AMENDED
Contract No. R007-015
"Dakota Turbines"
Submitted by Posi Lock Puller, Inc.
Principal Investigator: Cris Somerville

PARTICIPANTS

Sponsor	Cost Share
Posi Lock Puller, Inc./Dakota Turbines LLC	$288,522
Posi Lock Puller, Inc./Dakota Turbines LLC	$140,000 (in-kind)
North Dakota Industrial Commission	$285,373
Total Project Cost	$713,895

Project Schedule – 18 months
Contract Date – December 29, 2009
Start Date – January 1, 2010
Completion Date – December 31, 2013

Project Deliverables:
Quarterly Report: March 31, 2010 √
Quarterly Report: June 30, 2010 √
Quarterly Report: October 31, 2010 √
Quarterly Report: December 31, 2010 √
Quarterly Report: March 31, 2011 √
Quarterly Report: June 30, 2011√
Quarterly Report: September 30, 2011 √
Quarterly Report: December 31, 2011 √
Quarterly Report: March 31, 2012 (waived)
Quarterly Report: June 30, 2012 √
Quarterly Report - September 30, 2012 √
Quarterly Report - December 31, 2012 √
Final Report: December 31, 2013 √

OBJECTIVE/STATEMENT OF WORK:
This project is to create the most reliable, cost-effective and most efficient small wind turbine on the market and is scalable from 5 – 100 kW. Small wind turbines range up to 100 kW. The design includes several unique features that will allow the turbine to generate energy at speeds that aren't productive today. Their patent-pending "Sliding Stator Technology" provides a load management system that allows for the independent control of the level of generation. Individual coils are customizable and replaceable. It will also have large turbine features such as pitchable blades, active yaw, and computer controls. These features will produce a small wind turbine that has a payback period for the consumer of less than 10 years. Currently, the standard payable period is 25 years.

STATUS
Contract executed. Work is beginning on the project.

April, 2010 – The first quarterly report has been received. During this quarter Dakota Turbines developed a test sled to assist them with the testing of their small wind turbines. During this time the company has implemented and/or verified changes that needed to be made on the turbine. They have identified the blade design they will use going forward. Improvements have been made to the blade mounting system. The coils have now been designed and should increase the electrical output system. During this time period they have also made progress with their Sliding Stator Technology Patent. The inverter control system has been converted to a single solid state board, has been tested and is fully functional and being used in all the final testing processes. The optimization process is complete except for the upper power levels. These issues are being worked on with the respective vendors. The project has fallen behind the projected time schedule but significant progress was made during the January – March 31, 2010 time period.

July, 2010 – The second quarterly report has been received. During this time period, April 1, 2010 through June 30, 2010 Dakota Turbines redesigned the turbine to be all aluminum with the exception of the magnets and the magnet plates. The physical, mechanical re-design of the turbine is complete with virtually all components ordered and the majority in-house. The turbine control boards are currently undergoing "function" tests via software programs. They have overcome the component failure problems on the upper power range on the inverter. Some of the changes that have had to be made will, as it turns out, result in savings to the total cost of the inverter. Progress has also been made to getting the inverter UL certified.

October, 2010 – The third quarterly report has been received. During this time period, July 1, 2010 through September 30, 2010 Dakota Turbines faced a number of challenges which resulted in making design, layout and materials changes which would allow them to obtain a UL Certification. These developmental issues have resulted in very significant improvements to both the turbine and inverter. Originally this project was focused on the development of a 30kW +/- system. With the changes made during this time period Dakota Turbines is now anticipating a 40kW +/- system. It is anticipated that during the next quarter the actual testing of the turbine and inverter will begin.

December, 2010 – The fourth quarterly report has been received. During this time period, October 1, 2010 through December 30, 2010 Dakota Turbines resolved two questions regarding the turbine. The new coils were tested and performed as the simulation software had projected. Testing under real world conditions also confirmed that these coils will be used in the NexGen turbine. In regards to the new longer blade design, testing showed more power per mph of wind speed, however the deflection was more than expected. Dakota Turbines has identified the steps needed to resolve the deflection issue. Dakota Turbine stated the NexGen turbine is near completion; the control board and related software is near completion and the physical control panel is being assembled into a metal enclosure which will reside on the turbine and the NexGen tower is in place and complete. Considerable work was completed on the inverter and is now fully functional and encased in a production grade enclosure. Dakota Turbines states: "At the start of this project our goal was to make the most efficient wind turbine on the market. Using the information in the database dated Aug. 2010, it appears we have already accomplished that goal."

April, 2011 – The fifth quarterly report has been received. During this time period, January 1, 2011 through March 31, 2011 Dakota Turbines tested its turbine system and found that they need to reposition and angle the blade mounting hardware in the blade mold. This will take some time to implement and result in a new set of blades. In regards to the inverter control software the final optimization must be done with the turbine flying. While they are waiting for the turbine system to be redone, the Contractor will work on improving the potential output throughout the entire range of rpm's. After a talk-through with the UL officials, UL decided that the wire used to monitor heat sensors in the turbine coils and various components throughout the inverter should be rated to 600 volts. This will require wiring to be changed in the epoxy of the turbine coils and several of the major components of the inverter. The Contractor writes:

"We find ourselves again waiting for components to meet UL requirements. We anticipate the wire and components to meet UL standards to arrive sometime in early May. We also hope the blades will be available in about the same time frame. If both happen in a timely manner, we will have a fully functional turbine system flying by the end of the grant period. The data collection hardware and software for the SWCC process is in-house. The anemometer, wind vane and environmental sensors will not be ordered until we are literally ready to start testing as they require recertification on a calendar year basis. The hardware that monitors the turbine output is in-house and we will be utilizing htat as part of our test sled operations. Connecting the wind and environmental sensors is pretty much "plug-n-play", so we should be ready to start the SWCC process with little additional effort when we get to that point in time. We are especially disappointed this quarter, in as much as we were hoping to be able to offer preliminary documentation of the efficiencies of our turbine system. We have snapshots of data from both the test bed and the previous turbine giving proof of what is possible. Comparing that projected data against everyone else's projected data, gives us confidence as to how we will compare to the competition. But with the SWCC protocols now in place, we would prefer to use those standards by which to make our first official announcement of our power curve and turbine efficiencies. If the new blades arrive in a timely manner, the final report will give proof that you have helped fund the most efficient small wind turbine on the market in our size range."

July, 2011 – The sixth quarterly report has been received. During this time period, April 1, 2011 through June 30, 2011 the Contractor's blade manufacturer determined he would not be able to change the mounting system on the Contractor's current blade design to address the tendency for it to pitch to the run position at higher rpm's. With the help of the Contractor the blade manufacturer's new blade mold is nearing completion and the Contractor hopes to receive the new blades sometime in August.

In regards to the inverter all the components with the 600 volt sensor wire are now installed. A variable speed controller has been added to the pump and the software and control module can now more accurately control not only the coal plates and oil bath temperatures.

The report concludes: "The failure of our fail safe system enlightened us to the considerable forces that can result from the position and relative angle of the blade mounting system. We installed a pressure sensor and have done considerable testing with our current blades to provide the data needed to determine what even minute changes to the mounting criterion can make on the blade twist forces caused by the lift experienced by the blade as it cuts through the air. This testing will allow us to build our new blade with a slight positive pressure to insure our fail safe system is in fact, fail safe by design. As with the many of the disappointments/issues we have had along the way in the development of this system, the failure of the fail safe system has turned into positive as we have gained an understanding of the factors involved. Not only will we have a fail safe system that we have knowledge of, and a confidence in its functionality, we will have eliminated the chance of exerting un-needed stresses on the pitch system over the long term.

The Industrial Commission, upon the recommendation of the Renewable Energy Council, granted additional funding in the amount of $106,873 and granted a one-year extension for completion of the project.

October, 2011 – The seventh quarterly report has been received. During this time period, July 1, 2011 through September 30, 2011 Dakota Turbines tested the new blades. In their report they state, "The new blades we were expecting in August arrived the 26th of September. After balancing to within a few hundredths of a pound both side to side and by tip weight, we eagerly mounted the blades and flew them. The first two days we had very little wind to work with, but were simply amazed at the power we were able to extract, and their forgiveness to both pitch and yaw routines. The third day we had enough wind to test our controlled and emergency/fail safe shut-down routines. When we pulled the disconnect, simulating the loss of the grid, the turbine went from 100 rpm's to an almost complete stop in 3 seconds. The wider blades obviously provided a much better braking system than had our previous blades which would coast to a stop over about 10 seconds. The sudden change in direction of the forces during that quick shut down made for some interesting oscillations of the turbine atop the tower. Although nothing dangerous to either the turbine or the tower, there is no need to dissipate all the torque involved within such a short period of time.

"We again measured the forces created by the angle of our mounting shaft in relation to the axis of the blade. We had created a positive pressure toward pitching to park as we had intended, thus making our fail safe system – fail safe again. We had however slightly over-shot on the side of caution, causing more pressure than needed. In designing the mold, the bracket that positions the mounting tube was made to be moveable to allow for us to fine tune the angle as necessary. We will continue to experiment and will have enough information to be able to make the next set of blades exert whatever pressures we deem necessary."

"Conclusion – Our unique passive fail safe system is once again fail safe. The positive pressure created by the blades under all run conditions, assures that the coil springs will return the blades to park unless everything is in a "powered on" and controlled situation. The current set of blades exerts a little more positive pressure than we think is required, but is well within a comfortable operating range of the pitch motor. We need to slow the controlled and emergency park speeds, but are otherwise excited to see what the new blades can do. The few days we have had to run them gives indication that they will meet and maybe even exceed our expectations."

January, 2012 – The eighth quarterly report has been received. During this time period, October 1, 2011 through December 31, 2011 Dakota Turbines received UL field certification. Dakota Turbines stated in their report: "Having received the field certification, we now will have to build and send a couple inverters to the UL labs for what they call their "destructive tests." They will purposely short circuit or otherwise cause the inverters to fail in 4 to 6 "events". Upon completion of those tests, the inverter will receive a UL 1741 listing. To complete the UL 6142 process would involve another UL visit to our shop with a turbine and adjacent inverter on our test stand. If all that goes well, we would then receive a UL 6142 listing of the tower, turbine and inverter as a system. As of now, we are the first turbine manufacturer to pursue this designation."

Dakota Turbines concludes in their report: "Our optimization of the pitch routine is now to control that rotational power within our generation output and rotor speed limits. Realizing early on in the testing of the blades that control would be an issue, we spent considerable time this quarter making sure our over-speed and emergency shutdown routines were rock solid. We fully realize that by the time we have our pitch algorithms finalized, we will have a well-tested over speed shutdown system".

A waiver was granted for the submission of a report for the first quarter of 2012

July, 2012 - The next report has been submitted for the period January 1, 2012 - June 30, 2012. The full report is available in the Commission files. Dakota Turbines states in the conclusion of this report: "As with every quarter before, this quarter is a mixture of setbacks and successes. The loss of a supply of the current blade design will not affect our going to market in 2013, but it has pushed back the AWE/SWCC certification process a year, and has considerably muddied the UL listing processes. Although this will involve a new blade itself, with the modern software available, the blade will be designed and tested to be within our parameters before it even leaves the drawing board. Although it will have its own specific characteristics that will change the startup routine and power curve settings slightly, these are simply tweaks that could even be adjusted at the customer's site, right from our offices.

The two major issues are not being able to have 3rd party verifiable production numbers available to the consumer, through the AWEA/SWCC testing and verification process, for marketing toward the 2014 production year. And determining the most efficient and cost effective means of achieving a UL listing between now and the 2013 construction season.

We believe there to be an existing relatively local demand to purchase a limited run of turbine systems for the 2013 season. The actual installation of these turbines would also provide an opportunity to train certified installers that would then be responsible for installation of our systems into the future. Other than the required electrician to connect our inverter to the grid, the rest of the system is plug-and-play simple to install. We would, however, like to give someone from each company a more detailed understanding of the inverter and turbine systems to be able to make any minor repairs in the field requiring only phone or computer related support.

November, 2012 - The next report has been submitted for the period July 1 - September 30, 2012. The full report is available in the Commission files. Dakota Turbines states in the conclusion of this report: "With only one quarter left in our Project time frame, we are not going to meet either of the two major goals we had set out to achieve on the front end of this effort. The Small Wind Certification of the entire system, and the UL listing of the inverter. We have been running behind schedule since the ink first dried on our contract with the Renewable Energy Council. Even with the major design and production layouts in place, the details of solving the small issues within several of the processes took way more time than anticipated. We wound up having to take the manufacture of major components in-house to solve problems in a few instances. The coils for the turbine itself, and the whole control module and driver software for the inverter, were the two primary efforts that used large amounts of time and effort. The coils we needed for the turbine were said to be impossible to build, so we wound up doing it ourselves. And if we had continued to utilize the off the shelf control module we had anticipated using, we would be stranded at the point everyone else is at, instead of having a 96% efficient inverter.

Even though we will not achieve two of our goals within the grant period, we have exceeded our "Primary Objective" as stated in the grant application. It was our objective to create a turbine system with a payback period of under 10 years. Using the same criterion as were in place at the time of the application, including the price of $.07, our projected payback period is under 9 years. If you use the current price of $.92, our payback is under 7 years.

March, 2013 - The next report has been submitted for the period October 1, 2012 - December 31, 2012. The report states:

Overview:

Last quarter we reported on significant progress in the optimization of the control software throughout the wind regime. All these changes, whether to the power curve, the pitch algorithms, or timing and degrees of pitch can all now be made from the office. The new Windows based monitoring software is a major step forward in functionality from the earlier version. With the same database capabilities as we had before, we can verify the effects of any changes we make to the control software. This process is ongoing, and will be well into the future.

We reported last quarter that the passive brake on our yaw system failed to make any significant difference toward solving our tail wag issue. We installed and tested an active brake system this quarter, the results of which are reported below.

We also reported unexpected IGBT failures last quarter, under very low power conditions. The suspected cause of those failures was addressed and proved to be a fix for that issue. Also detailed below.

The Turbine:

We installed an active yaw brake that releases to yaw and then locks the turbine to the tower when not moving. This allows us to transmit the tail wag twisting motion we experience under certain conditions from the yaw gears to the tower as a whole. This will take considerable stress off the yaw system, but does not solve the tail wag problem itself. Although there is considerable literature on the study of the causes of the quick twisting motions we call tail wag, there are no definitive solutions for the problem that affects all up-wind turbines. With new blades coming in the near future, we are simply going to wait and see what difference they make before trying any further modifications.

Other than the installation of the brake system, the only efforts towards the turbine have been the continuation of the optimization of the control software. As this process continues to evolve, the actual operation of the turbine, especially in the upper wind speeds, becomes increasing smooth. The larger pitch changes that once caused considerable changes in the force of the wind on the turbine and tower, are now smaller, quicker, and more in tune with the variability of the wind itself. As we continue this optimization process, not only will we increase the kW output of the turbine, but we will significantly decrease the stresses put on the whole system as we more closely follow the changes in the wind itself.

The Inverter:

Last quarter we had identified a theory as to why we suddenly blew IGBT's under light wind and output conditions. The theory proved to be correct, and the new bus bars did in fact provide a solution to the problem. As with seemingly every other change we have made, this improvement also came with a problem of its' own. Fortunately the issue was very minor, easily identified, and quickly fixed. This has been the only change or fix done to the inverter in several months.

Conclusion:
After a yearlong shake down process, the two problems identified above are the only significant changes made. With the control software optimization to date, we now comfortably and smoothly ride through the 20/30 mph gusty winds that used to buffet the turbine and tower. When the new blades arrive we anticipate a short and easy adaptation to any minor software controls that might be required. At that point in time we can move forward on both the UL and SWCC fronts.

The completion of this project is on hold until work can be done with the new blades.

Final Report received 4/4/2016. It states in part:

Original Objective/Statement of Work:
This project is to create the most reliable, cost-effective and most efficient small wind turbine on the market and is scalable from 5 – 100 kW. Small wind turbines range up to 100 kW. The design includes several unique features that will allow the turbine to generate energy at speeds that aren't productive today. Their patent-pending "Sliding Stator Technology" provides a load management system that allows for the independent control of the level of generation. Individual coils are customizable and replaceable. It will also have large turbine features such as pitchable blades, active yaw, and computer controls. These features will produce a small wind turbine that has a payback period for the consumer of less than 10 years. Currently, the standard payable period is 25 years.

There were 3 main tasks associated with the project:

1. Duration and stress testing of the existing turbine.
2. Update of major physical components.
3. Software and control hardware configurations.

Results:
First, the project has been officially been given a new name: Dakota Turbines. Today Dakota Turbines has far surpassed the original objectives of the project. I will address each one individually and then expand on the more-recent accomplishments. These 3 issues are what the grant dollars helped fund.

1) Duration and Stress Testing
Our system has been formally tested by a Professional Engineer, pursuant to the AWEA 9.1 (Small Wind Certification) specifications for structural analysis. This analysis includes both instantaneous strain and long-duration fatigue testing. There were several points of concern as a result of the initial testing, and quick/simple remedies were executed. The system as it is now has passed structural analysis and we have the PE-Stamped verification to satisfy the Small Wind Certification efforts.

2) Many updates have been carried out. Some minor physical upgrades were a result of the Structural Analysis performed as already mentioned. Other improvements have been made such as:

- Integrated and more-robust yaw drive system
- Improved coatings for better corrosion protection
- Upgrade to ultrasonic wind instrument for more-reliable performance
- Modifications to allow better access to equipment by service personnel

3) Software and control measures, and their associated hardware components, have also undergone several updates. All control algorithms that control turbine functions and inverter power conversions have been streamlined for better performance, yet simpler in design (lay-out). Inverter issues such as

'stray inductance' within the DC Bus system and bridge-rectifier cooling have been discovered and remedied.

Additional Results:
In addition, we have made advances beyond our original scope of work. These are beyond the original grant project and no grant dollars were spent on these more-recent accomplishments. Some more prominent examples are:

- New remote-monitoring and user-interface software. We have all of our machines networked to our server computer in our office. This monitoring system watches and logs all of the data from all system continuously. If something doesn't seem right, the server system will contact service personnel to investigate. The user-interface software is more advanced and is how our customers can monitor their system performance from the internet. They can run production reports from this platform without taking manual production readings at the site.

- We have developed creative loading algorithms that have eliminated the need for the original 'Sliding Stator' technology. The system is mechanically simpler and less-expensive to produce, while achieving the same goal of super-efficiency and excellent low-wind performance. The Patented Sliding Stator technology still has value as potential solutions for both alternators and motors.

- We have received a patent for our unique blade-pitching system. This innovation is our most highly-prized feature. It has proven itself to be ultra-reliable, having never failed in any of our machines. The system ALWAYS safely parks the turbine, gently shutting the system down, in any fault scenario encountered. It is mechanically very simple and is inexpensive to produce. For this reason, Dakota Turbines can offer a small wind machine with 'large wind' features and benefits.

- We now have 2 additional Patents Pending. One is for our unique inverter cooling system, that utilizes a vertical geo-thermal well to use the earth as a heat-sink. This is in contrast to competitors' inverters that are air-cooled, forcing dirty, humid air into their electronics enclosures and through/around the sensitive electronics.

The other Patent Pending is for our revolutionary stator-coil winding technique. Early in our project, we encountered a phenomenon called 'Eddy Current Losses' which is something that can occur in permanent-magnet alternators like ours. These losses are inherent to the winding design and cannot be avoided without a new winding technique that specifically addresses this issue. Nothing on the market, either products or techniques, could solve this for us. So we developed our own winding product and technique that involves using many small wires in parallel, bonded into a flat ribbon and wound-up over a core plug to form the coils. As it turns out, this method is something revolutionary to the winding industry and unique enough to file for a Patent.

- We have developed manufacturing and assembly processes for the entire wind turbine system. Since we manufacture and assemble all of the major design components (turbine, blades, alternators, inverters, etc) this has been a major task. Many manufacturing processes, like the Patent-Pending coil winding previously mentioned, have required innovating completely new techniques and products. Our blade manufacturing area has gone through two major 'resets' since we have moved from our original blade design to a new, highly-improved one. This change required a complete re-tooling of the manufacturing processes.

- Our RPM and Yaw-Position sensing systems have been improved. We have updated the systems to using the most reliable sensing technology available. We use contactless magnetic encoders for the Yaw sensing, which have reliability and robustness advantages over other encoder styles. Our

RPM sensors are now induction-style proximity switches which have immunity to electrical noise and mechanical vibrations. The changes have required PCB (Printed Circuit Board) revisions to accommodate the new technology.

- Our inverter is fully-listed to the UL1741 standard. It also is certified for use in Canada.

Sales and Marketing:
We currently have 40 turbines in operation, sold and installed mostly between 2014 and 2015. These are spread-out among six states: Colorado, Kansas, Nebraska, Iowa, Minnesota and North Dakota. Sales continue to come in but are slowing due to the depressed agriculture economy right now. To combat this, Dakota Turbines is investigating creative financing solutions to help customers with the up-front capital investment. We are also looking at ways to reduce our LCOE (Levelized Cost of Equipment). Currently, our small wind industry in our class-size averages $0.16 per kwh, and Dakota Turbines stands at approximately $0.12 per kwh. So we are doing very well to offer an advanced wind turbine with modern features, and coming closer to parity with conventional sources of electricity. As our industry matures and volumes increase, our LCOE will continue to fall amidst rising utility-power prices. Renewable energy is truly on the verge of mainstreaming. This is proven by the advances that the solar industry has made in recent years. The high-volume manufacturing advantages coupled with new and innovative financing packages have caused an industry boom for solar. The same can happen with wind, if Federal and State incentives remain long-enough for our industry to develop a strong foundation and get sales volumes up to drive the costs down further.

Employment and Local Economic Impact:
The Dakota Turbines team currently includes 10 full-time employees. These are good-paying and high-skilled jobs ranging from manufacturing technicians to electrical engineers. Our annual payroll for 2015 alone was $470,000. In 2015 we spent $1,150,000 on COGS (inventory) and $2,000,000 on other expenses (operating, R&D, ETC). The beneficiaries of these expenses are mostly local suppliers of goods and services to Dakota Turbines. This directly benefits the local economy, creating and maintaining many other jobs outside of the Dakota Turbines company.

Any Next Steps:
Next steps in the evolution of Dakota Turbines will be to roll-out new and innovative financing packages to make investments in our equipment even more affordable. Our marketing area needs to grow beyond the Upper-Midwest. We are becoming very active as industry advocates, especially working closely with DWEA, the Distributed Wind Energy Association. We will be working with DWEA and other industry advocates to push for Federal and State policies that are friendly to Distributed Wind. Although we are already among the least-expensive small turbines when comparing the LCOE in our size class, we and other manufacturers in our industry are pushing very hard for further reductions. We need to certify to the new UL6142 standard for small wind systems, just as all of the other manufacturers are working on now. We have plans for more product options such as 3-phase inverters, and one-day we would like to have other sizes of wind turbines available. Also, we want to integrate hybrid technology, incorporating solar and/or energy storage into our small wind systems.

Final Thoughts:
Dakota Turbines has come a long, long ways in the last few years. We did not realize how long and difficult a project like this would be at the on-set. Developing a small wind turbine is equivalent to designing an automobile to travel 150,000 miles per year, for at least 20 years. And it must do so with minimal maintenance. It must withstand all of the challenges that Mother Nature can produce. We are confident in our design, that it is robust and efficient just as we intended. We have produced numerous novel design elements that have resulted in 2 patents and 2 more patents pending. Our goal of growing

the company to need high-skilled employees and becoming a major contributor to our local economy is being realized.

We will never forget the investment that the ND Industrial Commission and Renewable Energy Council have made in our venture. I hope that we have demonstrated a huge success for these grant dollars. I also hope that the tax-payers of this great State see that the investment has already been returned many times by way of our economic impact and investment in our local economy. Again, thank you for your confidence in us. We may not have reached success without your help during the most critical stages of our development.

Updated 12/31/2016