Final Technical Report

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Working Partners:

- C. T. Taylor Company, Inc.
- Lake Erie Electrical
- URS
- Stevens Engineers & Constructors
- Astro Manufacturing
- I.A. Lewin Structural Engineering
- MAGNET
- Ohio State University

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Disclaimer:

Any findings, opinions, and conclusions or recommendations expressed in this report are those of the author (Majid Rashidi, Ph.D., P.E.) and do not necessarily reflect the views of the Department of Energy.

Proprietary Data Notice:

This report does not include any protected data. This project has resulted in four US patents, all in print; no patentable material is disclosed in this report.

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Executive Summary:

Wind is as low energy density resource. A typical 225 KW wind turbine, with a blade swept diameter of about 81 feet, should operate for about 15 minutes under a sustain wind speed of about 17 mil/hr to produce the same amount of energy contained in one gallon of gasoline. Considering the concrete foundation, mast, blade components, gearbox, and the electric generator of this wind turbine and comparing these massive elements with a plastic container that stores one gallon of gasoline reveals the fact that wind is a low energy density resource.

The wind power captured by a turbine is proportional to the 2nd exponent of its blade radius; at the same time, it is proportional to the 3rd exponent of the wind speed. The primary goal of this project has been to design and develop an innovative wind tower system that capitalizes on the dependency of the captured wind power to the cubic exponent of the wind velocity for a selected wind turbine. The stage-gate process used in this project includes the following steps:

- Proposed an innovative wind tower system with an axisymmetric wind deflecting structure. Symmetrically mount plurality of rooftop size wind turbines near the axisymmetric structure. The purpose of the wind deflecting structure is to increase the ambient wind speed that in turn results in an overall increase in the power capacity of the wind turbines. The wind turbines are arranged along two symmetric columns, mounted diametrically opposite of each other, around and near the exterior surface of the axisymmetric structure.
- A conceptual model was considered, with four turbines, two on each side of the cylinder. Each turbine diameter was set to be about 7 feet. The cylindrical wind deflecting structure was designed to be 24 feet.
- Computation Fluid Dynamic Analysis was used to simulate the wind flow near and around the wind deflecting structure. The results of CFD validated the original hypothesis about wind speed amplification near the exterior surface of the wind deflecting structure. An overall average wind-speed-amplification-factor of 1.6 was predicted by the CFD analysis across the swept area of the wind turbine.

Executive Summary (Continue)

- The next step was to build and test a scaled-down table-top model of the system to experimentally validate the results predicted by CFD analysis. The test results of this step validated the results of the CFD analysis.
- The next step was to fabricate, install, and test a full scale wind tower system having a cylindrical wind deflecting structure. The system was fabricated with 4 turbines, each at 1.65 KW name-plate-rating. The system has actively controlled yaw mechanism. The full scale wind tower was installed on the rooftop of a five story high building on Cleveland State University Campus. A fifth turbine, similar to the four turbines installed on the fabricated tower, was installed on the same rooftop. The purpose of this fifth turbine was to be a reference turbine for power comparison. The test results from this phase of the project further validated the results obtained computationally. The experimental results showed a power increase factor ranging from 2 to 4 times with respect to the fifth reference turbine, depending on the wind conditions and directions.
- The next step was to fabricate, install, and test a full scale wind tower system having a spiral wind deflecting structure. This system was also fabricated with 4 turbines, again each at 1.65 KW name-plate-rating. The system has actively controlled yaw mechanism. This second prototype was installed on the canopy of the Ballpark of Cleveland Indians Baseball team in Downtown Cleveland. The preliminary experimental data obtained from the second full scale prototype further validated the CFD results. This second prototype showed that each individual wind turbine reaches its maximum power production capacity at a wind speed of about 18 mil/hr, while the same turbine, installed in a stand-alone configuration, requires about 30 mil/hr in order to produce its peak power capacity.

This work has resulted in Four US patents, 2 technical publications, one presented and the second one to be presented, at ASME conferences. The work has also been featured at local, national, and international media and publications.

Cleveland State University has licensed the technology to a newly developed company to commercialize wind towers fabricated according to the design presented in this work, for Telecom Tower applications.

Background:

Majid Rashidi, Ph.D., P.E. of Cleveland State University (CSU) has designed an innovative wind tower system that is aligned with the small distributed wind energy systems initiative of Energy Efficiency and Renewable Energy of the U.S. Department of Energy.

The first prototype of a wind tower was designed, fabricated and installed in May 2009 on the Plant Service Building located on the campus of the Cleveland State University. Figure 1 shows a picture of the system after its installation. During the first quarter of 2012 the fabrication and installation of the second CSU experimental wind tower were accomplished. The new system was installed at the Progressive Ballpark of the Cleveland Indians Baseball team. Figure 2 shows a picture of the second prototype.

Figure 1 – First Wind Tower Prototype Installed in 2009

Figure 2 – Second wind tower prototype installed in 2012

Project Objective - The system presented in this work is intended for conversion of wind energy into useable electricity at geographic sites where the wind speed is relatively low, and where conventional wind turbines do not yield usable electric power. As the result of the unique modular attributes of this design, the system can be scaled up along its vertical axis, while keeping its footprint, as well as the size of its individual turbines, unchanged for different targeted power ratings.

Approach: Wind is a low energy density resource. In order to better understand the energy density of wind, it is helpful to compare the energy content of one gallon of gasoline to the energy delivered by a typical 225 KW wind turbine having a blade swept diameter of about 81 feet. The total energy contained in one gallon of gasoline is about 130 MJ. Joule is a relatively small unit of energy. If someone raises a cup of coffee from his/her waist line to his/her mouth, about one Joule of energy is required. This means that with the energy stored in one gallon of gasoline the action of raising a cup of coffee can be repeated for 130 million times. A typical 225 KW wind turbine needs to operate for about 15 minutes, under a sustained wind speed of about 17 mi/hr to produce the same amount of energy as that of one gallon of gasoline. Considering the concrete foundation, the mast, blade components, gearbox, and the electric generator of this wind turbine, and comparing these massive elements with a plastic container that could store one gallon of gasoline, one can realize the fact that wind is a low energy density resource.

Wind power produced by a typical wind turbine is proportional to the 2nd exponent of its blade radius, at the same time it is proportional to the 3rd exponent of the wind speed. In this project the main goal has been to develop a wind tower system that capitalizes on the dependency of the wind power to the cubic exponent of the wind velocity. The technology focuses on the use of round structures to increase the wind speed as the stream of the wind passes the structure and approaches the turbines.

Approach (continue)

The stage-gate process used in this project included the following steps:

- A series of computational effort have been undertaken to examine the influence of using a wind deflecting structure for increasing the ambient wind speed. The structures were taken to be a cylinder, and subsequently a spiral shape configuration.
- Design, fabricate, and test two scaled-down models to validate the results predicted by the computational model. Although these validations were qualitative in nature, nevertheless they created confidence in fabricating two full-scale prototypes.
- Design, fabricate, install, and test a full-scale wind tower with a cylindrical wind deflecting structure. The results from this first prototype confirmed those predicted by the mathematical modeling of the system via CFD analysis. The results obtained from this phase paved the way for design and fabrication of a full-scale wind tower having a spiral wind deflecting structure.
- The preliminary results obtained from the second prototype further validated the initial hypothesis of using wind deflecting structure in increase the power capacity of the typical roof-top wind turbines.

Relevant qualifications of the team members: The team that was assembled to accomplish the goals and objective of this project comprised of a group of professional individuals and organizations that have demonstrated track records in their areas of expertise. The links to access the websites of the team members are provide herein. Additional information on the relevant qualifications of the team members may be obtained by using the following links:

Cleveland State University (Engineering)	http://www.csuohio.edu/engineering/care/home.html
C. T. Taylor Company, Inc.	http://www.cttaylor.com
Lake Erie Electrical	http://www.lakeerieelectric.com
URS	http://www.urscorp.com
Stevens Engineers & Constructors	http://www.stevenssec.com
Astro Manufacturing	http://www.astromfg.com
I.A. Lewin Structural Engineering	http://www.lewinandassociates.com
MAGNET	http://www.manufacturingsuccess.org
Ohio State University	ameri.1@osu.edu
Cleveland State University (Business College):	
	http://facultyprofile.csuohio.edu/csufacultyprofile/detail.cfm?FacultyID=O_ICMELI

Critical Review of the literature - Wind is a low energy density resource; therefore, researchers and designers have been trying to develop wind energy harnessing systems that deliver reasonable and useful amount of electrical energy. Generally there are two schools of thoughts when it comes to the design and development of wind towers, namely a single large scale wind turbines versus many of the small scale wind harnessing machines. In one approach, the system is designed with a relatively large size structure, with turbine blades ranging from 150 to 200 feet in length. These systems are capable of producing electricity at a single site in the range of 2 to 5 MW. The large structural components of these systems pose design and fabrication challenges, as well as reliability issues related to the mechanical failures. Among other structural issues of large scale wind turbines, the gear boxes of these systems still require R&D work for improved performance and reliability. In a second approach, wind energy is converted to electrical energy via many small scale wind turbines, typically in KW scales. Such system do not have the structural issues and challenges of the large turbines, however, the number of small turbines required to generate useful amount of electrical energy is high.

The project pursued and reported in this final report falls in the category of small-scale wind tower system, producing electrical power at KW level, more specifically at a name-plate-rating of 6.5 KW.

Results and Discussion

Research and Development - Previously submitted quarterly reports of this project discloses the first series of the results generated by numerical simulations of the system's performance. These results are summarized in an ASME Publication¹.

Construction and installation of the first prototype - Before allocating the grant funds provided by the DOE for this project, it was decided to examine feasibility of the proposed concept at a small scale. Figure 3 is a photograph of a scaled-down model of the system. Here the diameter of the wind deflecting structure is about 20", with the turbine bald diameter of about 4". A floor-fan was used to simulate wind flow. The test results from this test rig paved the way to fabricate a full scale model.

Figure 3 – A scaled down model of the design concept

The experimental results obtained from the full scale model, installed on the rooftop of the Plant Service Building on Cleveland State University Campus, confirmed the results of CFD analysis. Details of the fabrication, installation, and the experimental results of this phase were included in several of the Quarterly Reports submitted for this project. Figure 4 is a typical experimental result that shows the performances of four typical rooftop wind turbines, as they are installed next to the cylindrical wind deflecting structure, and compared them to a similar 5th turbine, not affected by the wind-deflecting structure. In Figure 4, P1 P2, P3, and

¹ Ameri, Ali, Rashidi, Majid, "Analysis of a Concept for a Low Wind Speed Tolerant Axial Wind Turbine", ASME TURBO EXPO 2011, June 14-18, Vancouver, Canada, GT2011-46102.

P4 are the average powers of the four turbines installed around the cylinder; P5 is the average power generated by a stand-alone reference turbine on the same rooftop.

Cleveland State University

Energy Output June-August 2009

Bar on far right is control turbine (P5).

Figure 4 – Experimental results from full-scale system shown in Figure 1

Figure 5 show three photos of the construction and installation process of the first Wind Tower prototype installed at Cleveland State University campus.

Cleveland State University

Construction and Installation, Spring 2009

Figure 5 - Construction and installation of the first CSU wind tower prototype.

Previously submitted Quarterly Report for this project discloses the result of a CFD numerical simulation of the system's performance.

Construction and installation of the second prototype - Similar to the procedure of building the first prototype, and before allocating the grant funds provided by the DOE for this project, it was decided to first examine the feasibility of the proposed second generation concept (Spiral wind deflecting structure) at a small scale. Figure 6 is a photograph of a scaled-down model of the system. Here the diameter of the wind deflecting structure is about 12", with the turbine blade diameter of about 2.5". A floor-fan was used to simulate wind flow.

Figure 6 – A photograph of a scaled down model for a second generation prototype

The scaled down model verified the theoretical results predicted by the Computational Fluid Dynamic analysis in terms of wind speed amplification factor. This step helped to establish confidence in pursuing the fabrication of a full-scale model. The details of fabrication and installation of the second spiral prototype has been reported in the 13th, 14, 15, and 16th Quarterly Reports for this project.

The experimental results obtained from the full-scale model that was installed on the canopy of the Ballpark in Downtown Cleveland confirmed the results predicted by the CFD

analysis. A summary of the experimental results obtained in this phase of the project were included in the 16th Quarterly Report submitted for this project. A summary of the experimental results, describing the performance of both prototypes, are shown in **Table 1** and **Table 2**, and are presented in the next section of this report.

The instantaneous yaw positions of the wind turbines in both models (cylindrical and spiral) are determined (measured) by potentiometers. In case of the second prototype, an improper wiring caused several months of delay in yaw-control of the system. Unshielded control wires were strap-tied to the turbine out power cables carrying relatively high electric power. This resulted in a malfunction of the yaw-control computer hardware. Details of the improper wiring were included in the 16th Quarterly Progress Report.

Experimental methodology – For the first prototype system, installed in Spring 2009, the power output of the four turbines were instantaneously compared to the power of a stand alone reference turbine that was installed on the same rooftop, but not affected by the cylindrical wind deflecting structure. The four turbines, installed on/around the cylinder were actively controlled for their yaw, while the yaw angle (orientation) of the stand alone reference turbine was passively controlled by its own two symmetrical weathervanes. The algorithm for actively controlling the yaw of the four turbines has been included in one of the Quarterly Reports of the project and is available under project award number: **DE-FG36-08GO88016**. The sampling time for recording the wind speed/direction data, and the power generated by each individual turbine were set to be 10 seconds. In other words, every 10 seconds the performance data of 5 turbines, plus the wind speed information were recorded in a Database file. As mentioned earlier, the details of the experimental methodology, and the results obtained, are reflected in a series of Quarterly Report under the award number mentioned above.

Both prototype systems, installed at Cleveland State University and at the Ballpark, were equipped with Swift Rooftop wind turbines shown in Figure 7. The power curve, published by Swift for a typical Swift wind turbine is shown in Figure 8.

Figure 7 – Photo of a Swift™ Rooftop Wind Turbine, 82 inches in diameter, 1.65 KW Name-Plate-Rating

Figure 8 – Power Curve of a typical the Swift wind turbine, Swift™

The Technical Specification of a typical Swift Wind Turbine is shown below²:

- Type Upwind, horizontal axis, rooftop-mountable wind turbine
- Power Output Over 1.5 kW @ peak production
- kW @ 11 m/s (24.6 mph)
- Annual Energy Production Approximately - 1,200 kWh @ 5 m/s (11.2 mph annual wind average)
- 1,900 kWh @ 6 m/s (13.4 mph annual wind average)
- Electric Power 240VAC, 60Hz output voltage
- Grid Connection G83 certified, grid-tied system
- Inverter 7 amp AC, custom designed brushless PMG
- Rotor (Blade/Ring) Diameter 7 ft (82.5")
- Braking System Dynamic & mechanical over-speed protection
- Unit Weight Approximately 250 lbs
- Cut-In Speed 3.58 m/s (8 mph)
- Maximum Designed Wind Speed 64.8 m/s (145 mph)
- Lateral Loading 600 lbs @ 40.2 m/s (90 mph)
- 400 RPM maximum in a 20.1 m/s (45 mph) wind
- Product Design Life 20 yrs*
- Noise/Acoustic Emissions Less than 35 dB (A) for all wind speeds @ hub
- EMI (Electromagnetic Emissions) CE certified, BS EN 6100
- Safety, Electrical & Reliability Standards Certified to - UL 1741

Based on the above performance specifications of a typical swift wind turbine, installed as a stand alone turbine, the experimental data obtained from the wind tower system installed at the Ballpark is summarized in Table 1.

TABLE 1

Performance Comparison - 4 Turbines at the Ballpark and 4 turbines installed stand alone

Wind Speed mil/hr	Power Generated , Watt Ballpark Prototype (4 turbines)	Power Generated , Watt Conventional Installation (4 turbines)
11	1,288	800
15	2,644	800
18	6,143	1,412

² Data taken from: <http://swiftwindturbine.com/specifications.php>

The middle column of **Table 1** shows the total electrical power produced and measured by four turbines at the Progressive Ballpark. The far right column in this table is the summation of the powers of four Swift turbines according to the power curve published by Swift™ Turbine manufacturer. As shown in Figure 8, the power generated by each of the Swift wind turbines at three wind speeds of 11 mil/hr (4.9 m/s), 15 mil/hr (6.7 m/s), and 18 mil/hr (8 m/s) are 45 Watt, 200 Watt, and 353 Watt respectively. Therefore, four stand alone Swift wind turbines, without the spiral wind deflecting structure are expected to produce 180Watt, 800 Watt, and 1,412 Watt of electricity at the wind speeds of 11, 15, and 18 mil/hr.

The results presented in **Table 1** indicates that compared to the conventional turbine installations, an average value of 4.69 in increased electrical power is obtained from the Swift wind turbines as the results of the spiral wind deflecting structure that was proposed, fabricated, and studied in this research work.

Further, the power productions of both prototypes³, obtained experimentally, were compared and the results are shown in **Table 2**.

TBALE 2

Performance Comparison - 4 Turbines at the Ballpark and 4 Turbines installed at CSU

Wind Speed mil/hr	Power Generated , Watt Ballpark Prototype (Spiral) (4 turbines)	Power Generated , Watt CSU Prototype (Cylinder) 4 turbines)
11	1,288	1300
15	2,644	2,600
18	6,143	4,000

The performance data shown in **Table 2** indicates that at lower wind speeds, about 11 mil/hr, the two systems (spiral versus cylinder) provide almost the same level of powers, at in both cases the power is increased when compared with that of produced by the stand-alone

³ Prototypes installed at Cleveland State University and at the Ballpark (cylindrical and spiral wind deflecting structures)

conventional installation. However, as the wind speed increase to 18 mils/hr, the spiral wind deflecting structure outperforms the cylindrical one by a factor of about %53.

Accomplishments

Product development – During the course of this project two products were developed. First, a wind tower was developed with the goal of increasing the wind speed and directing the wind flow toward a plurality of small-scale wind turbines, each at a name plate rating of 1.6 KW. The system was first analyzed using Computational Fluid Dynamic software. Figure 1 on page 9 is an actual photo of the system that was installed at the rooftop of Plant Service Building on the campus of Cleveland State University. Figure 9 is another photo of the system with additional information depicting the major features of the system.

Figure 9 – Major Features of the first prototype, installed in May 2009

The turbines of the system shown in Figure 9 are 82.5” in diameter and are installed around a cylindrical shape wind deflecting structure that is about 25 feet in diameter.

Publication in Scientific/trade journals – Two scientific publications have appeared in ASME Conferences proceedings [⁴] [⁵]. Additionally, the first wind tower prototype developed as the result of this work appeared on the front cover of June 2012 Issue of the **WindTech International**. A related article starts on Page 7 of this magazine. The web address to access this article is: www.windtech-international.com/2012/june-2012. Figure 10 shows the cover of June 2012 Issue of the WindTech International. **Appendix A** contains the article written by Dr. Rashidi and printed in this magazine. Yet additionally, an article appeared in the August 2012 Issue of the **Popular Mechanics Magazine**, featuring the second prototype installed at the Ballpark of Cleveland Indians Baseball Team.

Figure 10 – Front Cover of WindTech International June 2012 Issue

⁴ Ameri, Ali, Rashidi, Majid, “Analysis of a Concept for a Low Wind Speed Tolerant Axial Wind Turbine”, ASME TURBO EXPO 2011, June 14-18, Vancouver, Canada, GT2011-46102.

⁵ Rashidi, Majid, Jaikrishnan R. Kadambi, David Kerze, “Wind Flow Regime Around a 3 Dimensional Helical Structure”, ASME International Congress, November 9-15 2012, Houston, Texas.

Publication in Scientific/trade journals – The results of this project were reflected in numerous websites. A selected list of these web sites is shown below. A general Google search will produce more results.

- <http://green.blogs.nytimes.com/2008/11/21/giving-turbines-a-boost-with-curves/>
- <http://www.usatodayeducate.com/staging/index.php/blog/professors-innovative-idea-may-put-wind-back-in-clevelands-sails>
- <http://www.businessweek.com/ap/2012-03/D9TPN7L80.htm>
- <http://www.businessweek.com/stories/2009-06-24/green-business>
- <http://cleantechnica.com/2012/04/13/cleveland-indians-wind-turbine-corkscrew/>
- http://news.cnet.com/8301-11386_3-57412287-76/corkscrew-wind-turbine-brings-juice-to-indians-stadium/
- <http://blog.cleantechies.com/2012/03/30/winds-of-innovation-at-mlb-stadium/>

Patents – A total of four US patents resulted from this work are listed below:

- **US 7,540,706**, “*Wind Harnessing System*”, Inventor Majid Rashidi
- **US 7,679,209**, “*Wind Powered Electricity Generating System*”, Inventor Majid Rashidi
- **US 7,845,904**, “*Wind Harnessing System*”, Inventor Majid Rashidi
- **US 8,002,516**, “*Wind Harnessing System*”, Inventor Majid Rashidi

Appendices B, C, D, and E present copies of the first pages of the above patents. All four patents have been assigned to Cleveland State University.

Licensing Agreement – Technology transfer & Commercialization activities:

A newly established company in Ohio, Amplified Wind Solution, obtained exclusive licensing to develop and market wind tower system that are targeted for installation on top of the Telecom Towers. **Appendix F** presents a signed copy of the Licensing Agreement between Cleveland State University and the Amplified Wind Solution LLC. Based on the licensing agreement, the technology developed as the result of this work is intended for creating renewable energy source for Telecom towers. Details of the licensing Agreement are presented in **Appendix F**.

Conclusion

The up to date experimental and computational results of this research at CSU have shown when a turbine is installed next to a round structure, cylindrical or spiral, the turbine's energy output is increased by a factor ranging from 3 to 4 times. This can be views as increasing the power capacity of a typical rooftop wind turbine. This arrangement also results in lowering of the cut-in wind speed for the turbine. The wind tower designed at CSU may be retrofitted to existing cylindrical structures such as a silo and/or a water tower. Figure 11 shows a series of typical water towers that could be suitable potential sites for installation of small wind turbines.

Applicable to existing Water Towers

Figure 11 – Round structures that could be potential sites for installation of small wind turbines

The primary conclusion of this project is the ability to increase the power capacity factor, C , of a typical rooftop wind turbine from roughly $C = 0.15$ to about $C = 0.45$ to 0.50 for a low wind speed region such as Cleveland, Ohio. In one embodiment of the proposed system, the wind deflecting structure, either cylindrical or spiral, could be a light-weight inflatable structure that is secured to a tower by tension members. In this case, the yaw control

mechanism could be a passive, weathervane type. The inflatable structure may have an air-pump to keep the inflation at a desired level in case of small air-leakage. As presented in the next section, Commercialization Aspects and Path, the system could also be complete wind tower system uniquely designed to produce electricity for Telecom towers.

Commercialization Aspect and Path – The first phase of commercialization effort to reduce the results of this research work into a commercial product is to redesign the system at a smaller scale, about 7 feet diameter spiral structure, to produce electric power for typical Telecom towers. The Amplified Wind Solution (AWS), a newly established company, is in the process of raising funds to build the first prototype for this purpose. The company is participating in the 2013 Energy Challenge to be considered for funding opportunities. At the same time AWS is seeking funds from private and other source to produce the first commercially viable system for Telecom application. Design For Manufacturing (DFM) is the main goal of AWS. As the first step in cost reduction, the active yaw-control of the system will be replaced with a passive weathervane type alternative. This is achievable because the overall system is about 3 to 4 times smaller than the two prototypes developed under this project. Another facet of AWS effort is to hire business development consultant to determine its customer in the chain of Telecom towers vendors, producers, and installers. AWS has estimated that an initial capital of \$120,000 is needed to design and develop a commercially viable wind tower system for Telecom application under the licensing agreement obtained from Cleveland State University for the technology developed in this work.

Lessons learned – The most relevant lesson learned from this work was the importance of structural design and fabrication aspects of a typical wind tower. The structural aspects of large scale wind tower system at MW power level are orders of magnitude more challenging than those of wind tower at KW rating scale. These structural aspects include the concrete foundation, structure of the mast, blade size, and gearbox structural reliability. But work on this project, which was focused on smaller wind turbine system, revealed that it is indeed the structural aspects of a wind tower system that provides the final challenge in design and fabrication.

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Appendix A

Rashidi, Majid, “*A Wind Tower System for Low Wind Speed Regions*”, WindTech International, Volume 8, No. 4, Page 7-9, June 2012

Researchers at Cleveland State University (CSU), an urban school in Cleveland, Ohio, have designed a wind tower system that is aligned with the small distributed wind energy systems initiative of Energy Efficiency and Renewable Energy of the US Department of Energy. The patented system is designed to facilitate the conversion of wind energy into useable electricity at locations where the wind speed is relatively low, and where conventional wind turbines do not yield significant amounts of electrical power. One of the goals of this research project at CSU is to reduce the cost for generating electricity via reducing the overall cost of the system. As a result of the unique modular attributes of the design the system can be scaled up along its vertical axis, while at the same time keeping its footprint and the size of its individual turbines unchanged for different targeted power ratings.

By Dr Majid Rashidi, Cleveland State University (CSU), USA

A Wind Tower System for Low Wind Speed Regions

Reducing the Cost of Energy by Reducing Overall Cost of the System

Figure 1. CSU's experimental wind tower with a name-plate rating of 6.4kW

The Cleveland State University (CSU) wind tower system design concept focuses on the use of cylindrical wind-deflecting structures to

increase wind speed as the stream of wind approaches the turbines. Figure 1 shows a picture of the first fully functional proposed wind

tower, fabricated and installed on the rooftop of the Planet Service Building located on the CSU campus.

Figure 2. Power curves of a typical turbine installed near cylinders of various diameters

The cylindrical wind-deflecting structure shown in Figure 1 increases the wind speed in its vicinity, where the four turbines are installed. This in turn will

result in a lowering of the cut-in wind speed for the turbines. The design configuration of Figure 1 can be retrofitted onto a silo or a water tower. The turbines shown

in Figure 1 are 2 metres (about 6.6 feet) in diameter and are capable of turning (yaw) about the vertical axis of the cylinder. A double worm-gear reducer actively turns the turbines around the cylinder in order to direct them into the prevailing wind. The diameter of the cylinder shown in Figure 1 is about 9 metres (about 29.5 feet). A fifth turbine, not shown in Figure 1, has been installed on the same rooftop, far from the cylinder, so that it is not affected by the cylindrical wind-deflecting structure. The purpose of the fifth turbine is to have a reference stand-alone turbine with a base-line performance in order to examine the effect of the wind-deflecting structure on the performance of the other four turbines.

Features of the Wind Tower

The unique features of this wind tower are as follows:

- Able to be retrofitted to existing cylindrical structures such as water towers and silos.
- Suitable for use in urban areas with low wind speed regimes

Figure 3. Experimental results for the performance of the prototype wind tower at CSU

to 6 miles per hour (mph), 8 to 10 kilometres per hour (kph)).

- Boosts the capacity of standard rooftop wind turbines by a factor of 3 to 4 times.

Before fabrication and installation of the system shown in Figure 1, comprehensive computational studies were performed in order to examine and predict the benefits of installing the turbines around a cylindrical structure. One of the aims of these studies was to determine the appropriate ratio for the diameters of the cylinder and turbines. Figure 2 shows the results of a computational fluid dynamic analysis conducted for this purpose.

In Figure 2, the far right graph (light blue) is the power curve of a stand-alone turbine which received no wind speed augmentation. The four other graphs to the left of the stand-alone power curve are those for the same type of turbines when installed near a cylindrical wind-deflecting structures of 5, 15 and 35 feet (approximately 1.5, 4.5 and 10 metres) in diameter respectively. As shown in Figure 2, when a typical standard wind turbine is installed near a cylindrical wind-deflecting structure, its power generation capability reaches its maximum rated capacity at a lower natural wind speed when compared with the same turbine installed in a standard manner on a mast. For example, consider a turbine installed near a cylinder having a diameter of 15 feet (about 4.5 metres). The power curve for this case is shown in red in Figure 2. In this case when the natural wind speed is about 18 mph (29 kph), the turbine will produce about 1580 watts, whereas the same turbine with a customary installation on a mast (light blue font) produces only 580 watts.

Experimental Results

Figure 3 shows a comparative performance of the turbines in Figure

1 obtained experimentally. This figure is a bar-graph depiction of the average powers for the months of June to October 2009. In this figure, P1, P2, P3 and P4 are the average power outputs generated by the four turbines installed around the main cylindrical wind-deflecting structure of Figure 1, while P5 is the average power generated by the fifth reference turbine which is not affected by the cylinder. As shown in Figure 3, the four turbines of the CSU wind tower have consistently outperformed the reference turbine (no. 5).

The computational results of this work have revealed that a cylindrical wind-deflecting structure increases the wind speed by an average factor of 1.56 by the time the airflow reaches the wind turbines installed near the cylinder. For example, when the natural wind speed is about 10 mph (16 kph), a cylindrical wind-deflecting structure increases the wind speed to about 15.6 mph (25 kph). Since the power contained in a stream of wind is proportional to the cubic exponent of its speed, the increased factor of 1.56 in wind speed results in an increase factor of about 3.8 in the wind power reaching the turbines. The experimental results, obtained from CSU's wind tower prototype, validate the computational results. The experimental and computational results of the research at CSU have shown that when a turbine is installed next to a round structure, the turbine's electrical energy output is increased. This arrangement also results in a lowering of the cut-in wind speed for the turbine. The wind tower designed at CSU may be retrofitted to existing cylindrical structures such as a silo and/or a water tower. In the case of active water towers, the generated electric power can simply be stored in the water tower, in the form of gravitational potential energy, by pumping

water into the elevated reservoir.

A group of students at the Business and Engineering colleges of CSU have formed a company to commercialise the wind tower system. Their marketing strategy is to first implement the technology on farms where cylindrical structures, such as silos and/or water towers, are already integral parts of the infrastructure. Using these pre-existing cylindrical structures, the installation cost will mostly be spent on the equipment and components for retrofitting the turbines. ■

Biography of the Author

Majid Rashidi, PhD, PE is the Betty L. Gordon Distinguished Professor of the Mechanical Engineering Department,

and Chair of the Engineering Technology Department at Cleveland State University in Cleveland, Ohio. His area of research includes machine design, dynamics of gear-trains, and fluid-solid interactions in machinery. He holds eight US patents, four of which relate to wind-power-harnessing systems.

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Appendix B

PATENT # 1

US 7,540,706, “*Wind Harnessing System*”, Inventor Majid Rashidi

US007540706B2

(12) **United States Patent**
Rashidi

(10) **Patent No.:** **US 7,540,706 B2**
(45) **Date of Patent:** **Jun. 2, 2009**

(54) **WIND HARNESSING SYSTEM**

(75) Inventor: **Majid Rashidi**, Pepper Pike, OH (US)

(73) Assignee: **Cleveland State University**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 242 days.

4,236,083 A 11/1980 Kenney
4,288,199 A 9/1981 Weisbrich
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(Continued)

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **11/445,663**

WO WO02/084115 7/2002

(22) Filed: **Jun. 2, 2006**

(65) **Prior Publication Data**

US 2006/0273597 A1 Dec. 7, 2006

(Continued)

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Related U.S. Application Data

(60) Provisional application No. 60/687,622, filed on Jun. 3, 2005.

International Search Report from co-pending International Application No. PCT/US2006/021791 with an International Filing Date of Jun. 5, 2006; claiming benefit of U.S. Appl. No. 60/687,622, filed Jun. 3, 2005 entitled "Wind Harnessing System" (Applicant: Cleveland State University).

(51) **Int. Cl.**
F03D 1/02 (2006.01)

(Continued)

(52) **U.S. Cl.** **415/60; 415/71; 415/908; 416/121**

(58) **Field of Classification Search** 415/4.1, 415/4.3, 4.5, 60, 71, 905, 908, 909; 416/9, 416/120, 121, 122, 130, DIG. 4
See application file for complete search history.

Primary Examiner—Edward Look
Assistant Examiner—Dwayne J White
(74) *Attorney, Agent, or Firm*—Calfee, Halter & Griswold LLP

(56) **References Cited**

(57) **ABSTRACT**

U.S. PATENT DOCUMENTS

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4,156,580 A 5/1979 Pohl

A wind harnessing system comprises a substantially helical structure including at least a portion of a spiraling groove and at least one energy converter positioned at least partially within the portion of the spiraling groove. In other embodiments, wind grooves formed by adjacent bands which are fixed with respect to one another, carry energy converters which are moveable with respect to these fixed bands.

16 Claims, 5 Drawing Sheets

Appendix C

PATENT # 2

US 7,679,209, “*Wind Powered Electricity Generating System*”, Inventor Majid Rashidi

US007679209B2

(12) **United States Patent**
Rashidi

(10) **Patent No.:** **US 7,679,209 B2**
(45) **Date of Patent:** **Mar. 16, 2010**

(54) **WIND POWERED ELECTRICITY
GENERATING SYSTEM**

(75) Inventor: **Majid Rashidi**, Pepper Pike, OH (US)

(73) Assignee: **Cleveland State University**, Cleveland,
OH (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 306 days.

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5,313,103 A 5/1994 Hickey

(Continued)

(21) Appl. No.: **11/775,315**

FOREIGN PATENT DOCUMENTS

(22) Filed: **Jul. 10, 2007**

WO WO 02/084115 10/2002

(65) **Prior Publication Data**

US 2009/0015017 A1 Jan. 15, 2009

(Continued)

(51) **Int. Cl.**
F03D 9/00 (2006.01)
F03D 1/02 (2006.01)

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(52) **U.S. Cl.** **290/55; 415/60**

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(58) **Field of Classification Search** 290/43,
290/44, 54, 55; 415/60, 71
See application file for complete search history.

(Continued)

(56) **References Cited**

Primary Examiner—Nicholas Ponomarenko

(74) *Attorney, Agent, or Firm*—Calfée, Halter & Griswold
LLP

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4,421,452 A 12/1983 Rougemont

(57) **ABSTRACT**

An electrical energy generating system converts wind power to electrical power with a wind deflecting structure that divides wind impinging on the structure into two separate accelerated flow paths. One or more turbines are positioned in proximity to the wind deflecting structure such that a portion of the vanes of the turbine is placed within one of the accelerated flow paths. An energy converter is coupled to the turbine that converts rotary motion of the turbine into electricity.

12 Claims, 7 Drawing Sheets

Appendix D

PATENT # 3

US 7,845,904, “*Wind Harnessing System*”, Inventor Majid Rashidi

US007845904B2

(12) **United States Patent**
Rashidi

(10) **Patent No.:** **US 7,845,904 B2**
(45) **Date of Patent:** **Dec. 7, 2010**

(54) **WIND HARNESSING SYSTEM**

(75) Inventor: **Majid Rashidi**, Pepper Pike, OH (US)

(73) Assignee: **Cleveland State University**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 740 days.

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(21) Appl. No.: **11/746,319**

(Continued)

(22) Filed: **May 9, 2007**

FOREIGN PATENT DOCUMENTS

(65) **Prior Publication Data**

WO WO 02/084115 10/2002

US 2008/0279690 A1 Nov. 13, 2008

(Continued)

(51) **Int. Cl.**

F03D 1/02 (2006.01)

F03D 1/04 (2006.01)

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Alfred L. Weisbrich, Gunther J. Weisbrich, William Smith, "Naval & non-Naval Warp Offshore Wind Power Systems With Integral Fuel Cells". Jan. 6-9, 2003, AIAA and ASME 41st Aerospace Sciences Meeting and Exhibit, retrieved from <<http://www.warp-eneco.com/documents.php>> on Jan. 28, 2010.*

(52) **U.S. Cl.** **416/60**; 415/909; 416/120
(58) **Field of Classification Search** 415/60,
415/213.1, 215.1, 909; 416/120, 121, 122;
52/40, 65, 651.01, 651.07

See application file for complete search history.

(Continued)

(56) **References Cited**

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4,156,580 A 5/1979 Pohl
4,236,083 A 11/1980 Kenney

Primary Examiner—Edward Look

Assistant Examiner—Jesse Prager

(74) Attorney, Agent, or Firm—Calfee, Halter & Griswold LLP

(57) **ABSTRACT**

A wind harnessing system comprises a substantially grooved shell disposed about a rigid frame. The grooved shell can be constructed of lightweight shell panels connected to one another and to the frame. Alternatively, the grooved shell can be constructed of inflatable shell sections.

29 Claims, 16 Drawing Sheets

Appendix E

PATENT # 4

US 8,002,516, “*Wind Harnessing System*”, Inventor Majid Rashidi

US008002516B2

(12) **United States Patent**
Rashidi

(10) **Patent No.:** **US 8,002,516 B2**
(45) **Date of Patent:** **Aug. 23, 2011**

(54) **WIND HARNESSING SYSTEM**

(75) Inventor: **Majid Rashidi**, Pepper Pike, OH (US)

(73) Assignee: **Cleveland State University**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **12/419,474**

(22) Filed: **Apr. 7, 2009**

(65) **Prior Publication Data**

US 2009/0191056 A1 Jul. 30, 2009

Related U.S. Application Data

(63) Continuation of application No. 11/445,663, filed on Jun. 2, 2006, now Pat. No. 7,540,706.

(60) Provisional application No. 60/687,622, filed on Jun. 3, 2005.

(51) **Int. Cl.**
F03D 7/02 (2006.01)

(52) **U.S. Cl.** **415/4.3**; 415/71; 416/9; 416/120

(58) **Field of Classification Search** 415/4.1, 415/4.3, 4.5, 60, 71, 905, 908, 909; 416/9, 416/120

See application file for complete search history.

(56) **References Cited**

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(Continued)

Primary Examiner — Edward Look

Assistant Examiner — Dwayne J White

(74) *Attorney, Agent, or Firm* — Calfee, Halter & Griswold LLP

(57) **ABSTRACT**

A wind harnessing system comprises a substantially helical structure including at least a portion of a spiraling groove and at least one energy converter positioned at least partially within the portion of the spiraling groove. In other embodiments, wind grooves formed by adjacent bands which are fixed with respect to one another, carry energy converters which are moveable with respect to these fixed bands.

17 Claims, 5 Drawing Sheets

Appendix F:

Copy of the Licensing Agreement for the technology developed in this project

LICENSE AGREEMENT

This Agreement is entered into on September 26, 2012, between Cleveland State University a state supported university and instrumentality of the State of Ohio, located at 2121 Euclid Avenue Cleveland, Ohio 44115 ("CSU") and Amplified Wind Solutions LLC ("AWS"), a Limited Liability Company formed under the laws of the State of Ohio located at 2190 Professor Ave., Cleveland, OH 44113 ("LICENSEE").

BACKGROUND

CSU owns certain PATENT RIGHTS (as later defined) relating to CSU US Patent numbers (1) US 7,540,706 B2 – Wind Harnessing System, (2) US 7,679,209 B2 – Wind Powered Electricity Generating System, (3) US 7,845,904 B2 – Wind Harnessing System and (4) US 8,002,516 B2 – Wind Harnessing System and has the right to grant licenses under PATENT RIGHTS, (subject only to a royalty-free nonexclusive license previously granted to the United States Government);

CSU desires to have the PATENT RIGHTS developed and commercialized to benefit the public and is willing to grant a license for this purpose;

LICENSEE has represented to CSU, to induce CSU to enter into this Agreement, that LICENSEE INTENDS TO develop, reproduce, modify, make, or have made, make derivative works, enhance, distribute, market, and sell products similar to the LICENSED PRODUCT(s) (as later defined) using the LICENSED PROCESS(es) (as later defined) and that it shall commit itself to a thorough, vigorous, and diligent program of exploiting the PATENT RIGHTS so that the public shall benefit; and LICENSEE desires to obtain a license under the PATENT RIGHTS upon the terms and conditions set forth below.

The parties therefore agree as follows:

ARTICLE 1 - DEFINITIONS

For purposes of this Agreement, the following words and phrases have the following meanings:

1.1 "CONFIDENTIAL INFORMATION" means confidential or proprietary information relating to the PATENT RIGHTS, LICENSED PRODUCTS or LICENSED PROCESSES. CONFIDENTIAL INFORMATION may be in written, graphic, oral or physical form and may include scientific knowledge, know-how, processes, inventions, techniques, formulae, products, business operations, customer requirements, designs, sketches, photographs, drawings, specifications, reports, studies, findings, data, plans or other records, biological materials, and/or software. CONFIDENTIAL INFORMATION shall not include:

- (a) information which is, or later becomes, generally available to the public through no fault of the recipient;
- (b) information which is provided to the recipient by an independent third party having no obligation to keep the information secret;

- (c) information which the recipient can establish was previously known to it or was independently developed by it without reference to the CONFIDENTIAL INFORMATION;
 - (d) information that is required to be disclosed to comply with applicable law or court order, including Ohio Revised Code Section 149.43, provided that the recipient gives prior written notice of the required disclosure to the discloser.
- 1.2 "LICENSED PROCESS" means any process that is covered in whole or in part by an issued, unexpired claim or a pending claim contained in the PATENT RIGHTS.
- 1.3 "LICENSED PRODUCT" means any product or product part which:
- (a) is covered in whole or in part by an issued, unexpired claim or a pending claim contained in the PATENT RIGHTS in the country in which any such product or product part is made, used or sold; or
 - (b) is manufactured by using a process or is employed to practice a process which is covered in whole or in part by an issued, unexpired claim or a pending claim contained in the PATENT RIGHTS in the country in which any LICENSED PROCESS is used or in which such product or product part is used or sold.
- 1.4 "LICENSEE" means Amplified Wind Solutions LLC and any company, corporation, or business in which Amplified Wind Solutions LLC owns or controls at least fifty per cent (50%) of the voting stock.
- 1.5 1.6 "NET SALES" means the gross amount of all sales or leases of LICENSED PRODUCTS and PROCESSES by LICENSEE, Affiliates, or sublicensees to any customer less:
- (a) discounts allowed in amounts customary in the trade;
 - (b) sales, tariff duties and/or use taxes directly imposed and with reference to particular sales;
 - (c) freight and insurance, if separately itemized on the invoice and paid by the customer; and
 - (d) amounts allowed or credited on returns.
- 1.6 "PATENT RIGHTS" means all of the following CSU intellectual property:
- (a) the United States and foreign patents and/or patent applications listed in Appendix A;
 - (b) United States and foreign patents issued from the applications listed in Appendix A and from divisionals and continuations of these applications;
 - (c) claims of U.S. and foreign continuation-in-part applications, and of the resulting patents, which are directed to subject matter specifically described

- in the U.S. and foreign applications listed in Appendix A;
- (d) claims of all foreign patent applications, and of the resulting patents, which are directed to subject matter specifically described in the United States patents and/or patent applications described in (a), (b) or (c) above;
 - (e) any reissues of United States patents described in (a), (b) or (c) above;
 - (f) know-how, specifications, and other technology necessary to practice the US patents described in (a)-(e) above and any improvements thereto; and
 - (g) the CSU technology related to a track system design as conceptually presented in Appendix B and incorporated by reference.

ARTICLE 2 - GRANT

2.1 CSU grants to LICENSEE and LICENSEE accepts, subject to the terms and conditions of this Agreement, an exclusive, non-transferable license under PATENT RIGHTS and, to the extent not prohibited by other patents, to make, have made, use, develop, reproduce, modify, make, have made, make derivative works, enhance, distribute, market, lease, use related trademarks or service marks, and sell the LICENSED PRODUCTS to and to practice the LICENSED PROCESSES within the telecommunications industry (encompassing those commercial entities engaged in the distribution of sound, images, data or other information via cables, broadcasting, relay or satellite networks, encompassing telephone, telegraph and telex communication, the transmission of radio and television programs, internet access provision and the maintenance of such networks).

2.2 This Agreement is effective when signed by all parties and shall extend for two years with a 90 day notice of termination by CSU to LICENSEE prior to the end of the two year term, unless sooner terminated as provided in Article 11. However, during the above two year term should LICENSEE: (1) secure funding, including but not limited to grant award(s) (beyond the start-up DOE \$150,000 grant award) or venture capital funding in an amount equal to or exceeding \$100,000; and (2) achieve annual Gross Sales equal to or exceeding \$100,000, the contract automatically shall be extended an additional three years, for a total of a five year term with a 90 day notice of termination by CSU to LICENSEE, unless sooner terminated as provided in Article 11.

2.3 LICENSEE agrees that LICENSED PRODUCTS leased or sold in the United States shall be manufactured substantially in the United States.

2.4 CSU reserves the right to practice under the PATENT RIGHTS for noncommercial research and educational purposes.

2.5 The invention(s) that is/are the subject of the PATENT RIGHTS resulted from research sponsored in part by Department of Energy, and the license granted under this Agreement is expressly made subject to the rights of the United States Government under 35 U.S.C. 200-212 and applicable governmental regulations.

ARTICLE 3 – LICENSE FEES and ROYALTIES

3.1 LICENSEE shall pay royalties to CSU until the term of the PATENT RIGHTS expires or until this Agreement is terminated. Royalties shall include:

Phase I Start Up Period. No Royalty. This period commences upon the effective date of this agreement and terminates 18 months after the first Product is sold or at the start of Phase II.

Phase II: Early Commercialization: One and one half percent (1.50%) of the annual Net Sales with an annual minimum royalty of 2,000. This period commences one year after the first Product is sold up to annual Gross Sales equal \$240,000.

Phase III Commercialization: Four percent (4%) of the Net Sales with an annual minimum royalty payment of \$5,000. This period commences once the annual Gross Sales reaches \$240,001 and above.

3.2 LICENSEE shall be responsible for the payment of all taxes, duties, levies, and other charges, including, but not limited to, sales, use, gross receipts, excise, VAT, and any other taxes, any withholdings or deductions, import and custom taxes, any duties, or any other charges imposed by any taxing authority with respect to the royalties payable to CSU under this agreement. Should LICENSEE be required under any law or regulation of any government entity or authority, domestic or foreign, to withhold or deduct any portion of the payments on royalties due to CSU, then the sum payable to CSU shall be increased by the amount necessary to yield to CSU an amount equal to the sum it would have received had no withholdings or deductions been made. CSU shall cooperate with LICENSEE in the event LICENSEE elects to assert, at its own expense, CSU's exemption from any such tax or deduction.

3.3 LICENSEE is not obligated to pay multiple royalties based on the fact that any LICENSED PRODUCT, its manufacture, use, lease or sale is covered by more than one PATENT RIGHTS patent application or PATENT RIGHTS patent licensed under this Agreement.

3.4 Royalty payments shall be paid in United States dollars in Cleveland, Ohio, or at such other place as CSU may reasonably designate consistent with the laws and regulations controlling in any foreign country. If any currency conversion is required in connection with the payment of royalties, such conversion shall be made by using the exchange rate as published on the last business day of the applicable calendar month in the eastern edition of The Wall Street Journal.

3.5 Royalty payments shall be made twice yearly with submission of the reports required by Article 6, except the minimum annual royalty payment, which shall be due as provided in Paragraph 3.1.b. Such payments and reports shall be due within fourteen (14) days of March 31, and September 30 of each calendar year. Late payments, including payments due for patent cost reimbursement, shall be subject to a charge of one and one-half percent (1.5%) per month or \$100, whichever is greater. The payment of such late charge

shall not foreclose CSU from exercising any other rights it may have resulting from any late payment.

ARTICLE 4 – SUBLICENSES

4.1 LICENSEE has the right to enter into sublicensing agreements. LICENSEE agrees that any sublicenses granted by it shall provide that the obligations to CSU of Articles 2, 6, 8, 9, 10, 11 and 14 of this Agreement shall be binding upon the sublicensee as if it were a party to this Agreement. LICENSEE further agrees to attach copies of these Articles to sublicense agreements.

4.2 LICENSEE shall forward to CSU copies of all sublicense agreements promptly upon execution by the parties.

4.3 LICENSEE shall not receive from sublicensees anything of value in lieu of cash payments in consideration for any sublicense under this Agreement, without the express prior written permission of CSU.

4.4 In accordance with paragraph 11.8, termination of the license granted to LICENSEE by Licensor under this Agreement will terminate all sublicenses which may have been granted by LICENSEE, unless mutually agreed in writing otherwise by Licensor and the relevant sublicense.

ARTICLE 5 - DUE DILIGENCE

5.1 LICENSEE shall use its best efforts to bring one or more LICENSED PRODUCTS or LICENSED PROCESSES to market through a thorough, vigorous and diligent program for exploiting the PATENT RIGHTS and to continue active, diligent marketing efforts for one or more LICENSED PRODUCTS or LICENSED PROCESSES throughout the life of this Agreement.

ARTICLE 6 - REPORTS AND RECORDS

6.1 LICENSEE shall keep full, true and accurate books of account containing all particulars necessary to show the amounts payable to CSU. The books of account shall be kept at LICENSEE's principal place of business or the principal place of business of the appropriate division of LICENSEE to which this Agreement relates. The books and supporting data shall be open at all reasonable times for five (5) years following the end of the calendar year to which they pertain, for inspection by CSU or its agents to verify LICENSEE's royalty statement or compliance in other respects with this Agreement. Should such inspection lead to the discovery of discrepancy in reporting which is greater than two percent (2%) to CSU's detriment, LICENSEE agrees to pay the full cost of such inspection.

6.2 LICENSEE shall provide to CSU a written annual report on or before September 1 of each calendar year. The annual report shall include: reports of progress on research and development, regulatory approvals, manufacturing, sublicensing, marketing and sales during the preceding twelve (12) months, and plans for the coming year.

6.3 After the first commercial sale of a LICENSED PRODUCT or LICENSED

PROCESS, LICENSEE shall provide reports twice per year to CSU. The reports shall be delivered within fourteen (14) days after March 31, and September 30, of each year. The reports shall give particulars of the business conducted by LICENSEE and its sublicensees during the preceding quarter that are pertinent to a royalty accounting, including:

- (a) number of LICENSED PRODUCTS manufactured and sold by LICENSEE and all sublicensees;
- (b) total billings for LICENSED PRODUCTS sold by LICENSEE and all sublicensees;
- (c) accounting for all LICENSED PROCESSES used or sold by LICENSEE and all sublicensees;
- (d) royalties due on additional payments from sublicensees under Paragraph 3.1.d;
- (e) any minimum annual royalty payment credits applicable against running royalties;
- (f) total royalties due; and
- (g) names and addresses of all sublicensees.

ARTICLE 7 - PATENT PROSECUTION

7.1 CSU shall, in its sole discretion, be responsible for the preparation, filing, prosecution and maintenance of any and all applications and patents included in the PATENT RIGHTS. CSU shall consult with LICENSEE as to the preparation, filing, prosecution and maintenance of such applications and patents and shall furnish to LICENSEE copies of documents relevant to any such preparation, filing, prosecution or maintenance. CSU and LICENSEE shall cooperate fully in determining, in a timely manner, the countries in which patent protection shall be pursued and maintained. Each party shall provide to the other prompt notice as to all matters that come to its attention and which may affect the preparation, filing, prosecution or maintenance of any such patent applications or patents. In particular, LICENSEE will immediately notify CSU if LICENSEE or a sublicensee (or optionee) does not qualify as a "small entity" as provided by the United States Patent and Trademark Office.

ARTICLE 8 - INFRINGEMENT

8.1 LICENSEE or its sublicensee(s) has the right to prosecute in their own name and at their own expense any infringement of the PATENT RIGHTS, so long as the license is exclusive when the legal action is commenced. CSU agrees to notify LICENSEE promptly of each infringement of the PATENT RIGHTS of which CSU becomes aware. Before LICENSEE or its sublicensees commences an action for infringement, LICENSEE or sublicensee shall notify CSU and carefully consider the views of CSU and the public interest.

8.2 CSU agrees to join, subject to the approval of the Ohio Attorney General, as a

party plaintiff in any lawsuit initiated by LICENSEE, if requested by LICENSEE, with all costs, attorney fees and expenses to be paid by LICENSEE.

8.3 If LICENSEE undertakes to enforce and/or defend the PATENT RIGHTS by litigation, LICENSEE may withhold one hundred percent (100%) of the payments otherwise thereafter due during the course of such litigation to CSU under Article 3. LICENSEE may apply the amounts withheld to reimburse up to half of LICENSEE's litigation expenses, including reasonable attorneys' fees. If LICENSEE recovers damages in the patent litigation, the award shall be applied first to satisfy CSU's and LICENSEE'S unreimbursed expenses and legal fees for the litigation, and next to reimburse CSU for any payments under Article 3 which are past due or were withheld pursuant to this Article 8. The remaining balance shall be divided equally between LICENSEE and CSU.

8.4 No settlement, consent judgment or other voluntary final disposition of the suit may be entered into without CSU's consent, which shall not be unreasonably withheld.

8.5 If LICENSEE and its sublicensee(s) elect not to exercise their right to prosecute or defend an infringement of the PATENT RIGHTS, CSU may do so at its own expense, controlling such action and retaining all recoveries.

8.6 If a declaratory judgment action alleging invalidity of any of the PATENT RIGHTS is brought against LICENSEE or CSU, then CSU, at its sole option, has the right to intervene and take over the defense of the action at its own expense.

ARTICLE 9 - PRODUCT LIABILITY

9.1 LICENSEE shall at all times during the term of this Agreement and thereafter, indemnify, defend and hold CSU, its trustees, directors, officers, and employees, (collectively, the "Indemnitees") harmless against all claims, proceedings, demands and liabilities of any kind whatsoever, arising out of the death of or injury to any person or persons or out of any damage to property, or resulting from the production, manufacture, sale, use, lease, consumption or advertisement of the LICENSED PRODUCT(s) and/or LICENSED PROCESS(es) or arising from any obligation of LICENSEE under this Agreement ("LIABILITY"), except claims that the PATENT RIGHTS infringe third party intellectual property or due to a defect in the PATENT technology. Notwithstanding the above paragraph 9.1, such indemnification shall be limited to the extent the LIABILITY is caused by acts of the LICENSEE, and in no event shall LIABILITY exceed amounts CSU may recover through LICENSEE's insurance policy(ies) maintained in accordance with paragraph 9.2 below.

9.2

- (a) LICENSEE shall, at all times after the effective date of this Agreement and prior to the occurrence of an event described in Subparagraph 9.2.b, maintain commercial general liability insurance in amounts adequate to assure its obligations to CSU under Section 9.1 of this Agreement.

- (b) Beginning at the time any product, process or service relating to, or developed pursuant to, this Agreement is being commercially distributed or sold (other than for the purpose of obtaining regulatory approvals) by LICENSEE or by a sublicensee or agent of LICENSEE, LICENSEE shall, at its own expense, procure and maintain commercial general liability insurance in amounts of not less than one million dollars (\$1,000,000) per incident and one million dollars (\$1,000,000) annual aggregate and naming Indemnitees as additional insureds. During clinical trials of any such product, process or service, LICENSEE shall, at its sole expense, procure and maintain commercial general liability insurance in such equal or lesser amounts as CSU may require. The general commercial liability insurance required under this paragraph shall provide (i) product liability coverage and (ii) broad form contractual coverage for LICENSEE's indemnification under this Agreement.
- (c) LICENSEE shall provide CSU with written evidence of such insurance upon request of CSU. LICENSEE shall provide CSU with written notice at least fifteen (15) days prior to the cancellation, non-renewal or material change of such insurance; if LICENSEE does not obtain replacement insurance providing comparable coverage within such fifteen (15) day period, CSU shall have the right to terminate this Agreement effective at the at the end of such fifteen (15) day period without notice or any additional waiting periods.
- (d) Should LICENSEE carry any "term-based" commercial general liability insurance policy, LICENSEE shall maintain such term-based commercial general liability insurance beyond the expiration or termination of this Agreement during (i) the period that any product, process, or service relating to, or developed pursuant to, this Agreement is being commercially distributed or sold by LICENSEE or a sublicensee or agent of LICENSEE and (ii) a reasonable period after the period referred to Paragraph 9.2.d.i above which in no event shall be less than 5 years.

9.3 EXCEPT AS OTHERWISE EXPRESSLY SET FORTH IN THIS AGREEMENT, CSU, ITS TRUSTEES, DIRECTORS, OFFICERS, EMPLOYEES, AND AFFILIATES MAKE NO REPRESENTATIONS AND EXTEND NO WARRANTIES OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, VALIDITY OF PATENT RIGHTS CLAIMS ISSUED OR PENDING, AND THE ABSENCE OF LATENT OR OTHER DEFECTS, WHETHER OR NOT DISCOVERABLE. NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS A REPRESENTATION MADE OR WARRANTY GIVEN BY CSU THAT THE PRACTICE BY LICENSEE OF THE LICENSE GRANTED SHALL NOT INFRINGE THE PATENT RIGHTS OF ANY THIRD PARTY. CSU, ITS TRUSTEES, DIRECTORS, OFFICERS, EMPLOYEES AND AFFILIATES SHALL NOT BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, INCLUDING ECONOMIC DAMAGE OR INJURY TO PROPERTY AND LOST PROFITS, REGARDLESS OF WHETHER CSU IS ADVISED, HAS OTHER REASON TO KNOW, OR IN FACT DOES KNOW OF THE POSSIBILITY.

ARTICLE 10 – CONFIDENTIALITY

10.1 During the course of this Agreement, CSU and LICENSEE may provide each other with CONFIDENTIAL INFORMATION. All CONFIDENTIAL INFORMATION shall be designated in writing as such by the discloser. CSU and LICENSEE each intend to maintain the confidential status of their CONFIDENTIAL INFORMATION. Each shall exercise reasonable care to protect the CONFIDENTIAL INFORMATION from disclosure to third parties; no such disclosure shall be made without the other's written permission. Upon termination or expiration of this Agreement, CSU and/or LICENSEE shall comply with the other's written request to discontinue using and/or return all CONFIDENTIAL INFORMATION. This Confidentiality provision shall continue for a period of three (3) years following the termination or expiration of this Agreement.

ARTICLE 11 – TERMINATION

11.1 If LICENSEE becomes bankrupt or insolvent, or files a petition in bankruptcy court, or if the business of LICENSEE is placed in the hands of a receiver, assignee or trustee for the benefit of creditors, whether by the voluntary act of LICENSEE, this Agreement shall automatically terminate.

11.2 If LICENSEE fails to make any payment due to CSU, CSU has the right to terminate this Agreement effective on thirty (30) days' written notice, unless LICENSEE makes all such payments within the thirty (30) day period. If LICENSEE has not made all such payments to CSU by the time the thirty (30) day period expires, this Agreement shall automatically terminate.

11.3 If LICENSEE defaults on its obligations under Paragraph 9.2, CSU shall have the right to terminate this Agreement without further notice as provided under Subparagraph 9.2(c).

11.4 Upon any material breach or default of this Agreement by LICENSEE other than those occurrences listed in Paragraphs 11.1 through 11.4 (the terms of which shall take precedence over the handling of any other material breach or default under this Paragraph 11.5), CSU has the right to terminate this Agreement effective on ninety (90) days' written notice to LICENSEE. Such termination shall become automatically effective upon expiration of the ninety (90) day period unless LICENSEE cures the material breach or default before the period expires.

11.5 LICENSEE has the right to terminate this Agreement at any time on three (3) months' written notice to CSU if LICENSEE:

- (a) pays all amounts due CSU through the effective date of the termination;
- (b) submits a final report of the type described in Paragraph 6.3;

- (c) returns any confidential or trade-secret materials provided to LICENSEE by CSU in connection with this Agreement;
- (d) suspends its use of the LICENSED PROCESS(ES) AND LICENSED PRODUCT(S) (subject to Paragraph 11.6 below);
- (e) provides CSU with all data and know-how developed by LICENSEE in the course of LICENSEE's efforts to develop LICENSED PRODUCTS and PROCESSES. CSU shall have the right to use such data and know-how for any purpose whatsoever, including the right to transfer same to future licensees, however, "data" under this subparagraph 11.6(e) shall be limited to LICENSED PRODUCT technology data and does not include LICENSEE proprietary business information such as business plans, financial data, marketing strategy, customer lists, and the like; and
- (f) provides CSU the right to access any regulatory information filed with any US or foreign government agency with respect to LICENSED PRODUCTS and PROCESSES.

11.6 If LICENSEE has filed patent applications or obtained patents to any modification or improvement to LICENSED PRODUCTS or PROCESSES within the scope of the LICENSED PATENTS, LICENSEE agrees upon request to enter into good faith negotiations with CSU or its future licensee(s) for the purpose of granting licensing rights to said modifications or improvements in timely fashion and under commercially reasonable terms.

11.7 Termination of this Agreement shall not release CSU and LICENSEE from any obligation that matured prior to the effective date of such termination. Articles 1, 9, 10, 11 and 14 shall survive termination. LICENSEE and any sublicensee may, however, after the effective date of such termination, complete and sell LICENSED PRODUCTS in the process of manufacture and sell all LICENSED PRODUCTS already in existence at the time of termination, if LICENSEE pays CSU as required by Article 3 and submits the reports required by Article 6 of this Agreement.

11.8 Upon termination of this Agreement for any reason, any sublicensee not then in default may seek a license from CSU. CSU agrees to negotiate such licenses in good faith, under reasonable terms and conditions.

ARTICLE 12 - PAYMENTS, NOTICES, AND OTHER COMMUNICATIONS

12.1 Any payment, notice or other communication required by this Agreement shall be sufficiently made or given on the date of mailing if sent by recognized express carrier or certified first class mail, postage prepaid, addressed to CSU or LICENSEE at its address below or as it designates by written notice to the other.

For CSU:

Technology Transfer Office
Cleveland State University
2121 Euclid Avenue
Cleveland, OH 44115-2214
(216) 667-2125; FAX (216) 687-3736

Copy to: Office of General Counsel

Cleveland State University
2121 Euclid Avenue AC 327
Cleveland, OH 44115-2214
Attn: General Counsel

For LICENSEE:

Amplified Wind Solutions LLC
2190 Professor Ave.
Cleveland, OH 44113
(614)579-7331

Attn: Nicole Zmij

ARTICLE 13 - REPRESENTATIONS AND WARRANTIES

13.1 LICENSEE represents and warrants that it has the full corporate power and authority to enter into this Agreement, that this Agreement constitutes the binding legal obligation of LICENSEE, and that the execution and performance of this Agreement by LICENSEE will not violate or conflict with any other agreement to which LICENSEE is a party or by which it is bound or with any law, rule or regulation applicable to LICENSEE.

ARTICLE 14 - MISCELLANEOUS PROVISIONS

14.1 This Agreement shall be construed, governed, interpreted and applied according to Ohio law, except that questions affecting the construction and effect of any patent shall be determined by the law of the country in which the patent was granted.

14.2 CSU and LICENSEE acknowledge that this Agreement sets forth their entire understanding concerning the subject matter of this Agreement, and no modification of the Agreement will be effective unless both CSU and LICENSEE agree to it in writing.

14.3 The provisions of this Agreement are severable. If any provisions of this Agreement are determined invalid or unenforceable under any controlling body of law, such invalidity or unenforceability shall not affect the validity or enforceability of the remaining provisions.

14.4 LICENSEE agrees to mark the LICENSED PRODUCTS sold in the United States with all applicable United States patent numbers. All LICENSED PRODUCTS shipped to or

sold in other countries shall be marked to comply with the patent laws and practice of the country of manufacture or sale.

14.5 The failure of either CSU or LICENSEE to assert a right or insist upon compliance with any term or condition of this Agreement shall not constitute a waiver of that right or excuse a similar subsequent failure to perform any such term or condition by the other.

14.6 LICENSEE shall not use, either directly or indirectly, the name of Cleveland State University, or any of their officers, employees, students or board members in any publicity or advertising unless a copy is submitted to and approved in writing by CSU, however, for purposes of the Clean Energy Challenge being Sponsored by the Department of Energy Clean Energy Trust (the "Competition"), LICENSEE is granted permission to use the name of Cleveland State University, and employees or students as necessary to compete in the Competition.

14.7 LICENSEE agrees to comply with all applicable laws and regulations. In particular, LICENSEE understands and acknowledges that the transfer of certain commodities and technical data is subject to United States laws and regulations controlling the export of such commodities and technical data, including all Export Administration Regulations of the United States Department of Commerce. These laws and regulations prohibit or require a license for the export of certain types of technical data to certain specified countries. LICENSEE agrees to comply with all United States laws and regulations controlling the export of commodities and technical data, to be solely responsible for any violation of such laws and regulations by LICENSEE or its sublicensees, and to defend and hold CSU harmless if any legal action of any nature results from the violation.

14.8 LICENSEE may not assign this Agreement without the prior written consent of CSU.

14.9 Force Majeure. In the event any Party hereto is prevented from or delayed in the performance of any of its obligations hereunder (other than the payment of monies due and owing) by reason of acts of God, war, terrorism, strikes, riots, storms, fires, electrical or telecommunications outages or any other cause whatsoever beyond the reasonable control of the Party, the Party so prevented or delayed shall be excused from the performance of any such obligation to the extent and during the period of such prevention or delay, provided that such Party takes all reasonable steps to overcome such cause(es) as soon as is reasonably possible.

14.10 Nothing contained in this Agreement will be deemed to place the parties in a partnership, joint venture or agency relationship and neither party will have the right or authority to obligate or bind the other party in any manner.

14.11 This Agreement may be modified upon mutual written consent of the parties.

14.12 This Agreement may be executed in two or more counterparts, each of which will be deemed an original, but all of which taken together will constitute one and the same instrument.

The authorized signatures of CSU and LICENSEE below signify their acceptance of the terms of this Agreement as of the first date written above.

CLEVELAND STATE UNIVERSITY

By:

Name: Leonard D. Young

Title: Director Technology Transfer

AMPLIFIED WIND SOLUTIONS LLC

By:

Name: Nicole Zmij

Title: Chief Executive Officer

APPENDIX A

PATENT RIGHTS

United States Patent
Rashidi

(10) **Patent No.:** **US 7,540,706 B2**
(45) **Date of Patent:** **Jun. 2, 2009**

WIND HARNESSING SYSTEM

United States Patent
Rashidi

(10) **Patent No.:** **US 7,679,209 B2**
(45) **Date of Patent:** **Mar. 16, 2010**

WIND POWERED ELECTRICITY
GENERATING SYSTEM

United States Patent
Rashidi

(10) **Patent No.:** **US 7,845,904 B2**
(45) **Date of Patent:** **Dec. 7, 2010**

WIND HARNESSING SYSTEM

United States Patent
Rashidi

(10) **Patent No.:** **US 8,002,516 B2**
(45) **Date of Patent:** **Aug. 23, 2011**

WIND HARNESSING SYSTEM

APPENDIX B

SEE ATTACHED WIND AMPLIFICATION TRACK SYSTEM PROTOTYPE EXHIBIT