Harnessing the wind: The cable dimension

White Paper

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CONTENTS

SYNOPSIS

This report is intended to give a general overview of the global wind turbine market, and provide information about how Nexans is serving this diverse and growing market.

The paper opens with a review of recent economic, technological and global trends, and then focuses on several challenges facing OEMs, concluding with the expectations they have of cable suppliers. The second section presents Nexans' overall solutions for wind power OEMs and explains Nexans' service approach.

This report is followed by an Appendix containing a list of recent Nexans success stories, innovations and references.

I. INTRODUCTION: OPPORTUNITY IS STILL BLOWING IN THE WIND

"So you're manufacturing blades for some of the most advanced wind turbines in the world; each one as tall as Air Force One is long; each is capable of generating enough power for hundreds of homes, just by harnessing the wind. So what's going on here, what each of the employees of Siemens is involved with, is helping stake America's claim on a clean-energy future."
Barack Obama, speech given at Siemens Wind Turbine Blade Manufacturing Plant, Iowa (2010)

1. Recent economic trends and developments

According to the *World Wind Energy Report 2009,*[1] even after the recent economic crisis, the global wind power industry is alive and well and living nearly everywhere. Installed wind capacity has been more than doubling every third year. World total installed capacity has now surpassed the 160,000 MW level, and we are seeing the highest annual growth rates (over 30%) since 2001.

All wind turbines taken together are generating electrical power equal to the output of Italy, the world's seventh largest economy. This represents 2% of global electricity production. Additional figures inform us that the wind sector is now earning profits of over 50 billion € annually and employing some 550,000 people (projected to reach 1 million by 2012).

Meanwhile, the *Global Wind 2009 Report*[2] published by the Global Wind Energy Council was equally upbeat and optimistic and largely confirmed the WWE's findings, calculating that more than 38 GW of new wind power capacity was installed around the world in 2009.

It remarks that the 50% drop in investment was offset by a number of government economic stimulus packages, many of which contained a "green" component. In fact, the UN Environment Programme (UNEP) released a report recommending that one percent of global GDP be invested in green technologies to boost employment and reduce greenhouse gas emissions.

Finally, Roland Berger, Strategy Consultants, released a report entitled *Wind energy manufacturers' challenges*[3] which saw 2009 only as a "short calm for the wind market." Among other things, it predicted that:

- Long-term annual growth will continue at 17% until 2012
- Governments will continue to invest heavily in wind
- OEM profits will come under pressure by the demand for lower turbine costs
- Global delivery means that local supply networks must developed
- There will be fewer but larger orders which will mean more competition
- With scores of new entrants, an intense battle for market share is to be expected

[1] Free download at http://www.wwindea.org/home/images/stories/worldwindenergyreport2009_s.pdf , while the invaluable standard yearbook, *Wind Energy International 2009/2010* can be ordered at the same website.
[2] Free download at http://www.gwec.net/fileadmin/documents/Publications/Global_Wind_2007_report/GWEC_Global_Wind_2009_Report_LOWRES_15th.%20Apr..pdf
[3] A free PDF is obtainable at http://www.rolandberger.com/media/pdf/Roland_Berger_Wind_energy_20090904.pdf

The RB paper's subtitle is "Using turbulent times to become fit for future" and offers advice how to capture market, leverage technology, enhance supply chain, and restructure operations in an overall effort to access key market while keeping costs low.

2. Technological trends

Aside from social, economic and political realities, the world of wind power is also being driven by technological change which always strives to harness innovations and new materials and systems to "do more with less."

The NORDIC Conference (2009)[4] which explored technology trends of Wind Power Generators concluded that although wind power used to be a very OEM-driven market, it is increasingly a power-producer-driven market interested in increased reliability, higher return on investment and lower operational and maintenance costs.

This has raised questions about new more-reliable and efficient generator technologies, like PM synchronous, medium-speed generators (also called hybrid, integrated, or Multibrid concepts) which offer high efficiency and a lower top weight. However, fast market growth, and increase in turbine size and power, and several competing concepts means that these new technologies are not yet stabilized.

It seems that although size matters, onshore turbines are typically 1.5–3 MW, and offshore turbine larger in size, from 3–6–10 MW, with different technologies being used both on and offshore to optimize the annual energy yield for power producers.

In 2010, some fifty wind energy professionals were interviewed for *The Wind Energy Operations & Maintenance Report*.[5] The common consensus concerning O&M costs was that: "Efficiency is the most critical item in our business case. We need tangible strategies for controlling costs."

According to data from various turbine types, costs are estimated to increase on the average around 250% over their 20-year lives. This means that innovative ways have to be found, both through new rotor and turbine designs, and new methods of monitoring and operating turbines and windfarms, to bring costs down, especially when the units come out of warranty. With this in mind, wind technologies are working to resolve a number of challenges:

[4] An overview of this Conference can be consulted at http://www.eszk.org/content/archivum/ieee/nordic/Technology%20Trends%20of%20Wind%20Power%20Generators%20-%20Raimo%20Sakki.pdf

[5] See Press Release upon publication at http://www.renewableenergyworld.com/rea/partner/first-conferences/news/article/2010/06/wind-turbine-operations-and-maintenance-cost-trends-provide-a-glimpse-into-the-state-of-the-industry

- Modularization, standardization and a significant decrease in the number of components
- Lower weight, especially in the nacelle, achieved by new lighter and more compact designs
- Larger turbines for more efficient energy harvesting, and higher electrical power transmission
- New materials to resist environmental damage, including weather, sea conditions and lightning
- Increased reliability and efficiency, especially in gearboxes (which account for 40% of failures)
- Lower installation costs, longer operational lifetime, and minimal service and maintenance
- Expanded telecom capacity for condition monitoring, preventative maintenance and control

3. A global scorecard[6]

The **United States** installed 10 GW in 2009, maintaining its leading position in terms of total installed capacity: 35 GW. Recent wind energy projects accounted for about 40% of new power generation capacity, and wind power now satisfies 2% of the country's total electricity demand. Texans remains the leading state (+9 GW) followed by Iowa (3.67 GW).

China again served as a locomotive of the wind industry by adding nearly 14 GW within a year, more than doubling installations for the fourth year in a row. China also installed the first major offshore wind farm outside of Europe: a 21 MW wind farm near Shanghai. In addition, the growing wind power market in the country has encouraged domestic production of wind turbines and components. Two Chinese companies, Sinovel and Goldwind are now among the world's top five turbine OEMs, and are moving into international markets. The Wind Base program will soon build 127.5 GW of wind capacity in six Chinese provinces.

Position 2009	Country / Region	Total capacity end 2009 [MW]	Added capacity 2009 [MW]	Growth rate 2009 [%]	Position 2008	Total capacity end 2008 [MW]	Total capacity end 2007 [MW]	Total capacity end 2006 [MW]
1	USA	**35.159,0**	9.922,0	39,3	1	25.237,0	16.823,0	11.575,0
2	China	**26.010,0**	13.800,0	113,0	4	12.210,0	5.912,0	2.599,0
3	Germany	**25.777,0**	1.880,0	7,9	2	23.897,0	22.247,4	20.622,0
4	Spain	**19.149,0**	2.460,0	14,7	3	16.689,0	15.145,1	11.630,0
5	India	**10.925,0**	1.338,0	14,0	5	9.587,0	7.850,0	6.270,0
6	Italy	**4.850,0**	1.114,0	29,8	6	3.736,0	2.726,1	2.123,4
7	France	**4.521,0**	1.117,0	32,8	7	3.404,0	2.455,0	1.567,0
8	United Kingdom	**4.092,0**	897,0	28,1	8	3.195,0	2.389,0	1.962,9
9	Portugal	**3.535,0**	673,0	23,5	10	2.862,0	2.130,0	1.716,0
10	Denmark	**3.497,0**	334,0	10,6	9	3.163,0	3.125,0	3.136,0

Future prospects worldwide
(World Wind Energy Report 2009)

Germany is still in 3rd place having accumulated nearly 26 GW. It continues to lead Europe, adding 1.9 GW last year. Wind accounts for about 7% of the country's total power consumption, and the industry now employs 100,000 people.

[6] All of the figures cited are drawn from the *World Wind Energy Report 2009* and *Global Wind 2009 Report.*

Next comes **Spain** with the highest new installations of any European country (2.5 GW) bringing its total to 19 GW. Wind energy now represents Spain's third largest power generation source, covering 14.5% of the country's electricity demand.

Like China, **India** has moved up on the list in terms of cumulative installed capacity, now totaling 11 GW. Not only is substantial growth expected in the near future, it is also becoming an emerging producer of wind turbines.

Italy, France and the **UK** (6th, 7th and 8th place) all showed strong growth, adding just over 1 GW each to their wind power supply, while **Portugal** and **Denmark** retained their 9th and 10th position, with an accumulated capacity of about 3.5 GW each. It should be noted that in the last two countries, wind accounts for 15% and 20% of electricity, respectively.
Europe has traditionally been the world's largest market for wind energy development and has continued to see strong growth, accounting for 39% in terms of total new generation capacity. However for the first time, Europe accounts for less than half of total capacity worldwide. This is because of the dynamic progress in Asian markets and because of developments elsewhere as well:

- **Canada** has had a record year with nearly 1 GW of new capacity, with wind now accounting for 1.1% of electricity production
- **Brazil's** new capacity tripled last year and the country is soon likely to meet a 1.1 GW target.
- **Mexico's** installed capacity has more than doubled.
- **Australia** has doubled its capacity in just two years, with 51 windfarms supplying 1.6% of demand.
- Wind now supplies over 3% of **New Zealand's** demand.
- In North Africa, wind power continues to expand in **Morocco, Egypt, Tunisia** and **Kenya**, with Morocco seeing the largest recent addition of new capacity.

4. New OEM challenges and their impact on cables

Onshore wind turbines are still playing an important role in countries with a large landmass, like the US and Canada, or extensive upland areas, like Spain. However, offshore wind power has increasingly become an alternative in land-scarce Europe and the developing world. Over the next few years, offshore wind capacity in Europe alone is expected to grow by over 1 GW annually.[7] Furthermore, according to the European Wind Energy Association:

> Globally, the offshore wind market is expected to install nearly 43 GW of wind energy by 2020, and has recently accumulated wind turbine orders exceeding 6 GW, covering demand through 2013. The $10 billion (7.8 billion €) offshore sector is predicted to surge to $30 billion (23.4 billion €) in the next decade and Europe is set to lead global offshore expansion with around 76% of global offshore wind installed between 2009 and 2020.[8]

Each kind of wind turbine and wind park infrastructure has its own demands in terms of cabling. Factors like nacelle design, size, and customization are bound to affect the kinds of cables chosen by Original

[7] According to the Synergyst report: "Global Offshore Wind Power Market – Trends and Outlook (2010-2013): http://www.thesynergyst.com/reportdetails.aspx?pg=&%20sec=&key=Global+Offshore+Wind+Power+Market+%E2%80%93+Trends+and+Outlook+%282010-2013%29

[8] See "Global Wind Power Projects for 2010" at http://energy-conservation.suite101.com/article.cfm/global_wind_power_projections_for_2010 , based on data from the European Wind Energy Association

Equipment Manufacturers (OEMs), while location, land versus water installation, distances, or connection to a local or distant grid affect the kind of cable used, as well. Since so many, wind parks are remotely controlled, the skilful integration of energy and telecom cables is essential.

Manufacturers, installers, operators, and merchant power companies face numerous challenges in meeting their 2020 objectives.

4.1 Profitability

If wind power is going to successfully compete with other forms of power generation (like coal, or oil & gas) it must be a financially attractive alternative. Cost optimization can come from using standard, interconnective solutions wherever possible in tower and nacelle construction. However, special cables can also play a significant role by adding value, improving efficiency, providing protection, and prolonging a turbine's operational life.

Wind turbines represent 75% of the capital cost of an onshore project, but already costs are falling. According to Acciona Energia, turbine costs are likely to decline by 20% in the next three years.[9] OEM's will have to find creative ways to cope with this inevitable decrease.

In developing markets like China and India, import replacement objectives are met by setting up local plants for equipment, and using local producers wherever possible These local suppliers must not only be capable of delivering standardized low or medium-voltage cables – where mainly cost is a determining factor – they must also offer a full range of cables and cable solutions including high-end cables that add a new dimension to wind turbines, whether it be increased control, easier installation, lower maintenance costs, or higher reliability, efficiency and fire performance.

4.2 Global supply

In 2009, altogether 82 countries used wind energy on a commercial basis, out of which 49 countries increased their installed capacity.[10]

Thus, both emerging and established OEMs are global organizations chasing a world market. They are aware that if wind power is going to be a universal technology, it must be applicable anywhere, and that means assuring a supply of all equipment, cables and components worldwide, even if it means building local factories.

Although they usually have numerous cable suppliers available locally, it is evident that the wind power market has a real need for specialized expertise. Few modern industries combine such a diverse number of needs: onshore/offshore, OEM/infrastructure, energy/telecommunications. Cables must be able to withstand torque, prolonged vibration, sea-water corrosion, and continue to operate under fire conditions.

[9] Quoted in Roland Berger's *Wind energy manufacturers' challenges.*
[10] See World Wind Energy Report 2009.

Given the fact that wind turbines and infrastructure are often difficult to access (in remote mountainous areas or offshore), logistics is a key concern as well, with sequential delivery as a priority. Cable suppliers must also be able to assure prompt delivery, training and support services.

To eliminate the complexities of multiple sources of supply, wind power players ideally look for one cable company that can satisfy all of these needs worldwide, from initial feasibility studies and design to testing, training, kitting, maintenance, and lifetime support.

4.3 Innovation and upscaling

Few recent industries have shown such a vertical learning curve and rapid development as wind power. The most dramatic improvement is in size and performance. Twenty-five years ago, wind turbines generated 25 kW each. Today's onshore models generate on average 2.3 MW, and offshore from 3-6 MW, but 10 MW is definitely on the horizon.

Innovation is making it possible to capture more energy through larger blades, improved power electronics, composite materials and taller towers. The International Energy Agency (IEA) estimates that the price of wind turbines is reduced by 20% each time their average size doubles. Also, the industry has developed turbines to work at lower wind speeds, and new power gains have been achieved by reducing weight and the number of moving parts in the turbine using gearless generator systems.

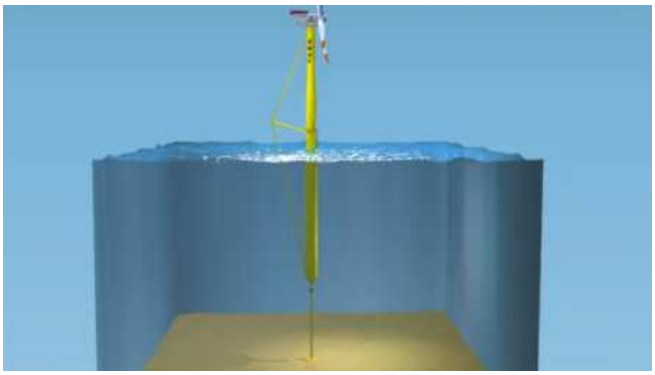
Since the building of towers is the biggest investment, re-powering (i.e. installing larger generators on existing towers) is going to be a major challenge. In fact, upscaling will account sizable portion of new installed capacity by 2014. Already, in Germany, wind turbines which are only 7-8 years old are being replaced with larger models, and that can even include complete tower replacement.

For the cable business, this kind of projected growth requires cabling and cabling solutions with adequate headroom to handle change, That is why medium-voltage cables are already replacing low-voltage cables in towers, in order to accommodate the fact that transformers are being moved up to the nacelle for turbines with high power output. To make weight gains, there is also a trend towards low-voltage aluminum cables. And there is increasingly more fiber in the tower for surveillance, condition monitoring, and control.

4.4 Meeting offshore opportunities

In several countries around the world, available land sites are saturated. There is also a public concern about visual and noise nuisance for residential areas, designated land, national parks, uplands of outstanding natural beauty, etc. Thus, there is underway an inevitable move offshore, and in some cases, considerably offshore: from 10 to 50 kilometers. The advantages are stronger and more stable winds, and the possibility of installing much larger wind turbines.

For example, Norway is currently planning to build the world's largest turbine, a 162-meter-tall floating "sway" turbine. It is also the most powerful, generating 10 MW to power remote offshore oil & gas installations or 2,000 onshore homes. Instead of resting on the seafloor, it consists of an enormous hollow pole which is filled with ballast beneath the water level creating a low center of gravity. This allows it to be anchored to the seabed far out at sea where winds are stronger and more consistent. It also has the advantage of being able to tilt from 5–8° and turn with the wind.[11]



"Sway" turbines

Within the European context alone, it is estimated that a sea area of 150,000 square kilometers with a water depth of less than 35 meters could be available for offshore schemes.

Wind turbines with a capacity of 454 MW were added in 2009, with major new offshore wind farms in Denmark, the UK, Germany, Sweden and China. By the end of the year, offshore wind farms could be found in 12 countries, ten of them in Europe and some minor installations in China and Japan. Total installed capacity amounted to almost two GW, i.e. 1.2% of total wind capacity worldwide.

From the cabling point of view, this will require cables that are resistant to salt-water corrosion and abrasion caused by sea currents and waves. It will also require an expertise in offshore technologies that assure that all in tower telecommunications and energy cables merge seamlessly with submarine cable infrastructure.

5. Incentives and customer expectations

OEMs, module manufacturers, engineering contractors and installers all have high expectations of a cable manufacturer:

- A complete range of quality wind turbine cables and accessories
- Light, flexible cables that can handle torque, temperatures, oil, heat, vibration
- Technical innovation that keeps pace with the wind industry
- Customized products and services, sets, kits, interconnectivity and accessories
- Easy assembly and installation, low failure rate, and exceptional durability
- Worldwide presence and expertise ensuring steady supply for international projects

[11] See http://www.sway.no/?page=206&show=198&news=745

II. NEXANS: WINDLINK® FOR WIND TURBINES WORLDWIDE

Rather than just provide cables and components, Nexans' widely-recognized WINDLINK® solutions can outfit a complete wind turbine, assuring that all elements are fully interoperable and compatible.

When new products are developed – like light aluminum or high-temperature energy cables – rigorous tests are done with connectors and power accessories under live conditions and mechanical stress to ensure compatibility and durability as an entire system.

Nexans produces every cable in the nacelle, tower and base, for both energy and telecommunications. Moreover, it manufactures active equipment, like intelligent Ethernet switches that can consolidate diverse monitoring, surveillance, diagnostic and control applications.

Nexans has a proven reputation for cable reliability and technical expertise, and substantial production capacity worldwide to assure OEMs of product availability, especially in emerging markets. High-quality cables and components keep wind parks operating, avoiding power losses and costly shutdowns.

WINDLINK®: a full range of cable solutions

1. WINDLINK® high-performance cables

1.1 For towers

Nexans manufactures **low-voltage loop rubber cables** (1kV) which reliably transmit energy produced in the generator to the transformer, usually located at the base of the tower. They come in Low-Smoke Zero-Halogen (LSZH) versions, and are also oil, abrasion, UV and ozone-resistant. Similar to the above are **medium-voltage loop rubber cables** which can handle up to 35 kV between the nacelle-based transformer and the switchgear at the base. For fixed applications, Nexans produces **low-voltage fixed installation cables** in both copper and aluminum.

Low-voltage loop rubber cables

Although aluminum singlecore are larger, they weigh half as much, making them cheaper, and easier to handle and install in high towers. Connecting the loop cable and bottom of the tower are **medium-voltage fixed installation cables** which are rubber-insulated or XLPE, halogen or halogen-free, and carry from 12/20 kV or 18/30 kV.

1.2 For nacelles

Nexans offers **low-voltage 120°C flexible cables** with EMC (Electromagnetic Compatibility). These silicone cables can endure intense heat (120°C). For large turbines (2.5–6 MW), **medium-voltage flexible cables** can withstand three full twists in either direction. Finally, **medium voltage 180°C singlecore cables** are used as ouput connections from the winding bars of Class H generators, and for current converter cabinets. These Siwo-Kul™ flexible, silicone-insulated connection cables carry high current in very hot conditions, and are also available in multicore versions.

Medium-voltage flexible cables

1.3 For both towers and nacelles

Nexans provides a wide range of cables and solutions. Flexible shielded **control cables** are used to carry energy (300V to 1 kV) and low frequency signals to control the motor drive or the generator for breaking, positioning or optimizing rotor RPMs. Special sheathing is available for ultra-low temperatures, while smaller LIHCH cables are halogen-free.

For condition monitoring, operations and control, Nexans has a wide choice of **electronic and data transmission cables**, ranging from special sensor cables (to measure wind-speed, temperature parameters) to Fieldbus cables used in parallel with energy cables to digitally control all electronic and mechanical devices, Profibus cables delivering up to 12 Mbit/s for complex control services, and data transmission cables offering Industrial Ethernet speeds. Encoder/feedback cables link the control unit to motors.

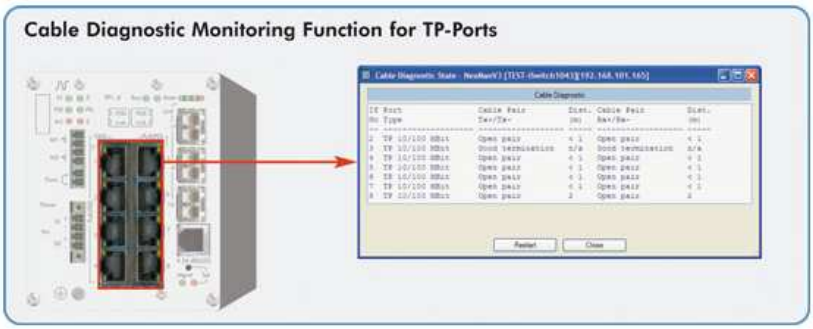
To assure high data transmission capacity for monitoring and control, Nexans' rugged halogen-free **fiber-optic cables** offer EMC in energy-dense areas. Their flexibility allows them to handle high torsion, and their larger cores make connectivity easier. Nexans also produces **fiber-optic accessories**, including a full range of indoor/outdoor waterproof and pressurized closures to protect, store and splice fibers. A range of cassettes and splicing frames optimize individual fiber management.

Built to withstand thermal cycling and tower vibration for the turbine's lifetime, Nexans **low and high-voltage connectors** offer protection, insulation and short-circuit stability. Safe-to-touch T-shaped connectors are designed for the new generation of compact switchgears and transformers, and can also accommodate the larger cross-sections of large turbines and cable-to-cable connections.

To facilitate assembly and installation, Nexans **low-voltage sets and pre-connectorized kits** which bundle energy, control and data cables into one harness, while **medium-voltage jumpers** are relatively

short lengths of MV cable which are equipped on both sides with accessories to connect generators, transformers and switchgears.

Active switch systems for communication and monitoring are small and rugged switch systems containing up to 3 fiber optic SFP (Small Form Factor Pluggable) uplink ports and 8 TP (twisted pair) copper ports to realize multiple applications via just one fiber. They are able to supply connected devices – like IP cameras, WLAN access points and IP telephones – with PoE (Power over Ethernet), and come with a fiber optic and copper cable diagnostic monitoring function.

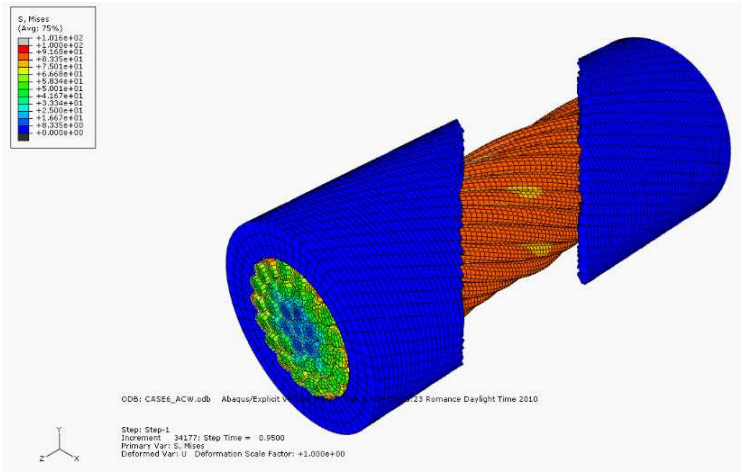


Active switch systems

2. Solutions and services beyond manufacturing

Nexans does more than just sell cables and components to the growing wind power industry; it is continuing to invest heavily in research and development to find ways of improving wind turbine performance. Nexans has the cable industry's most extensive R&D capability, with 450 researchers and technicians trained in all disciplines, including materials science, cable and systems design, and cable/network testing and simulation. Nexans often works alongside customers in our international research center, and in our 10 competence centers on four continents. Serving a global business like wind is facilitated by our industrial presence in 39 countries.

A worldwide presence around the world



Mechanical Simulation (Nexans Research Center)

Recent wind-turbine achievements include:

- Modifying cables to accommodate much larger turbines and generators
- Replacing low-voltage with medium-voltage cables for wind turbines with transformers located in the nacelle
- Improving flexibility to deal with high-torsion and vibration
- Creating new insulations for heat/cold/oil resistance and fire performance
- Developing lighter aluminum cables for important cost savings
- Integrating both telecom and energy functions wherever possible
- Increasing the data carrying capacity of all transmission cables
- Finding new ways to monitor and manage wind turbines remotely
- Developing technical and service solutions for wind turbine sustainability

Since today's wind park developers come from a diverse background, Nexans is increasingly called upon to give its considered opinion and advice concerning cable type, most appropriate design, configuration and so on. This kind of technical support, especially at the project design stage, allows OEMs to choose the best and most cost-effective cable solution according to location and projected use.

Nexans considers that it is not just selling a cable product, but an integrated solution to wind turbine manufacturers that includes a broad range of cables, accessories, connectors, sets, kits and even active switch systems. Along with this go a host of services that combine material and design science, engineering, testing, prototyping, training in safe installation and maintenance, and eventual upscaling and recycling in keeping with our own sustainable development program.

By offering a turbine-focused global solution, Nexans provides the extensive resources (in energy and telecommunications) needed to help the wind power industry achieve its ambitious objective of providing 12% of the world's electricity by 2020.

III. APPENDIX: Some recent Nexans success stories, innovations and references

- Nexans developed new test equipment to make our cables more reliable and efficient. To find a more flexible core for LV and MV cables, this test bench reproduces the way cables move in a wind turbine.

- To GE Wind and Nordex, Nexans delivered complete cable kits for wind turbines, including control cables, optical fiber and energy cables. The kits make installation rapid and easy. Connectors are pre-installed, avoiding waste and reducing faulty cable preparation.

- Nexans manufactured and cut ready-to-install cables for Alstom Ecotècnia. With one purchase order, the company can thus assure a high level of control and logistics during turbine assembly and installation.


Plug and play kits for Alstom Ecotécnia

- Nexans has supplied Alstom Ecotécnia and Nordex with LV loop rubber cables. The compounds developed can operate from -40°C to +90°C, making them ideal for both hot and cold climates.

- Nexans delivered control cables to Escha, WinWinD and GE Wind. These oil-resistant cables are designed to last for 20 years and more.

- Nexans sells pre-cut and pre-connectorized fiber to GE Wind and other important manufacturers in Europe for easy "plug and play" installation.

- In Germany, Nexans (GPH) supplies thousands of LV and MV connectors and accounts for 90% of the UK MV connector market, while in China ABB is installing Nexans systems in Inner Mongolia.

[i]

[i] Photo credit: Nexans, ZanArtphoto