacts would be typical for economic activity at the projected expenditure levels.

Ultimate Technological and Economic Impacts:

The technical advance of the "Sliding Stator Technology" (see Appendix I for description), and the resulting economic impacts, are potentially unlimited. The patent pending Sliding Stator Technology contributes to efficiencies allowing for a verifiable payback of our "current turbine" of just 12 years, compared to verifiable paybacks of the conventional turbines of 25 years - and beyond.

The simple mechanical design of SST allows for its' scalability across the whole range of distributed generation of 5 to 100kW. AWEA's "2009 Market Study" defines the potential for distributed generation by 2020 as 50,000MW, or about $125 Billion dollars.

DOE is spending 10's of millions of dollars funding projects to increase electrical generation at low wind speeds. The sliding stator technology allows us to generate electricity at wind speeds 1/2 of what is required to even cause a conventional turbine to spin. We already know that to be fact. Part of what this project will define is how the SST might also affect efficiencies across the whole of the wind regime.

Although not of significance as a technical advance, our single phase inverter project will produce a product where none exists. That will be of very real importance to the vast majority of rural residents in ND and the US, who sit along single phase distribution lines.

The Small Wind Certification Process will soon define the economic viability of all turbines that want to be sold into the small wind market. The very stringent protocols, and 3rd party verifiable data, will not bode well for conventional turbine technologies. For small wind turbines to reach their potential in the mix of electrical generation, there will have to be an underlying economic justification in doing so. That is currently not the case, and 80 years of attempted improvements to conventional technologies has not yielded any significant improvements.

We believe our sliding stator technology, or modifications thereof, has the ability to cross the technological boundaries to economic viability of small wind turbines. It would be our hope that the Renewable Energy Council would agree, and help us put our verifiable data on the SWCC web site for all the world to see.

STANDARDS OF SUCCESS

The very opportune timing of the formation of the Small Wind Certification Council, along with the pending adoption of the protocols that will apply to all small wind turbines, we will have documented and comparable data with which to gauge the success of our turbine against all others.

Upon completion of the certification of our turbine, it is Posilocks' intent to produce the turbines at our facility here in Cooperstown, ND. Even so, whatever level of production we would seek to attain would not put a dent in the potential demand as predicted by AWEA. Their 2009 Market Study projects the demand in the distributed generation arena to exceed the capability of all manufacturers combined capacity to fill it. Demand could achieve 50,000MW by 2020, worth over $125 Billion dollars.

No matter what the actual efficiency of our turns out to be, its improvement over conventional turbine technology will be very significant. We would anticipate that our technology will somehow have an impact on the distributed generation industry as a whole. It is our hope that our patent is strong enough to cause economic returns to any use or modification of our technology. If everything plays out as anticipated, we would ask ND to help us leverage and/or otherwise make best use of this opportunity.

BACKGROUND/QUALIFICIATIONS

The fact that a project such as this should originate out of Posilock Puller Inc. would surprise no one familiar with the company's track record. Posilock already holds 30+ patents world-wide, and sell several one-of-a-kind products into the Inter-National marketplace.

Cris Somerville is the originator of the turbine project idea, and head of development. Cris is part owner of the family company Posilock Puller Inc. He is also Division Manger of PL MFG, a precision machine shop of over 30 CNC machines, that was formed in 1999 to do most of the component manufacture for the Posilock Puller. In his 18 years with the company, Cris has been in charge of product development from concept, to design, and ultimately through the manufacturing processes that bring a product to market. Many of the 30+ patents referenced above, came about under his direction and supervision.

Mitch, lead engineer, has been with the company for 22 years. Although his primary responsibility is the machine shop, his vast knowledge of all things metal, has been invaluable in the physical design.

James is the lead on all things electrical and software. His experience with computers, software, and networking spans 35 years, with almost 20 years as the head of a college IT dept. His experience on the electrical side spans 38 years and runs the gamut from trouble-shooting and repair, to system design, and power electronics. Although very competent by any conventional measure, his ability to anticipate solutions to unique problems, and get it right the first time is truly amazing.

Keith comes to the project with 42 years of management experience across several fields. 11 years of wind data collection and analysis, along with 12 years of Commercial Level, Community Based wind power development. He is the chairman of "M-Power", that has developed the 160MW project at Luverne, ND, being built this summer.

EERC and its vast resources across several disciplines, is available on a consulting basis. The UND Mechanical Eng. Dept. will be actively involved in the stress and duration testing processes. Posedge, a Company specializing in software and power electronics, is available on an as-needed basis.

MANAGEMENT

Like any significant effort, the Dakota Turbines Project is made up of dozens of individual tasks that have to fall in place in a logical and timely manner for the Project to move forward. Weekly meetings and continuous ongoing reports, keep Cris abreast of the progress on the individual tasks. He then assigns resources and/or personnel to those areas that need to be completed to allow us to move forward with the overall project.

Since the turbine project deals directly with "Mother Nature", and the wind regime available to us on any given day, no schedule is set in stone. The primary need at this point in time is to gather all the information we can from running the turbine and inverter across all wind speeds within the wind regime. Many of the decisions about options or changes that will be made, hinge on the data we gather from the current configuration.

The major listings in the timetable need to get done in the time frames indicated to keep the project moving forward on the schedule we have set for ourselves. Virtually all tasks are well underway, and ongoing, with many being addressed in the down time in the operation of the turbine itself.

We know for example, the general direction we will go in creating new coils that are cost-effective and more efficient. The specific details of the size wire, number of turns, geometry, etc. - is contingent however, on the results of other changes we make in minor components over the next few months.

Everyone involved in this project is excited by the initial results we are getting from the testing to date. With the new Small Wind Certification Process, the timing to bring a turbine to market couldn't be better. State and Federal incentives for small wind, and social attitudes in general, indicate that now is the time to be moving into the small wind market. As such, there is an urgency felt by all involved - that it is very important that we make every attempt to keep this project on the schedule we have set for ourselves.

Time Table

TimeTable

1/1/2010 - 7/1/2011

	2010					6/10 thru	2011
Task	**Jan.**	**Feb.**	**March**	**April**	**May**	**5/11**	**June**
Software Optimization	X=========	==========	==========	==========	==========	==========	=========X
Electrical System Optimization - Turbine	X=========	==========	==========	==========	==========	==========	=========X
Data Analysis Toward Optimization	X=========	==========	==========	==========	==========	==========	=========X
Monitor Original Turbine	X=========	==========	==========	==========	==========	==========	=========X
Build Inverter w/printed circuit boards	X========	=======X					
Design and build new Blades	X========	=========	=======X				
Design and build new Coils			X========	=======X			
Build New Generation Turbine			X========	=======X			
SWCC Site Certification				X======X			
Install New Generation Turbine					X		
Certification Data Collection					X========	=========	=======X
Start UL Certification Process					X		
UL Listed Inverter - Certified Turbine							X
Reports To ND REC -quarterly			X		X	X X X	X
Reports to SWCC - As Required							

BUDGET

PosiLock - Dakota Tubines® - 18 Month Budget

1/1/2010 - 7/1/2011

Project Description	NDIC'S Share	Applicant Share (Cash)	Applicant Share (Inkind)	Other Project Sponsors Share
Personnel				
Project Leader/Management			$ 140,000	
Lead Electrical/Software Dev.	$ 30,000	$ 30,000		
Certification & Data Collection	$ 30,000	$ 30,000		
In-House Labor/Assistance		Unknown		
Contract Services				
Blade Design - 1st Generation	$ 7,500	$ 7,500		
Blade Design -2nd Generation	$ 2,500	$ 2,500		
Blade Manufactue - 1st Gen. - Temp. Mold	$ 3,750	$ 3,750		
Blade Man. 2nd Gen. - Production Mold	$ 12,500	$ 12,500		
UL Certification - Inverter	$ 30,000	$ 30,000		
Mechanical Design - as needed		Unknown		
Electronics & Software - as needed		Unknown		
Equipment/Components				
Turbine Component/Updates				
Current Turbine - Continued Dev.	$ 5,000	$ 5,000		
New Coils	$ 2,500	$ 2,500		
2nd Generation Model Electronics	$ 1,500	$ 1,500		
Inverter				
Current Model - Continued Dev.	$ 1,000	$ 1,000		
1st Production Model	$ 3,500	$ 3,500		
2nd Generation Production Model	$ 2,500	$ 2,500		
Inverter Enclosures (3)	$ 3,750	$ 3,750		
Monitoring Equipment (SWCC required)				
Turbine Monitoring Equipment	$ 11,250	$ 11,250		
Power Monitoring Equipment	$ 6,250	$ 6,250		
New Generation Turbine & Tower				
Improved Turbine for Certification	$ 25,000	$ 25,000		
TOTALS:	$ 178,500	$ 178,500	$ 140,000	0
			TOTAL PROJECT COSTS:	$ 497,000

CONFIDENTIAL INFORMATION

There is no confidential information contained in this grant application. The information contained in Appendix I, was put in an appendix because it did not need explanation within the grant application itself. But, because the Sliding Stator Technology is key to our turbine project, we thought an explanation was necessary to gain an understanding of how our turbine is unique.

PATENTS/RIGHTS TO TECHNICAL DATA

The "Sliding Stator Technology" is patent pending. Posilock Puller Inc. is listed as patent holder, and would intend to remain as such.

There will be no "technical data" produced that we can think of that would need to remain proprietary. Much of the effort will be in fact, to produce data for public consumption in the Small Wind Certification Process.

STATE OF NORTH DAKOTA
OFFICE OF STATE TAX COMMISSIONER
Cory Fong, Commissioner

August 27, 2009 Ref: L1867489792

POSI LOCK PULLER INC
PO BOX 246
COOPERSTOWN ND 58425-0246

I, Myles S. Vosberg, Director of Tax Administration for the North Dakota Office of State Tax Commissioner, certify that the records in the North Dakota Office of State Tax Commissioner do not show any indebtedness owed to the State of North Dakota by POSI LOCK PULLER INC, with respect to income taxes, sales and use taxes, or any other taxes collected by and payable to the Tax Commissioner's office. This company is, therefore, in good standing with the North Dakota Office of State Tax Commissioner. This certification does not include ad valorem property taxes collected by the respective county treasurers.

Dated this August 27, 2009 at Bismarck, North Dakota.

/s/Myles S. Vosberg
Myles S. Vosberg
Director, Tax Administration

600 E. BOULEVARD AVE., DEPT. 127, BISMARCK, NORTH DAKOTA 58505-0599
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Cooperstown, ND 58425
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Transmittal Letter:

This document confirms Posi Lock Puller Incorporated's intent to proceed with the **"Sliding Stator Technology" Dakota Turbines®** Project as outlined in this application. After 3 years of development, and almost $700,000, we are well beyond proof-of-concept and are moving toward the Small Wind Certification Process which will provide a verifiable marketability. We are asking for assistance with what will be 18 months of durability and stress tests on the physical unit, software programming and component updates to the turbine itself, and to finish the simultaneous inverter project. The current turbine sitting on our tower along Hi-way 200, will produce about 35kW +/- of electrical output.

At the end of those 18 months we will have a turbine that will be more efficient than anything else on the market in the distributed generation range of 5 to 100kW. We will either be certified, or close to being certified to Small Wind Certification Protocols which will confirm in side by side data sets, our claims to efficiencies against existing turbines. The data provided by the certification process will give us the equivalent of an instant market history, and more importantly display our efficiencies directly against the data provided by other turbine manufacturers. The results of all SWCC tests will be displayed on a single web site for all the world to see. **www.smallwindcertification.org**

A parallel project involves the development of a commercial grade single phase inverter with which to connect a wind turbine to the grid. Extensive searches have not revealed a single phase commercial inverter available in the 10 to 100kW size range. Since the vast majority of all rural residents in the United States sit along single phase distribution lines, that would also preclude a large percentage of North Dakotas' residents from even considering wind generated electricity.

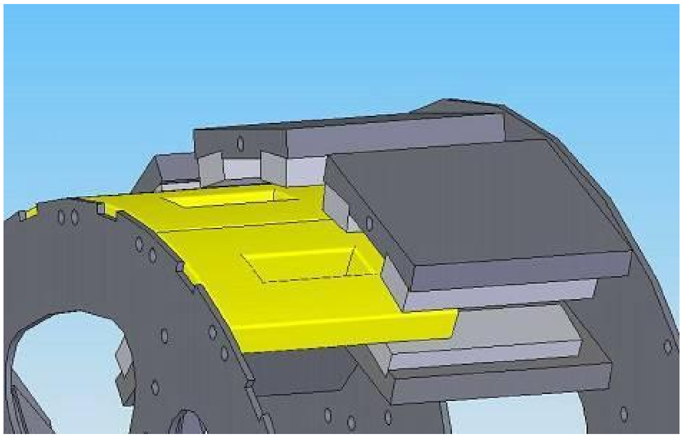
______________________________________ ____________

Cris Somerville Date

Appendix I -

Explanation of the Sliding Stator Technology - patent pending

Although the **"Sliding Stator Technology"** is not itself a directly funded portion of this project, it is the cause of the efficiencies that make this a project - period. As such, we believe a brief description of this patent pending technology is warranted.



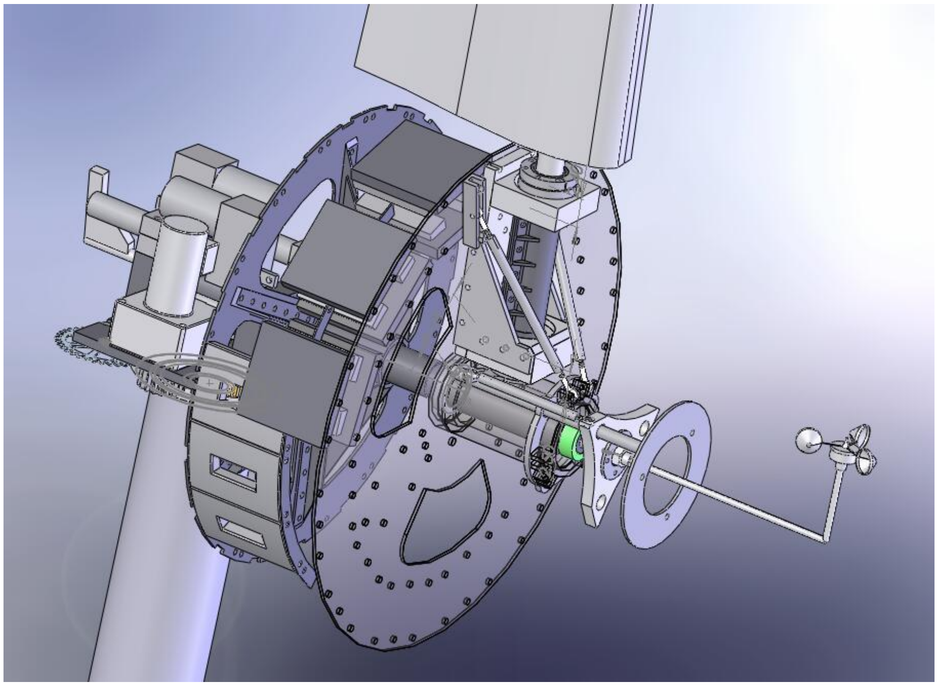
Pictured to the left is the design we have coined; **"Sliding Stator Technology"** The magnets are attached to the rotor disk on the right, with the coils attached to the stator disk on the left. Both sit on the axel shaft, with the coils stationary and able to move into, and out from between the magnets. This allows us to independently control the (load) level of generation.

In very low winds we can pull the stator all the way out and allow the turbine to spin with only the friction of the bearings as load. Once spinning, we can insert the stator and start generating electricity at wind speeds below where a conventional turbine can even begin to turn. Another example at lower winds speeds is when we remove the stator to a position of 75%, the resulting decrease in load causes an increase in rotor speeds, dramatically increasing the electrical output. Even if the only result of this technology was to allow us to eliminate the expensive, inefficient, and high maintenance gearbox found on most turbines - it would be a huge advantage.

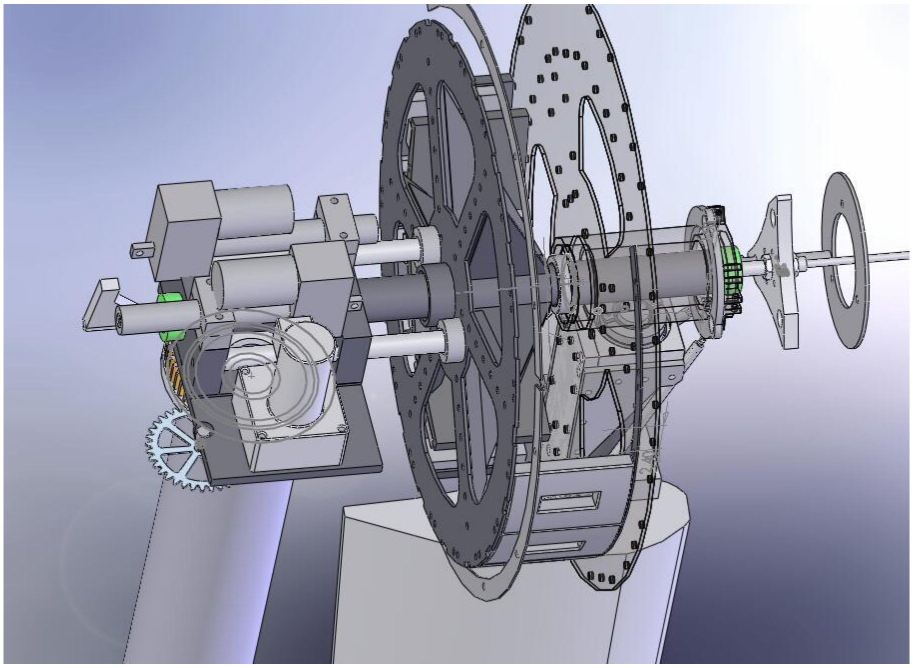
DOE is spending 10's of millions of dollars trying to solve the problem of wind generated electricity in low speed wind regimes. We think we have a solution! We are just beginning to experiment with how this design might be most effective, and quite honestly don't yet know to what level this technology might be utilized throughout the rest of the wind regime.

Appendix II - (very informal - but informative)

Posi Lock Turbine Pictorial Story -



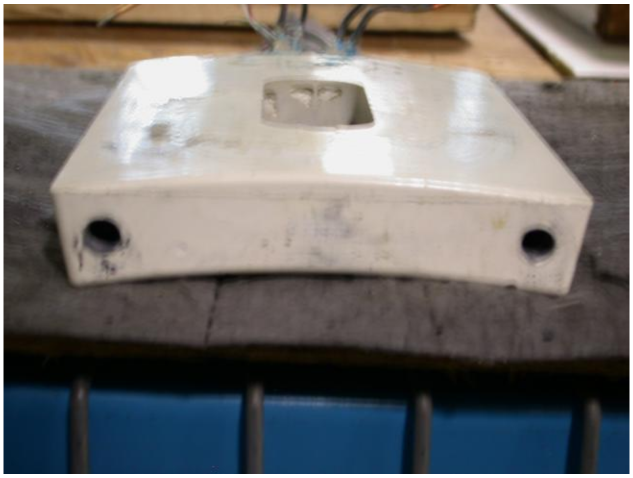
Pictured above and below are SolidWorks 3D Models of the Posi Lock Turbine. The picture above shows the rotor plate with the magnet plates on back and the blade brackets on front. Also shown is the pitch plate, moved by a shaft through the axel.



This picture shows the stator plate with the coils attached on the front side. Also shown are the two electric actuators that control the movement of the stator and adjust the pitch of the blades, and the gear motor that controls the yaw.

To the left is the first complete stator, cast as a single unit for the proof of concept turbine. The wire was #10 flat and 200 turns. The considerable testing this stator allowed us, gave us several insights in how and where to go from here. The small coil of wires to the left attach to the heat sensors cast within each coil. This gave us our first look at how the **Sliding Stator Technology** would play a part in optimizing the generation of our turbine.

The picture on the left below shows the first coil out of our new coil molding process. We now mold each coil separately, with each cast to accept the fiberglass bolts that hold them to the stator and stabilization ring on the outer end. The coils are easily replaceable on an individual basis in the case of mechanical damage or other problem. They also now become an off-the-shelf product that can be stocked or produced in a variety of specifications – if that is found to be advantageous.



The picture on the right is of one of many, many test coils. Because all we need is one coil and one set of magnets, we could test dozens of combinations with relative ease with a CNC vertical mill. The coils were placed in a fixture with “the hatchet” containing the magnets clamped in the tool holder. As such, the magnets could be spun across the coils at any speed desired. This allowed us to test various wire sizes, number of turns, and geometry – all in the very controlled environment of a computer controlled mill. This gave us comparative information of each change, and the ability to project the end result of a complete stator of any configuration.

The pictures above more dramatically show the stator out and stator in positions of our turbine. Although virtually everything has been physically changed on the current machine, the principle remains the same.

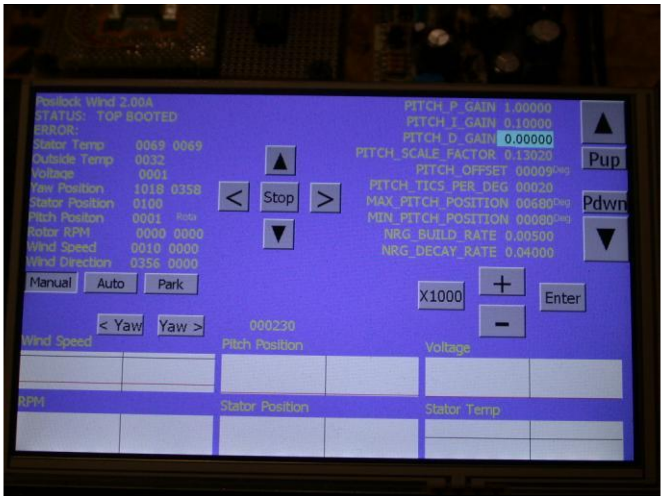
Shown above is the first day of testing of the first machine. Powered by a John Deere 4010, and tied to 3 stoves whose burners and ovens supplied the variable load for the initial testing. The total load of the 3 stoves was about 30kW. Although not very “scientific”, those were some pretty exciting days at Posi Lock. We burned a lot of diesel fuel heating the warehouse until we had all the information this configuration could give us, and it was time for it to fly. (An interesting side note - I can't remember the gear reduction of the drive gears, - appears 8/10 to 1 - but even so when in the 30kW generation area, the 4010 was blowing black smoke. Gives some indication of the power in the blades to do the same.)

Cris and James watching the body putty dry on the nose cone mold – mold. The mold started out as sheets of foam that were then cut to the shape designed and fitted in 3D on turbine models -such as picture one and two above. Fiberglass was eventually laid-up over the mold pictured, and that then with the addition of a frame, became the mold itself. A similar process created the back part of the housing. On the right is the initial fitting of the whole housing to the turbine itself. It fit just as the SolidWorks 3D modeling had projected.

Pictured to the left is the final layup of our current blade. We had the mold made from an AeroStar 5 meter blade. The modification of the hub portion of the blade, the ribs, and the pultruded fiberglass rod are of our design. Once the top skin is attached, we finish the seams, and blades are sanded and finished to a very smooth surface. Although we now know they are only 63% efficient, they have and will continue to get us a long way through the proto-type to near product testing.

On the left is the touch screen for the turbine user interface. From this single screen an operator can change any of the parameters of the control software. Besides providing numerical outputs, the screen features several graphical interfaces which plot outputs in real time. This will be the primary way in which the parameters of all the control systems will be optimized in real time, and in the real world conditions.

On the right are the two sealed containers that house the on-board control systems. The programs can be changed using the user interface, SD card or USB on the user interface, or eventually by using the wireless capability of the on-board system via laptop or satellite.



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Posilock Wind 2.00A
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Outside Temp      0032
Voltage           0001
Yaw Position      1018  0358
Stator Position   0100
Pitch Positon     0001   Rota
Rotor RPM         0000  0000
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000230
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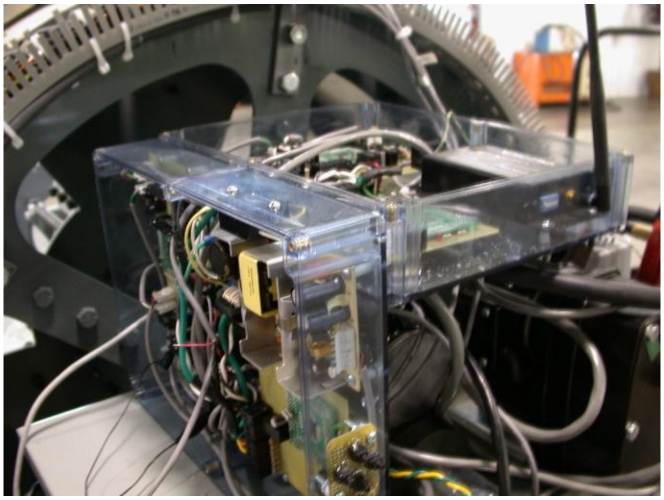
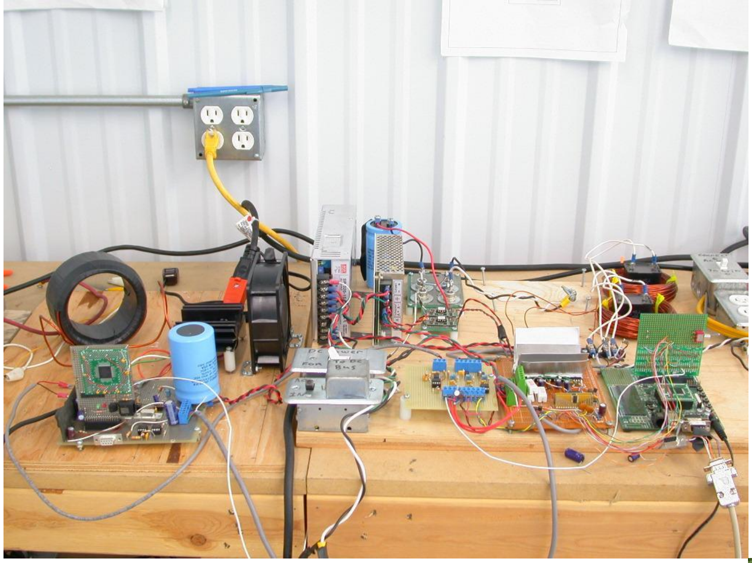


Cris and James are shown mounting the anemometers and vane to front of the turbine. This picture gives a relative look at the size of the turbine itself.

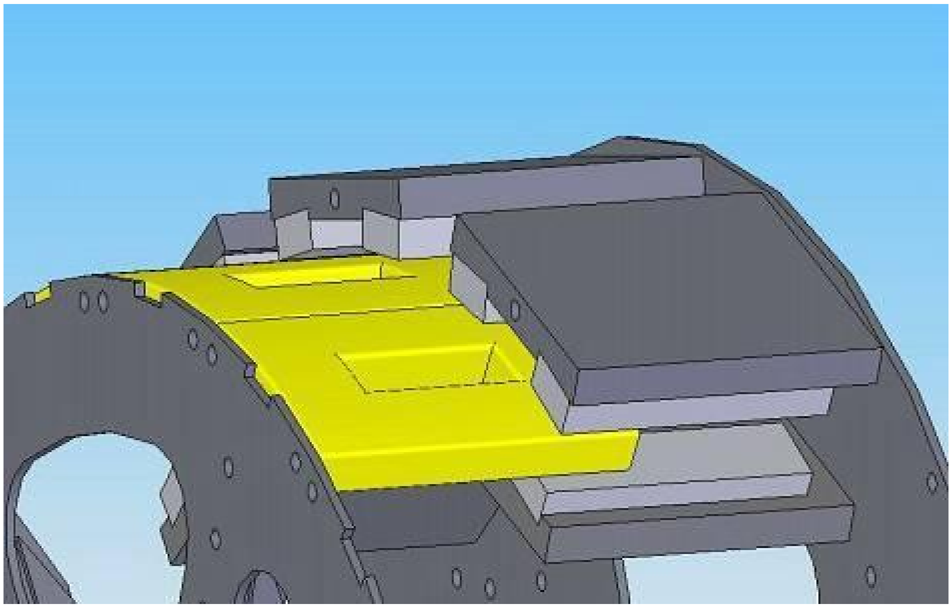
This picture shows the “rotavecta” anemometer at the front, and the NRG wind vane and anemometer closer to the turbine. A third anemometer below and in front of the blades was used to first calibrate the NRG, and then the rotavecta to that. We have since moved the rotavecta to the back of the housing. It is/was our thinking that the single rotavecta would provide both the wind direction and speed from a location on the back of the housing. Its vertical location is however, very sensitive in relation to the housing, so we are still undecided about how to deal with that. We anticipate going back to the front and verifying the wind speeds off a separate, nearby meteorological tower. (That meteorological tower is now in place, providing verification of wind speeds)



Shown to the left is a 3kW “Bench Model” of our inverter design. Virtually all the programming is done, and the functionality is proven. Continued low wind speed testing will be done to remove minor noise issues, until the last of the components for the 40kW model come in. (The 40kW equivalent has since been built and successfully tested)

An electric winch mounted on the tower itself, has proven to be invaluable in the early days of this project. The gin pole is pined directly to the anchor point. To lower the tower you simply pull the pin and flip a switch.

Below is the SolidWorks 3D rendering of the basic structure of the **Sliding Stator Technology**. The rotor plate and magnets on the right, rotate on the axel that the stator plate and coils on the left sit on. The axel and two guide rods keep the stator plate motionless and in perfect alignment with the rotor plate. The movement of the stator plate is achieved by the use of an electric actuator. This is the simple mechanical design that allows us to get the rotor spinning at almost zero wind speed, and to continue to generate at maximum output well beyond the point of optimal wind speeds.



Installing the blades on Proto-1 This was a fixed blade – downwind machine.

The first Proto-type flying. Note long conduit sticking out front with the anemometer on it!

Just a pretty photo, that shows the gin pole raising the tower.

This shows the rotavecta on the back of the housing. Note long shaft. We found that moving the anemometer up or down made significant changes in how it related to the NRG on front. (We are still experimenting with exactly how the on-board anemometer will be mounted)

AWEA Standard
AWEA 9.1 - 2009

DRAFT DOCUMENT
AWEA Small Wind Turbine Performance and Safety Standard

Approved by the
AWEA Standards Coordinating Committee
as a Draft Document
for review by Materially Affected Parties
2009 January 08

American Wind Energy Association
1501 M Street NW, Suite 1000
Washington, DC 20005

AMERICAN WIND ENERGY ASSOCIATION STANDARDS

Standards promulgated by the American Wind Energy Association (AWEA) conform to the AWEA Standards Development Procedures adopted by the AWEA Board of Directors. The procedures are intended to ensure that AWES standards reflect a consensus to persons substantially affected by the standard. The AWEA Standards Development Procedures are intended to be in compliance with the American National Standards Institute (ANSI) Essential Requirements. Standards developed under the AWEA Standards Development Procedures are intended to be eligible for adoption as American National Standards.

AWEA standards may be revised or withdrawn from time to time. Contact AWEA to determine the most recent version of this standard.

Published by:

American Wind Energy Association
1501 M Street, NW, Suite 1000
Washington, DC 20005
202.383.2500

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Disclaimer

AWEA Standards are developed through a consensus process of interested parties administered by the American Wind Energy Association. AWEA cannot be held liable for products claiming to be in conformance with this standard.

FOREWORD and BACKGROUND

The Foreword and Background sections are included with this document for information purposes only, and are not part of the AWEA Small Wind Turbine Performance and Safety Standard.

Foreword

The goal of this standard is to provide meaningful criteria upon which to assess the quality of the engineering that has gone into a small wind turbine meeting this standard, and to provide consumers with performance data that will help them make informed purchasing decisions. The standard is intended to be written to ensure the quality of the product can be assessed while imposing only reasonable costs and difficulty on the manufacturer to comply with the standard.

Background

The proposed AWEA Small Wind Turbine Performance and Safety Standard that follows is in the final stages of approval by the AWEA Standards Coordinating Committee. AWEA is recognized by the American National Standards Institute (ANSI) as an accredited standards writing body and the final standard will be an American National Standard. This standard has been developed in a regimented ANSI process for “voluntary consensus standards” which requires participation from a range of representatives for manufacturers, technical experts, public sector agencies, and consumers.

The draft that follows has been developed over the last five years in a process that involved over 60 participants, three meetings, 22 hours of conference calls, countless e-mails, a list serve, and five intermediate drafts. It represents hundreds of hours of detailed discussion, debate, compromise, revision, and formal response. The Canadian Wind Energy Association has been actively involved since the beginning and the British Wind Energy Association has now adopted and approved this standard almost word for word.

The proposed standard was developed by the AWEA Small Wind Turbine Standard Subcommittee, which is chaired by Mike Bergey of Bergey Windpower Co. Members of the subcommittee have included the following people. Please note that there has been some turnover in the subcommittee, some positions have changed, and not all members were active (though they did receive the drafts and correspondence).

Name	Affiliation	Stakeholder Category
Bill Colavecchio	Underwriters Laboratory	Certifying Agency
Lex Bartlett	Aeromag	Manufacturer
David Blittersdorf	Vermont	Manufacturer / Consumer
David Calley	Southwest Windpower	Manufacturer
Jito Coleman	Northern Power	Manufacturer
David Laino	Endurance	Manufacturer
Robert Preus	Abundant Ren. Energy	Manufacturer
Steve Turek	Wind Turbine Industries	Manufacturer
Dr. Craig Hansen	Windward Engineering	Technical Expert
Robert Poore	Global Energy Concepts	Technical Expert
Ken Starcher	Alternate Energy Institute	Technical Expert
Trudy Forsyth	National Renewable Energy Laboratory	Researcher / Technical Expert
Jim Green	National Renewable Energy Laboratory	Researcher / Technical Expert
Hal Link	National Renewable Energy Laboratory	Researcher / Technical Expert
Brian Vick	USDA/Bushland	Technical Expert
Brent Summerville	Appalachian State Univ.	Technical Expert
Alex DePillis	Wisconsin Energy Office	State Energy Office / Consumer
Jennifer Harvey	NYSERDA	State Energy Office
Cassandra Kling	New Jersey BPU	State Energy Office
Dora Yen	California Energy Comm.	State Energy Office
Paul Gipe	California	Consumer
Mike Klemen	North Dakota	Consumer
Heather Rhoads Weaver	Washington	Consumer / AWEA
Mick Sagrillo	Wisconsin	Consumer
Brad Cochran	Colorado	Interested Party
Samit Sharma	Canada	CanWEA
Svend de Bruyn	Detronics	Canadian Industry

Other participants in the development of this proposed standard have included (as they were affiliated at the time of their involvement):

Mark Bastasch
Ralph Belden, Synergy Power
Michael Blair
David Blecker, Seventh Generation
Sandy Butterfield, NREL
Bob Clarke, Ventera Energy
Dean Davis, Windward Engineering
John Dunlop, AWEA

Henry DuPont, Lorax
Mike Gray, Gray Engineering
Jeffrey Haase, State of Minnesota
Tod Hanley, Bergey Windpower
Robert Hornung, CanWEA
Arlinda Huskey, NREL
Dale Jones, Geocorp
Dan Juhl, DanMar
Steve Kalland, NCSU
Peter Konesky, State of Nevada
Andy Kruse, Southwest Windpower
Jean-Daniel Langlios
Amy Legere, Southwest Windpower
Malcomb Lodge, Entegrity Wind
Charles Newcomb, Entegrity Wind
Chuck Maas
Dennis Makeperce, E.R.D.
Tom Maves, State of Ohio
Michael Mayhew
Richard Michaud, US-DOE
Jacques Michel, E.R.D.
Paul Migliore, NREL
Lawrence Mott, Earth Turbines
Jennifer Oliver, Southwest Windpower
Philippe Quinet
Doug Selsam, Selsam Engineering
David Sharman, Ampair / BWEA
Robert Sherwin, Vermont Wind Power Int'l
Larry Sherwood, IREC
P.V. Slooten
Eric Stephens
Brian Smith, NREL
Jeroen van Dam, NREL / UL
David VanLuvanee
Jane Weismann, IREC
Kyle Wetzel, Consultant
Sean Whittaker, CanWEA

AWEA Small Wind Turbine Performance and Safety Standard

Table of Contents

AWEA Small Wind Turbine Performance and Safety Standard

Draft Standard Version 6.1 for adoption by the SCC (Version: 2008 October 13)

1 General Information

1.1 Purpose

This standard was created by the small wind turbine industry, scientists, state officials, and consumers to provide consumers with realistic and comparable performance ratings and an assurance the small wind turbine products certified to this standard have been engineered to meet carefully considered standards for safety and operation. The goal of the standard is to provide consumers with a measure of confidence in the quality of small wind turbine products meeting this standard and an improved basis for comparing the performance of competing products.

1.2 Overview

1.2.1 This performance and safety standard provides a method for evaluation of wind turbine systems in terms of safety, reliability, power performance, and acoustic characteristics. This standard for small wind turbines is derived largely from existing international wind turbine standards developed under the auspices of the International Electrotechnical Commission (IEC). Specific departures from the IEC standards are provided to account for technical differences between large and small wind turbines, to streamline their use, and to present their results in a more consumer-friendly manner.

1.2.2 No indirect or secondary standards references are intended. Only standards directly referenced in this standard are embodied.

1.3 Scope

1.3.1 This standard generally applies to small wind turbines for both on-grid and off-grid applications.

1.3.2 This standard applies to wind turbines having a rotor swept area of 200 m2 or less. In a horizontal-axis wind turbine this equates to a rotor diameter of ~ 16 m (~ 52 ft)

1.3.3 A turbine system includes the wind turbine itself, the turbine controller, the inverter, if required, wiring and disconnects, and the installation and operation manual(s).

1.3.4 In cases where several variations of a turbine system are available, it is expected that a full evaluation would be performed on one of the most representative arrangements. Other variations, such as different power output forms, need only be evaluated or tested in the ways in which they are different from the base configuration. For example, a wind turbine available in both grid-intertie and battery charging versions would need separate performance tests if both versions were to be certified, but would not need a separate safety evaluation in most cases.

1.3.5 Except as noted in Sections 2.1.1, 4.2, 5.2.5, 5.2.6, and 6.1.7.1, towers and foundations are not part of the scope of this standard because it is assumed that conformance of the tower structure to the International Building Code, Uniform Building Code or their local equivalent will be required for a building permit.

1.4 Compliance

1.4.1 Certification to this standard shall be done by an independent certifying agency. Self-certification is not allowed.

1.4.2 It is the intent of this standard to allow test data from manufacturers, subject to review by the certifying agency.

1.4.3 Compliance with this standard for the purposes of advertising or program qualification, or any other purpose, is the responsibility of the manufacturer.

1.5 Definitions

1.5.1 Definitions contained in IEC 61400-121, ed.1 (Performance); IEC 61400-11 (Acoustic Noise); and IEC 61400-2, Ed. 2 (Design Requirements) are hereby incorporated by reference.

1.5.2 Additional Definitions

1.5.2.1 AWEA Rated Power: The wind turbine's power output at 11 m/s (24.6 mph) per the power curve from IEC 16400-121.

1.5.2.2 AWEA Rated Annual Energy: The calculated total energy that would be produced during a one-year period at an average wind speed of 5 m/s (11.2 mph), assuming a Rayleigh wind speed distribution, 100% availability, and the power curve derived from IEC 16400-121 (sea level normalized).

1.5.2.3 AWEA Rated Sound Level: The sound level that will not be exceeded 95% of the time, assuming an average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, 100% availability, and an observer location 60 m (~ 200 ft.) from the rotor center[1], calculated from IEC 61400-11 test results, except as modified in Section III of this Standard.

1.5.2.4 Cut-in Wind Speed: The lowest wind speed at which a wind

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[1] Appendix A contains guidance on obtaining sound levels for different observer locations and background sound levels.

turbine will begin to have power output[2].

1.5.2.5 Cut-out Wind Speed: The wind speed above which, due to control function, the wind turbine will have no power output.

1.5.2.6 Maximum Power: The maximum one-minute average power output a wind turbine in normal steady-state operation will produce (peak instantaneous power output can be higher).

1.5.2.7 Maximum Voltage: The maximum voltage the wind turbine will produce in operation including open circuit conditions.

1.5.2.8 Maximum Current(s): The maximum current(s) the wind turbine will produce on each side of the systems control or power conversion electronics.

1.5.2.9 Overspeed Control: The action of a control system, or part of such system, which prevents excessive rotor speed.

1.5.2.10 Power Form: Physical characteristics which describe the form in which power produced by the turbine is made deliverable to the load.

1.5.2.11 Rotor Swept Area: Projected area perpendicular to the wind direction swept by the wind turbine rotor in normal operation (un-furled position). If the rotor is ducted, the area inscribed by the ducting shall be included.

1.5.2.12 Turbulence Intensity: The standard deviation of 1-second wind speed data divided by the mean of 1-second wind speed data averaged over a period of 1-minute.

1.6 Units

1.6.1 The primary units shall be SI (metric). The inclusion of secondary units in the English system is recommended [e.g., 10 m/s (22.4 mph)].

1.7 Test Turbine and Electronics

1.7.1 Tested wind turbines and their associated electronics shall conform to the specific requirements of the governing IEC wind generator standard for each test, but incorporating any amendments contained in this standard.

2 Performance Testing

2.1 Wind turbine performance shall be tested and documented in a test report per the latest edition of IEC 61400-121, but incorporating the additional guidance provided in this section.

2.1.1 In Section 2.1, Wind Turbine Generator System: When characterizing performance, the wind turbine generator system shall include the following components, as appropriate: the turbine; turbine tower; turbine controller,

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[2] As determined per Section 2.1.6

regulator, or inverter; wiring between the turbine and the load; transformer; and dump load. Power shall be measured at the connection to the load such that the losses in the complete wind turbine system are included.

2.1.2 Battery banks are not considered to be part of the wind turbine system for battery-charging wind turbines, but they are considered to be part of the system for grid-connected wind turbines that incorporate a battery bank.

2.1.3 Also in Section 2.1, Wind Turbine Generator System: The wind turbine shall be connected to an electrical load that is representative of the load for which the turbine is designed.

2.1.4 Also in Section 2.1, Wind Turbine Generator System: The wind turbine shall be installed using the manufacturer's specified mounting system. If a wind turbine is not supplied with a specific mounting system, the generator should be mounted at a hub height of at least 10 meters.

2.1.5 The total wire run length, measured from the base of the tower, must be at least 8 rotor diameters and the wiring is to be sized per the manufacturer's installation instructions.

2.1.6 The cut-in wind speed is the first wind speed bin in the averaged power curve that is positive.

2.1.7 Also in Section 2.1, Wind Turbine Generator System: The voltage regulator in a battery-charging system shall be capable of maintaining voltage at the connection of the turbine to the batteries within 10% of 2.1 volts per cell for lead acid batteries over the full range of power output of the turbine. The 1-minute average of the load voltage must be within 5% of 2.1 volts per cell for lead acid batteries to be included in the usable data set.

2.1.8 In Section 2.2.1, Distance of meteorological mast: If it is more practical to mount the anemometer on a long boom that is connected to the turbine tower, a separate meteorological mast is not required. To minimize the potential for the wake from the anemometer, the wind vane and their mounting hardware to influence flow into a small rotor, all such components shall be located at least 3 meters away from any part of the rotor. In addition, the anemometer mounting should be configured to minimize its cross-sectional area above the level that is 1.5 rotor diameters below hub height.

2.1.9 In Section 3.1, Electric power: Turbine output power shall be measured at the connection to the load.

2.1.10 In Section 3: In addition to electric power, voltage at the connection to the load shall be measured to ensure compliance with the requirements listed below.

2.1.11 In Section 3.4, Air density: The air temperature sensor and the air pressure sensor shall be mounted such that they are at least 1.5 rotor diameters below hub height even if such mounting results in a location less than 10 m above ground level.

2.1.12 In Section 3.6, Wind turbine generator status: Monitoring of small wind turbine status is required only when the turbine controller provides an indication of turbine faults.

2.1.13 In Section 4.3, Data collection: Preprocessed data shall be of 1-minute duration. In Section 4.4, Data reduction: Select data sets shall be based on 1-minute periods.

2.1.14 In Section 4.6, Database: The database shall be considered complete when it has met the following criteria:

2.1.14.1 Each wind speed bin between 1 m/s below cut-in and 14 m/s shall contain a minimum of 10 minutes of sampled data.

2.1.14.2 The total database contains at least 60 hours of data with the small wind turbine operating within the wind speed range.

2.1.14.3 The database shall include 10 minutes of data for all wind speeds at least 5 m/s beyond the lowest wind speed at which power is within 95% of Maximum Power (or when sustained output is attained).

2.1.15 In Section 5.1, Data normalization: For turbines with passive power control such as furling or blade fluttering, the power curve shall be normalized using Equation 5 (wind speed adjustment), Equation 6 (power adjustment), or an alternate method. Documentation must be provided to justify the use of an alternate method.

2.1.16 In Section 5.3, Annual energy production (AEP): In cases where the small wind turbine does not shut down in high winds, AEP measured and AEP projected shall be calculated as though cut-out wind speed were the highest, filled wind speed bin or 25 m/s, whichever is greater.

2.1.17 In Section 6, Reporting format: In addition to the information listed in clause 6, the description of the wind turbine and the test set-up shall include:

2.1.17.1 wiring sizes, conductor material, types, lengths and connectors used to connect the wind turbine to the load;

2.1.17.2 measured resistance of wiring between the inverter and the load or between the turbine and the load if no inverter is used;

2.1.17.3 voltage setting(s) for any over or under-voltage protection devices that are part of the small wind turbine generator system;

2.1.17.4 nominal battery bank voltage (e.g., 12, 24, 48 volts);

2.1.17.5 battery bank size (i.e., amp-hour capacity), battery type and age; and

2.1.17.6 description including make, model, and specifications of the voltage regulation device used to maintain the battery bank voltage within specified limits.

2.2 The Performance Test Report shall include the turbulence intensity for each data set (sequential, unbroken, time series) so that the reviewers can pass judgment on the appropriateness of the test site.

3 Acoustic Sound Testing

3.1 Wind turbine sound levels shall be measured and reported in accordance with the latest edition of IEC 61400-11 2002-12, but incorporating the additional guidance provided in this section.

3.1.1 The averaging period shall be 10 second instead of 1 minute.

3.1.2 Measuring wind speed directly instead of deriving wind speed through power is the preferred method.

3.1.3 The method of bins shall be used to determine the sound pressure levels at integer wind speeds.

3.1.4 It shall be attempted to cover an as wide a wind speed range as possible, as long as the wind screen remains effective.

3.1.5 A description shall be provided of any obvious changes in sound at high wind speeds where overspeed protection becomes active (like furling, pitching or fluttering).

3.1.6 A tonality analysis is not required, but the presence of prominent tones shall be observed and reported.

4 Strength and Safety

4.1 Except as noted below, mechanical strength of the turbine system shall be assessed using either the simple equations in Section 7.4 of IEC61400-2 ed2 in combination with the safety factors in Section 7.8, or the aeroelastic modeling methods in the IEC standard. Evaluation of, as a minimum, the blade root, main shaft and the yaw axis (for horizontal axis wind turbines) shall be performed using the outcome of these equations. A quick check of the rest of the structure for obvious flaws or hazards shall be done and if judged needed, additional analysis may be required.

4.2 Variable speed wind turbines are generally known to avoid harmful dynamic interactions with towers. Single/dual speed wind turbines are generally known to have potentially harmful dynamic interactions with their towers. Therefore, in the case of single/dual speed wind turbines, such as those using either one or two induction generators, the wind turbine and tower(s) must be shown to avoid potentially harmful dynamic interactions. A variable speed wind turbine with dynamic interactions, arising for example from control functions, must also show that potentially harmful interactions are likewise avoided.

4.3 Other safety aspects of the turbine system shall be evaluated including:

4.3.1 procedures to be used to operate the turbine;

4.3.2 provisions to prevent dangerous operation in high wind;

4.3.3 methods available to slow or stop the turbine in an emergency or for maintenance;

4.3.4 adequacy of maintenance and component replacement provisions; and

4.3.5 susceptibility to harmful reduction of control function at the lowest claimed operating ambient temperature.

4.4 A Safety and Function Test shall be performed in accordance with Section 9.6 of IEC61400-2 ed2.

5 Duration Test

5.1 To establish a minimum threshold of reliability, a duration test shall be performed in accordance with the IEC 61400-2 ed.2 Section 9.4.

5.2 Changes and additional clarifications to this standard include:

5.2.1 The test shall continue for 2500 hours of power production.

5.2.2 The test must include at least 25 hours in wind speeds of 15 m/s (33.6 mph) and above.

5.2.3 Downtime and availability shall be reported and an availability of 90% is required.

5.2.4 Minor repairs are allowed, but must be reported.

5.2.5 If any major component such as blades, main shaft, generator, tower, controller, or inverter is replaced during the test, the test must be restarted.

5.2.6 The turbine and tower shall be observed for any tower dynamics problems during the duration test and the test report shall include a statement of the presence or absence of any observable problems

6 Reporting and Certification

6.1 The test report shall include the following information:

6.1.1 Summary Report, containing a power curve, an Annual Energy Production curve, and the measured sound pressure levels (Section 9.4 of IEC 61400-11 ed.2). The report is intended to be publicly available once approved by the certifying agency.

6.1.2 Performance Test Report

6.1.3 Acoustic Test Report

6.1.4 The AWEA Rated Annual Energy

6.1.5 The AWEA Rated Sound Level

6.1.6 The AWEA Rated Power, at 11 m/s (24.6 mph)

6.1.7 Wind Turbine Strength and Safety Report

6.1.8 The tower top design loads shall be reported

6.1.9 Duration Test Report

6.2 The manufacturers of certified wind turbines must abide by the labeling requirements of the certifying agency.

7 Labeling

7.1 The AWEA Rated Annual Energy (AWEA RAE) shall be stated in any label, product literature or advertising in which product specifications are provided.

7.1.1 The AWEA RAE shall be rounded to no more than 3 significant figures.

7.2 The manufacturer shall state the AWEA Rated Power if a rated power is specified.

7.3 The manufacturer shall state the AWEA Estimated Sound Level if a sound level is specified.

7.4 Other performance data recommended to be stated in specifications about the turbine are:

7.4.1 Cut-in Wind Speed

7.4.2 Cut-out Wind Speed

7.4.3 Maximum Power

7.4.4 Maximum Voltage

7.4.5 Maximum Current(s)

7.4.6 Overspeed Control

7.4.7 Power Form

8 Changes to Certified Products

8.1 It is anticipated that certified wind turbines will occasionally be changed to provide one form of improvement or another. In some cases such changes will require review by the certifying agency and possible changes to the certified product parameters. The following guidance is provided concerning when product changes will require certifying agency review:

8.1.1 Any changes to a certified wind turbine that will have the cumulative effect of reducing AWEA Rated Power or AWEA Rated Annual Energy by more than 10%, or that will raise the AWEA Rated Sound Level by more than 1 dBA will require retesting and recertification by the certifying agency. Only those characteristics of the wind turbine affected by the design change(s) would be reviewed again.

8.1.2 Any changes to a certified wind turbine that could reduce the strength and safety margins by 10%, or increase operating voltages or currents by 10%, will require resubmission of the Wind Turbine Strength and Safety Report and recertification by the certifying agency.

8.1.3 Any changes to a certified wind turbine that could materially affect the results of the Duration Test will require retesting, submission of a new Duration Test Report, and recertification by the certifying agency.

8.2 For the first two years after turbine certification the manufacturer is required to notify the certifying agency of all changes to the product, including hardware and software. The certifying agency will determine whether the need for retesting and additional review under the guidelines provided in Section 8.1.

8.3 The use of Engineering Change Orders or their equivalent is recommended.

9 References and Appendices

9.1 References

9.1.1 Evaluation Protocol for Small Wind Systems, Rev. 3. NREL internal document.

9.1.2 IEC 61400-121 Ed. 1, Wind Turbines – Part 121: Power performance measurement of grid connected wind turbines.

9.1.3 IEC 61400-11, Second Edition 2002-12, Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

9.1.4 IEC 61400-2, Ed. 2, Wind turbine generator systems – Part 2: Design requirements of small wind systems.

Appendix A

Sound Levels for Different Observer Locations and Background Sound Levels

The AWEA Rated Sound Level is calculated at a distance of 60 meters from the rotor hub and excludes any contribution of background sound. As the distance from the turbine increases, the background sound becomes more dominant in determining the overall sound level (turbine plus background).

Background sound levels depend greatly on the location and presence of roads, trees, and other sound sources. Typical background sound levels range from 35dBA (quiet) to 50dB(A) (urban setting)

Equation 1 can be used to calculate the contribution of the turbine to the overall sound level using the AWEA Rated Sound Level. Equation 2 can be used to add the turbine sound level to the background sound level to obtain the overall sound level.

$$turbine\ \ sound\ \ level = L_{SWCC} + 10\log(4\pi 60^2) - 10\log\left(4\pi R^2\right) \qquad (1)$$

Where:
L_{AWEA} is the SWW Rated Sound Level [dBA].
R is the observer distance from the turbine rotor center [m]

$$overall\ sound\ level = 10\log(10^{\frac{turbine\ level}{10}} + 10^{\frac{background\ level}{10}}) \qquad (2)$$

Table 1 Overall Sound Levels at Different Locations for a AWEA Rated Sound Level of 40 dBA

Distance from rotor center [m]	L_{AWEA}: 40dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	55.6	55.6	55.7	55.9	56.6
20	49.6	49.7	50.0	50.9	52.8
30	46.1	46.4	47.0	48.6	51.5
40	43.7	44.1	45.1	47.3	50.9
50	41.9	42.4	43.9	46.6	50.6
60	40.4	41.2	43.0	46.2	50.4
70	39.2	40.2	42.4	45.9	50.3
80	38.2	39.4	41.9	45.7	50.2
100	36.6	38.3	41.3	45.5	50.2
150	34.1	36.8	40.6	45.2	50.1
200	32.8	36.1	40.4	45.1	50.0

Table 2 Overall Sound Levels at Different Locations for a AWEA Rated Sound Level of 45 dBA

Distance from rotor center [m]	L_{AWEA}: 45dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	60.6	60.6	60.6	60.7	60.9
20	54.6	54.6	54.7	55.0	55.9
30	51.1	51.1	51.4	52.0	53.6
40	48.6	48.7	49.1	50.1	52.3
50	46.7	46.9	47.4	48.9	51.6
60	45.1	45.4	46.2	48.0	51.2
70	43.8	44.2	45.2	47.4	50.9

80	42.7	43.2	44.4	46.9	50.7
100	40.9	41.6	43.3	46.3	50.5
150	37.8	39.1	41.8	45.6	50.2
200	35.9	37.8	41.1	45.4	50.1

Table 3 Overall Sound Levels at Different Locations for a AWEA Rated Sound Level of 50 dBA

Distance from rotor center [m]	L_{AWEA}: 50dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	65.6	65.6	65.6	65.6	65.7
20	59.5	59.6	59.6	59.7	60.0
30	56.0	56.1	56.1	56.4	57.0
40	53.5	53.6	53.7	54.1	55.1
50	51.6	51.7	51.9	52.4	53.9
60	50.0	50.1	50.4	51.2	53.0
70	48.7	48.8	49.2	50.2	52.4
80	47.6	47.7	48.2	49.4	51.9
100	45.7	45.9	46.6	48.3	51.3
150	42.3	42.8	44.1	46.8	50.6
200	40.0	40.9	42.8	46.1	50.4

Table 4 Overall Sound Levels at Different Locations for a AWEA Rated Sound Level of 55 dBA

Distance from rotor center [m]	L_{AWEA}: 55dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	70.6	70.6	70.6	70.6	70.6
20	64.5	64.5	64.6	64.6	64.7
30	61.0	61.0	61.1	61.1	61.4
40	58.5	58.5	58.6	58.7	59.1
50	56.6	56.6	56.7	56.9	57.4
60	55.0	55.0	55.1	55.4	56.2
70	53.7	53.7	53.8	54.2	55.2
80	52.5	52.6	52.7	53.2	54.4
100	50.6	50.7	50.9	51.6	53.3
150	47.1	47.3	47.8	49.1	51.8
200	44.7	45.0	45.9	47.8	51.1

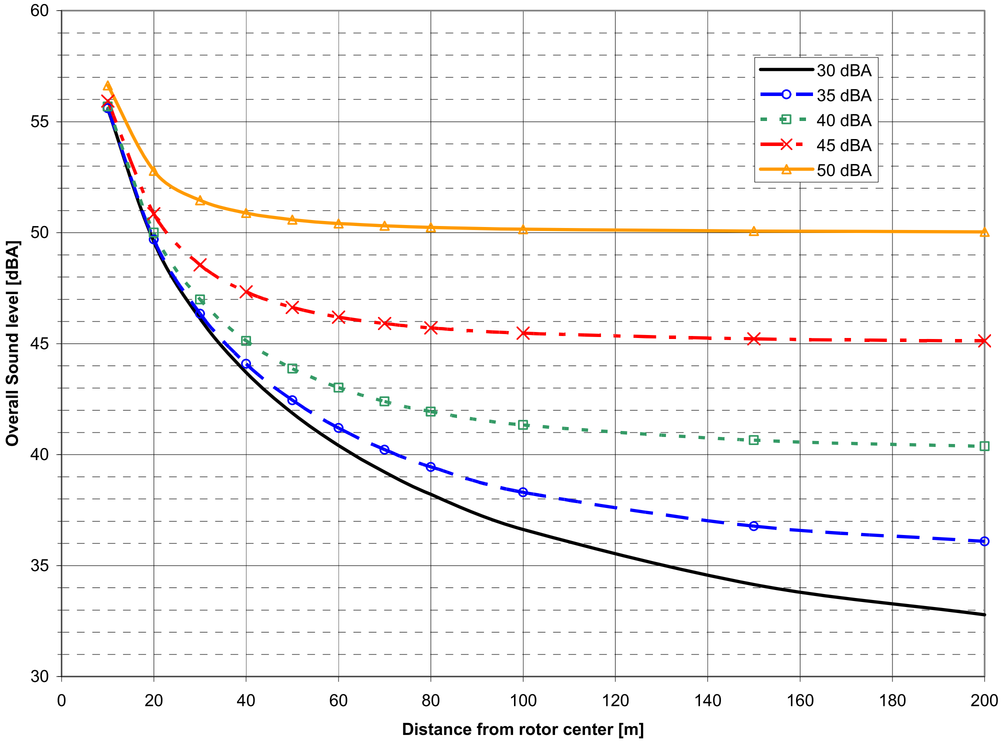

Figure 1. Sound levels as a function of distance and background noise levels for AWEA rated sound level of 40dB(A)

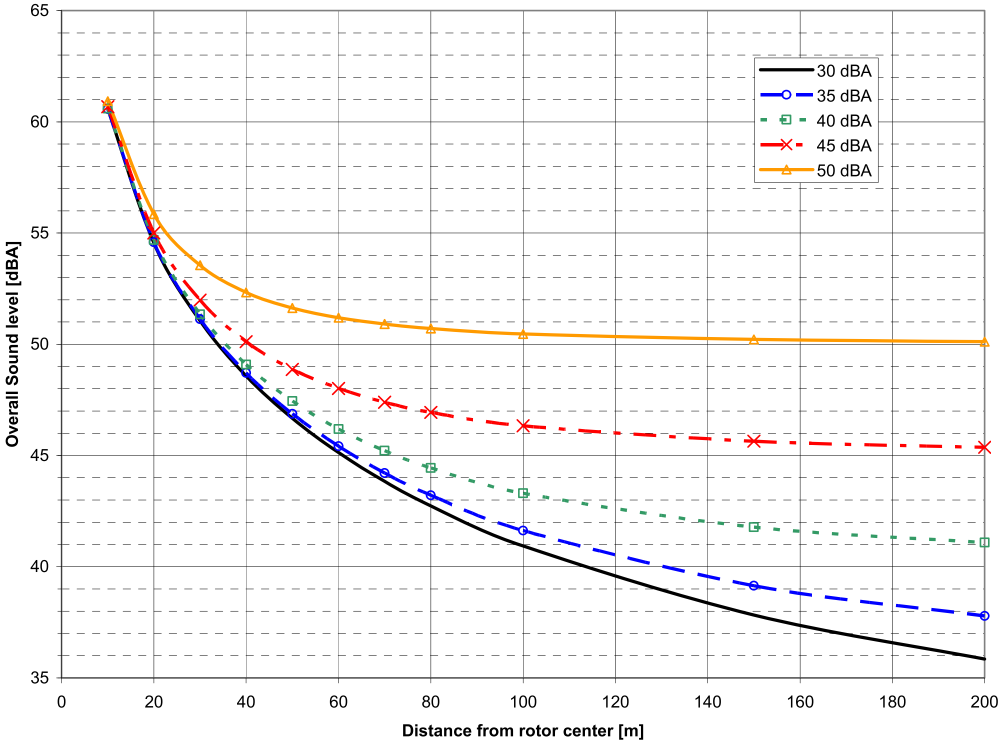

Figure 2 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 45dB(A)

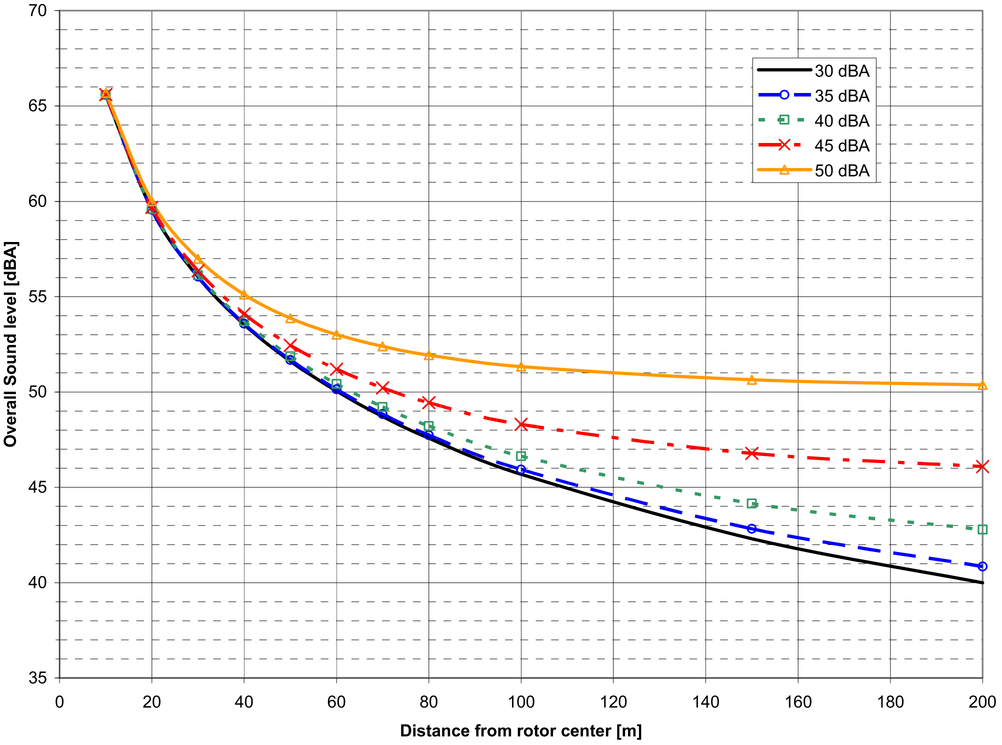

Figure 3 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 50dB(A)

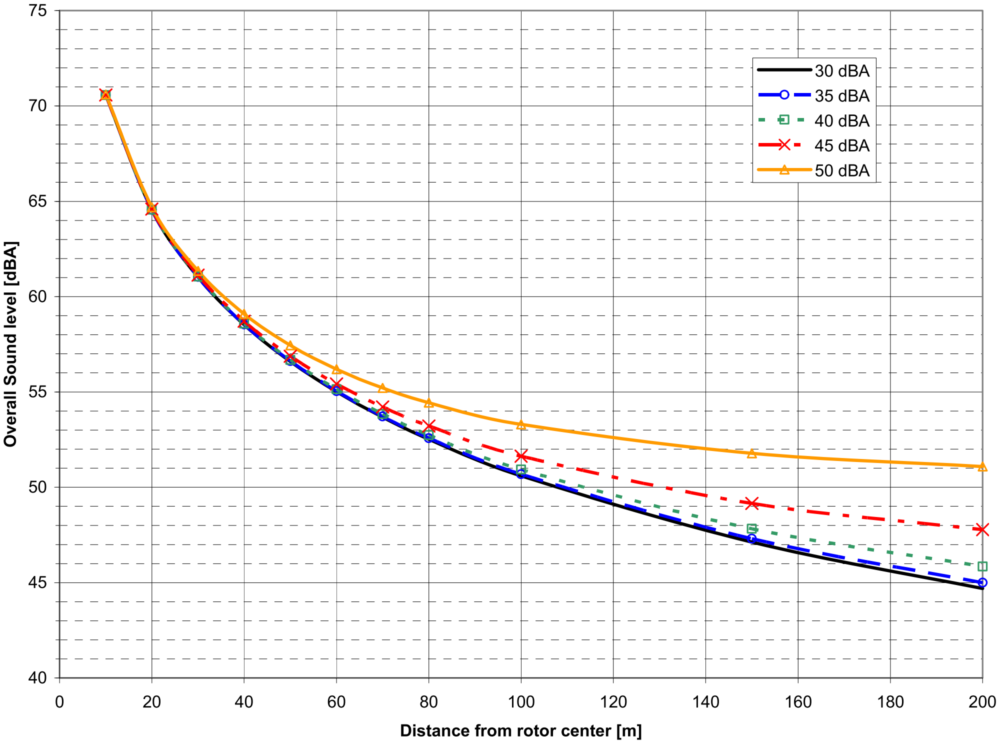

Figure 4 Sound levels as a function of distance and background noise levels for AWEA rated sound level of 55dB(A)