Improving LCOE by Training the Human Assets

Holistic operations knowledge and ongoing training are key factors in bolstering efficiency

By Shawn Lamb
Danish Wind Power Academy

When I worked for large international wind companies, like GE and Nordex, I saw entire infrastructures — engineering, EHS management, spare parts warehousing, SAP specialist, IT support, O&M schedulers, remote monitoring, process writers, etc. — created to support the operation. However, very few people actually climbed the turbines to do maintenance and troubleshooting. I have always considered the techs in the field to be the "all-stars" of the wind energy industry. But even the most experienced technicians need to be trained and re-trained on an ongoing basis. Without constant skills development, the rapid advances in wind technology will quickly surpass the expertise of even the most skilled technician.

Even the best turbine on the market — equipped with the most proven technology and boasting the longest and most reliable track record — can suffer catastrophic failures if the technician and support team don't know what they are doing. For example, when critical failures occur, as operators we are very good at pointing fingers at sub suppliers — like gearbox and bearing manufacturers — while overlooking the obvious O&M issues associated with that component. Maybe we should ask ourselves if the root cause was our own failure to keep the drivetrain correctly aligned, or if ignoring a "too high oil temperature" alarm for several months could have caused the failure instead.

Action at a Distance

The world's best work instructions (usually checklists) and technical support (sometimes thousands of miles away from the turbines) only become efficient and functional if you have technicians with the right attitude and skills to execute them correctly. In my experience, the engineering and remote support personnel can only describe at a distance what they want checked or performed on site. It is up to the site technicians to understand the turbine technology well enough to finish up on site and get the issue resolved. The communication and language between the back office and the field techs must be aligned in order to maximize the efficiency of the teams. Harmonizing the understanding of technology between engineering, operations, and the site techs can only be accomplished through training, and it is vital for feeding back and forth improvements and information, which gives quicker response times.

Generation Mindset

Having the "generation mindset" to understand not only the technology, but the entire wind farm operation, is important for a technician. Understanding the business model of the wind farm and what is best for the bottom line is also important for those who are on the turbines every day, not just those in the office. Many times the technicians will make day to day decisions that can affect downtime and generation availability. For example, if there

is a non-critical warning about a filter that needs changing, but the turbine is producing well with a good feed in tariff, it makes sense to wait until a lower wind day to plan the replacement. Training staff to understand ways to make decisions like this, enables them with the generation mindset.

Technicians with the true generation mindset are usually hard to find and even harder to retain since management views them as ideal candidates. Given that there is a major "brain-drain" in the U.S. power generation industry, it may be a better option to hire and train entry-level techs into the generation mindset.

Developing our human assets

Technicians are taking on a huge responsibility when working

ALSO IN THIS SECTION:

on a multi-million-dollar power production facility. It isn't fair for a company to send a worker to these highly automated, robotic power plants and expect them to be just "arms and legs" on-site. The reality is that they have to be trained and developed over many years. In doing so you are building their confidence and equipping them with the knowledge and resources to do their jobs — for years to come. It's often difficult for those in the wind industry to clearly see how developing their "human assets" will have a direct and quantifiable return on investment.

In such a low-margin and reactive industry as wind, the idea of spending money on training technicians (beyond safety requirements) seems like an afterthought. In order for this industry to mature and take its place with other worker-centric industries we have to address the workforce development component.

The reality is that site specific training can save money and increase performance on these assets. It has been shown that per-unit turbine performance and LCOE can be improved by teaching technicians how to operate, maintain, and troubleshoot the turbines in the most efficient way.

Condition-based training

As far as I know, the only place that uses a methodology of "condition-based training" is the Danish Wind Power Academy, an independent training organization from Middelfart, Denmark. I think that this concept is so unique and effective that it is worth sharing.

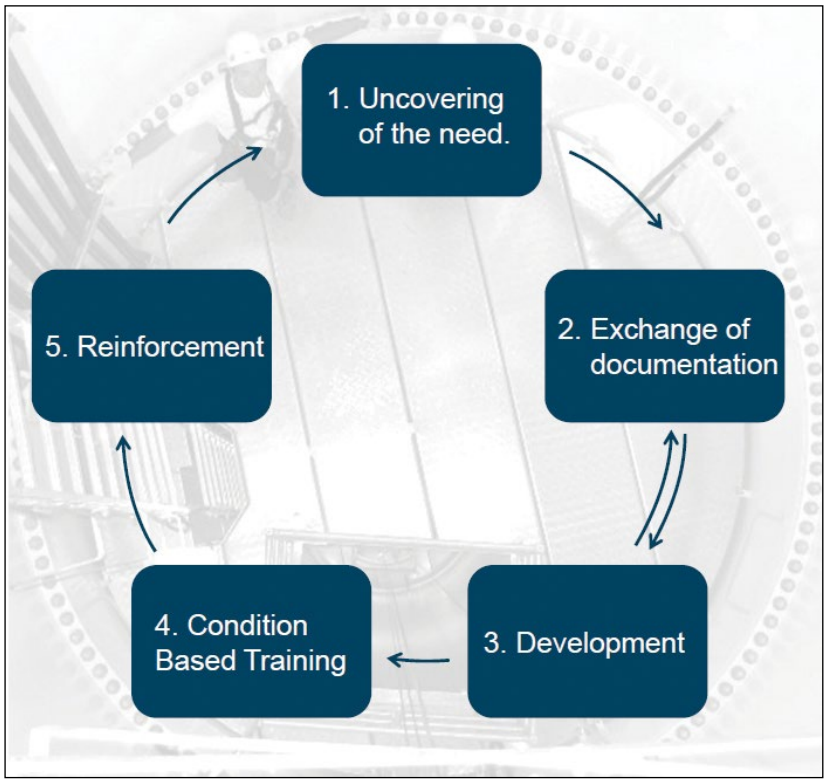
The process starts by uncovering the need for training at a particular site. This is done by analyzing the site performance for one year and deriving the top-10 downtime errors. Afterward, a skill-set analysis of the staff and technicians on site is done either through self-evaluations

or testing. The training is then customized around the "skills gap" of the operators as compared to the needs of the turbine. This training plan may include classroom, online, and on-turbine training. Most of time spent on the project is analysis and development. Only about 25 percent of the time is spent in actual training — whether in a classroom or on the turbines. There is also a continual learning component, where the instructors will follow the progress and changes (personal turnover) on-site to track progress in the O&M skills.

Case Study: Condition-based training

This "Condition-Based Training" has been a proven and successful technique for over a decade with various wind owners and operators around the world. For example, when the Danish Wind Power Academy set out to work with E.ON Climate & Renewables on its Papalote and Champion sites in Texas, the company was looking for an improvement in per-unit performance on over 460 MW of assets. The project included training the operational staff: risk, asset, operation, site management, lead techs, and assistant techs. The training was done with turbine-specific theory classes and with on-turbine training. The classes focused on the top downtime errors for each particular site and how to quickly fix or mitigate them.

By analyzing the performance before and then after, it was shown that there was a marked decrease in production loss within just six months after training. By optimizing the techs' skills towards what the turbine needed, the unplanned outage loss was minimized and the maintenance downtime was reduced. This type of team-based training also helped to boost morale on site, synchronize communication between teams, and contribute to employee retention.



Conclusion

In this new industry, it is important not to confuse technology for technicians. Even with the advancement in turbine technology, optimization techniques, and SCADA analytics, the turbine never performs better than those who are tasked with maintaining them. The workers that climb each day need to keep up with the increasing complexity of the wind turbines and aftermarket improvements. This can only be done by training them both in the classroom and on the turbines.

It has been shown that by employing a "condition based training" strategy on-site, operators can focus their staff on the specific errors that cause the most downtime and address them. This methodology will also help to develop a "generation mindset" amongst the technicians on site, which will ultimately lower the LCOE and improve performance.

Working Safely in the Blazing Summer Heat

Knowledge and precaution assist in avoiding jobsite heat emergencies

By Walter Christmas
Ecotech Institute

You wouldn't leave your dog in a car on a hot, sunny day. So, why would you leave your wind technician in a turbine to roast in the summer sun? Okay, seriously, heat stress is a very real concern that should not be taken lightly. Public service announcements warn us that a car can reach temperatures of 140° F within an hour in the sun. A wind turbine nacelle can get just as hot, especially when you consider that the gearbox can serve to heat things up from the inside out while solar energy works from the outside in.

According to the Center for Disease Control (CDC), "On average, 675 people die from complications related to extreme heat each year in the United States — more than tornadoes, hurricanes, floods, lightning or any other weather event combined." Heat cramps, heat exhaustion, and heat stroke affect thousands of Americans every year.

Company EHS policies often dictate safety measures that must be taken during these hot months. If these measures are officially written into the EHS policy, then OSHA requires that they be followed, even if they exceed official OSHA requirements. Shawn Lamb, CEO of Danish Windpower Academy Americas, said he remembers the Florida heat while rebuilding roofs for the disaster relief effort after Hurricane Charley. "We could only work 20 minutes at a time in shifts." Lamb, also a former instructor for GE Wind, said, "Palm Springs was the only GE site that would allow technicians to wear shorts." Shorts, normally considered to be less-than-ideal attire in terms of safety in a wind turbine, can be considered to be a hazard mitigation tool for dealing with extreme heat.

Three Stages of Heat Emergencies

While in charge of multiple crews as the Operations Manager for BIS Salamis and Resources Technician for Vestas, Ecotech Institute's Wind Energy Program Director, Auston Van Slyke kept a close eye on the technicians under his authority. "Remember, it starts with cramps and starts getting dangerous with exhaustion. If you reach heat stroke, permanent damage has already been done." As a part-time American Red Cross First Aid/CPR/AED instructor, Van Slyke trains wind turbine technicians how to recognize the three stages of heat emergencies:

Heat Cramps — The first stage of a heat emergency, heat cramps, are quite simply recognizable by the victim as muscle pain and tightness. Since these are also symptoms of a really effective workout at the gym, previous recreational activity, or overtaxing muscles during a work shift, it can be easily overlooked as a heat-caused issue. Such an oversight might allow the heat emergency to escalate to the next stage.

Treat heat cramps by moving to a cooler environment, resting, and drinking water and electrolytes at a slow but steady pace. Cramped muscles can be massaged and stretched for relief. The victim should not rule out seeking medical attention.

Heat Exhaustion — According to the American Red Cross (http://www.redcross.org/prepare/disaster/heat-wave), in addition to heat cramps, the second stage of a heat emergency can include any or all of the following symptoms:

- dizziness
- headache
- irritability
- extreme thirst
- nausea or vomiting
- pale skin
- heavy sweating
- fainting

In most cases, treat heat exhaustion the same way that you would heat cramps, but definitely seek medical attention right away. If the victim is vomiting or has fainted, do not make them drink water until these symptoms have passed. Heat exhaustion can escalate quickly to a potentially fatal condition.

Heat Stroke — Heat stroke is the most serious of the three stages of heat emergencies. In addition to all of the symptoms noted for heat exhaustion, the American Red Cross advises that heat stroke can include the following:

- body temperature over 105° F
- irrational behavior
- confusion
- rapid, shallow breathing
- rapid, weak pulse
- seizures
- loss of consciousness

A victim of heat stroke should be considered to be in a very serious condition. Call 911 immediately! The victim's body is past the point of having any ability to cool itself through the process of perspiring. While awaiting the emergency response, apply cool, damp cloths to the victim's neck, face, chest, arms and legs. Ice or cold packs, if there are any around, can be applied to the underarms, wrists and groin. A body temperature at or above 105° F will often lead to some level of brain damage and possibly even death, so it is critical to help the victim to reduce his to her body temperature while waiting for help to arrive.

Preventing heat stress

Awareness — Knowing the risks and watching for the signs of heat stress in both our coworkers and ourselves is key to working safely in a hot environment. Be especially aware of the onset of symptoms experienced by new employees. OSHA reminds us that it can take some people two to three weeks to acclimatize to a hotter environment as well as to the strenuous labor of working on wind turbines. New employees will often overwork themselves to prove themselves to veteran technicians; summer heat can turn this effort into a dangerous situation quickly. Assign less strenuous tasks for the new guys and gals until they can be trusted to work safely in the heat. Similarly, carefully watch even experienced coworkers who are returning from a two to three week vacation where they possibly spent their time enjoying cooler temperatures.

Hydration — Veteran turbine troubleshooter and wind energy instructor, Derek Johnson, has seen a common pattern amongst wind technicians. "So often you see wind techs neglect hydration because they are so focused on the task at hand," Johnson comments. OSHA recommends four cups (32 ounces) of water every hour. One cup every fifteen minutes is preferable to guzzling the full 32 ounces on the hour. Do not exceed six cups per hour as this

can deplete your body of electrolytes and cause other health complications that, if extreme, can be fatal. Mixing water with an electrolytic sports drink can help with this. Small hydration packs of powdered electrolytes, like the ones made by Sqwincher™, can be carried in a worker's pocket and mixed with water when needed. Alcohol and caffeine may dehydrate a body more than they help to hydrate one. Avoid alcohol consumption in general during the hottest periods of the year, and choose decaffeinated drinks instead. Did I lose you there, dear reader?

Reduce Workplace Temperature– Contrary to popular belief, fans do not cool the air. They do however increase evaporation from the skin, which has a cooling effect on the body. Placing some fans strategically in the nacelle to circulate air is a very easy measure with a huge reward. Be advised, however, that if a heat stressed person has reached the point that they stop sweating, a fan will have little effect, and at this point medical attention is past due. Ensuring maximum natural ventilation through a nacelle can help, so open any hatches that don't pose their own hazards to technicians such as any that a technician could fall through. If you've ever felt the air rush up a tower when the roof hatch of a nacelle has been opened, you can appreciate what a relief this can be. Also, whenever feasible, shutting down a turbine early to let the gearbox cool is a measure that comes with a small but worthwhile production price tag. Scheduling strenuous tasks for the early morning or evening hours is a common practice for many sites. Many companies will require or advise site managers to schedule the workday much earlier in the day during the summer months. Reporting for work at 5 a.m. may not sound like fun, but clocking out in the early afternoon is a nice perk.

Reduce Body Temperature — Everyone knows that standing in front of a fan is the place to be on a hot day. Take short breaks frequently to cool off; You won't be seen as a workplace hero by skipping breaks if it results in you being lowered to the ground in a rescue procedure. For that matter, encourage your coworkers to take cooling breaks as well. Workers can buy neckbands and pads with dried polymer crystals inside. These crystals swell to a gel in cold water that cools the skin and blood vessels within. Some bands and pads are made specifically for industry and construction workers and, when used according to the manu-

facturers, will not interfere with the effectiveness of personal protective equipment (PPE)

Monitoring the Risk

OSHA offers a free app for smartphones and tablets to monitor the heat risk level with real-time updates of current temperatures. The app also provides the signs and symptoms listed earlier in this article as well as advised treatment for each of the three conditions. OSHA's app also provides a calculator to combine temperature and humidity to determine the heat index often denoted by the term "feels like". For example, if the thermometer reads 108° F and humidity is at 83%, the heat index will tell you it "feels like 212° F" which is the temperature at which water boils at sea level. Ouch!

If the site has a technician or manager monitoring the SCADA system and watching for thunderstorms, this person can also keep an eye on outside temperature readings. The SCADA-watcher should engage in frequent communication with technicians in the turbines to remind them to rest and drink water, check nacelle heat readings, and to be ready for the distress call that might come.

At some point, common sense and a concern for safety will compel a site manager to simply shut down all repairs and maintenance for the day. When that happens, go home, stick your face in the freezer for a minute, drink a frosty non-alcoholic beer or decaffeinated iced coffee, and enjoy your time watching the Weather Channel to see what tomorrow will bring.

Moventas opens multi-brand service shop in Minnesota

Facility added to meet growing demand in the Midwest

Moventas

Moventas, one of the world's leading wind gear manufacturers and service providers, has opened a wind gearbox service workshop in St. Paul, Minnesota, answering the growing demand for multi-brand expert wind drivetrain service in the Midwestern U.S.

Moventas is expanding its network of high quality wind gearbox service centers in North America. With the addition of the St. Paul facility, Moventas is now within a day drive from nearly all of the installed North America fleet with locations in Oregon, Texas, Canada, and now Minnesota.

"Our four existing service and manufacturing facilities in North America are all located in the main wind energy corridors to offer our customers fast and responsive services," said Mike Grunow, vice president of sales and marketing at Moventas Americas. "We are excited to be investing in the Midwest with our St. Paul facility, where we are now local and able to apply our 35 years of experience as a leading wind industry service provider."

The investment is part of Moventas' service strategy, aiming to localize its operations and minimize wind farm owner lifecycle costs. Moventas services its own brand as well as most gearbox brands in the market and will be able to serve clientele in the rapidly growing Midwest area with full capability.

Plans for an open house and customer tours of the new facility are scheduled for this summer. In addition to its workshop service capabilities, Moventas plans to co-locate a custom Mobile Service Unit in the Midwest to carry out cost efficient up-tower field repairs. The self-contained, climate-controlled mobile service units are available for field work, including full helical and planetary replacements with specially fabricated Moventas tooling.

— Source: Moventas

3M Wind Energy

Continuing its longstanding tradition of innovation, 3M takes the approach of direct collaboration with the industry in developing its wind energy solutions

By Stephen Sisk

At the dawn of the last century, a group of investors pooled their resources and starting a mining operation in Minnesota. The group was looking for corundum, a valuable mineral used in abrasives.

The mining efforts fell short of expectations when it turned out the mine contained anorthosite — a different mineral which didn't fit the intended applications.

Instead of corundum, the investors were left with a conundrum. The group had to re-focus and innovate, or face financial ruin. Over the next decade or so, the company actively sought out the applicational needs of its customers in the abrasives industry and implemented a problem-based approach to meeting those needs.

That spirit of innovation and application-based approach are still apparent today for the company orginally known as Minnesota Mining and Manufacturing Company, now simply 3M. Throughout more than a century, the company has grown into a $30 billion-plus global giant, with a product portfolio ranging from high-tech health care to home arts-and-crafts to the wind energy industry.

"We are a materials company. We come up with material solutions for the customer," said Santhosh Krishna Chandrabalan, technical business development leader with 3M's Renewable Energy division. "When there is a particular need with a customer, we partner with the customer to understand what their needs are, and we can actually develop the right materials or solutions for them for that particular market."

The renewable energy division of 3M was built on that philosophy. While the company's products had been used by customers in the renewable energy field for some time, in 2009, near the onset of rapid growth in the wind industry, the company saw the need to have a dedicated segment of its organization specifically to serve the needs of those customers.

"We are always looking at new technologies and new markets — areas where we can add significant value," Chandrabalan said. "Even though we were active in the renewable energy area for a very long time, we wanted to bring focus to this market area. In 2009, the Renewable Energy division was started, bringing all different pieces together."

Renewable energy is one of 3M's 27 business divisions. Although it may seem to some that it would be easy to get lost in the shuffle and bureaucracy of a multinational corporation, Chandrabalan said the division's customers have quite the opposite experience. This is because the company's divisions operate with a high degree of autonomy.

"We are a very large company. However, every division is run mostly on its own," Chandrabalan

said. "We do have direction. We have a global strategy. But many times, for example, if the renewable energy division is launching a product, that is actually done by my division. It is not going beyond there. We are able to act quickly to a customer need, and we are able to solve those problems much easier than a very large company where the decisions need to go to the corporate level."

It's that kind of collaborative mindset — both with customers as well as with the many other divisions within the company — that allows 3M to continue along its long-held tradition of innovation.

"We partner with others in the industry — all the way from turbine manufacturers to the wind farm owners — to solve a particular problem," Chandrabalan said. "We are an industry leader in leading edge protection. When there's a problem, we don't go and just fix it, too. We educate the market. In leading edge protection, we were the pioneers to understanding leading edge erosion, its effects on the blades, and possible outcomes. We were able to come up with a solution to those issues. This is just one example of how 3M is far more than a materials supplier. We partner to be able to solve a particular need, and then we go from there."

3M's products and applications for the wind energy industry are generally separated into three categories: blade, nacelle, and tower.

Rotor blades make up largest category of these products, and represent the renwable energy divisions primary focus. These products are further subdivided into surface solutions, manufacturing process aids, and structure solutions. Individual products include specialized tapes, foam tapes, coatings, fillers, adhesives, and threadlockers.

Many of these products are cross-category in nature, and have similar applications in the nacelle and on the tower. These include electrical splices, electrical tape, wire management, and sealants, among others.

For a complete listing of 3M's products for wind energy applications, see the sidebar that accompanies this article.

For more information about 3M's solutions for the wind energy industry, visit http://solutions.3m.com/wps/portal/3M/en_US/Wind/Energy/.

3M Wind Energy Products

Operations & Maintenance
- Wind Protection Tapes
- Wind Fillers
- Acrylic Foam Tape
- Clean Sanding System

Manufacturing & Design
- Wind Blade Protection Coating W4600
- Wind Protection Tapes
- Wind Blade Bonding Adhesive W1101
- Wind Structural Adhesives
- Wind Threadlockers
- Dry Layup Adhesive
- Wind Sealants
- Acrylic Foam Tape
- Diamond Cutoff Wheels
- Clean Sanding System

Installation
- Cold Shrink Splices
- Cold Shrink Terminations
- Premium Electrical Tapes
- Cable Grounding Kits
- Wire Management and Marking Supplies
- Detectable Buried Barricade Tapes
- Locators and Markers

Safety
- Safety-Walk™ Materials
- Filtering Facepiece Respirators
- Half and Full Facepiece Respirators
- Powered and Supplied Air Respirators
- Hearing Protection
- Eye Protection
- Head and Face Protection
- Peltor™ Communications
- Fall Protection
- Speedglas™ Auto-Darkening Filters and Helmets
- Sorbents

— Source: 3M

Lanyard: Chad Lewis of ICL
Toolbox: Tiffany Cantu of EP&M International

Lanyard: Scott Kailer of JR Custom Metal Products
Toolbox: Joel LeBlanc, Vestas

Lanyard: Daniel Olson of GE (right)
Toolbox: Bob Mason of Nextera Energy (left)

Wind Systems **would like to thank everyone who stopped by our booth in Orlando.**

We'll see you all next year in New Orleans for WINDPOWER 2016!

Chris Imig
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Please tell our readers a little bit about the company — its history and genesis.
In the almost 30 years since we began making filters, our product line has expanded significantly. Hy-Pro now manufactures more than 400,000 different filter elements, an assortment of filter assemblies, and fluid conditioning equipment to combat a wide array of contaminants including water, sludge, varnish, acid and dirt.

How did the company become involved in filtration for wind power systems?
We strive to develop solutions to the problems faced by end users of hydraulic oil, lube oil and diesel fuel. There have been many articles written about wind generation and the failure of gearboxes, power units and servo valves in the wind industry. This illustrated the need for our product in the market as Hy-Pro's filters have proven over and over again to be superior at removing failure-causing contaminants. It was a logical step for Hy-Pro to partner up with wind generation farms to reduce failures in lube and hydraulic systems.

What are some of the products and applications for the wind power industry?
Hy-Pro manufactures high efficiency filters, portable loop filtration systems, filter assemblies and breathers for gearboxes and hydraulic reservoirs.

Could you talk a little about the importance of contaminant filtration in these applications?
To understand the importance of contamination control you have to understand the consequences of inadequate contamination control. For instance, when contaminated fluid causes a gearbox to fail the loss of energy production is not the only expense that must be calculated when determining the loss caused by the failure. You must also factor in the component (gearbox) replacement or repair and the maintenance engineer's time that must be spent on the problem. Proper contamination control can reduce these instances to a fraction of what they were previously.

What can happen in the absence of adequate contaminant and water filtration?
Failures like the one discussed above lead to decreases in production while maintenance hours and repair costs increase.

How does Hy-Pro's line of filtration products work to reduce those occurrences?
Our filtration products reduce failures because they retain trapped particles with 99.9 percent efficiency. Filters are not a black hole, and if they are not designed correctly they can actually become a source of contaminant as they unload the dirt back into the system. This lead to the development of the Dynamic Filtration Efficiency (DFE) filter test method. DFE is a standardized laboratory test that simulates real world conditions with varying flow rates and measures the amount of contaminant released from the filter throughout the test. We engineer our elements to excel at this test as well as the ISO 16889 Multi Pass Filter Test.

There are several filtration methods available to the industry. Could you describe the differences, and why Hy-Pro's methods/materials are ideally suited?
Hy-Pro's DFE testing ensures that our customers are receiving a world-class product. Our flexible manufacturing process allows us to define our lead times in days, not weeks which ensures that our product is delivered to our customers in a fraction of the industry's standard lead times.

Could you talk about how these filtration solutions are integrated into a wind farm's maintenance program/routine?
Hy-Pro has performed many tests of the filters and filtration systems used on wind generators. We have worked to increase the life of the filters and the life of the wind generator. Keeping the oil clean will result in less filter element change out.

What are some factors that make Hy-Pro filters ideal for the wind industry?
Hy-Pro's DFE testing ensures that our customers are receiving a world-class product. Our flexible manufacturing process allows us to define our lead times in days, not weeks which ensures that our product is delivered to our customers in a fraction of the industry's standard lead times.

SHERMCO STAFFER PENS ELECTRICAL MAINTENANCE E-BOOK

John Wiley Publishing, known for its extensive For Dummies collection of 'how-to' books, has published "*Electrical Systems Maintenance for Dummies*" by Lynn Hamrick, PE, from Shermco Industries.

The book is a primer for any company, facility or industrial entity that needs to ensure that its electrical systems are properly maintained. From high-voltage substations down to distribution panel boards, control equipment and motors/generators within facilities, companies, utilities and commercial buildings are often required to maintain and test their equipment to keep it functioning at its very best. This book is an introduction to best practices for maintaining these systems, so that money can be saved from costly repairs, replacements and downtown to operations.

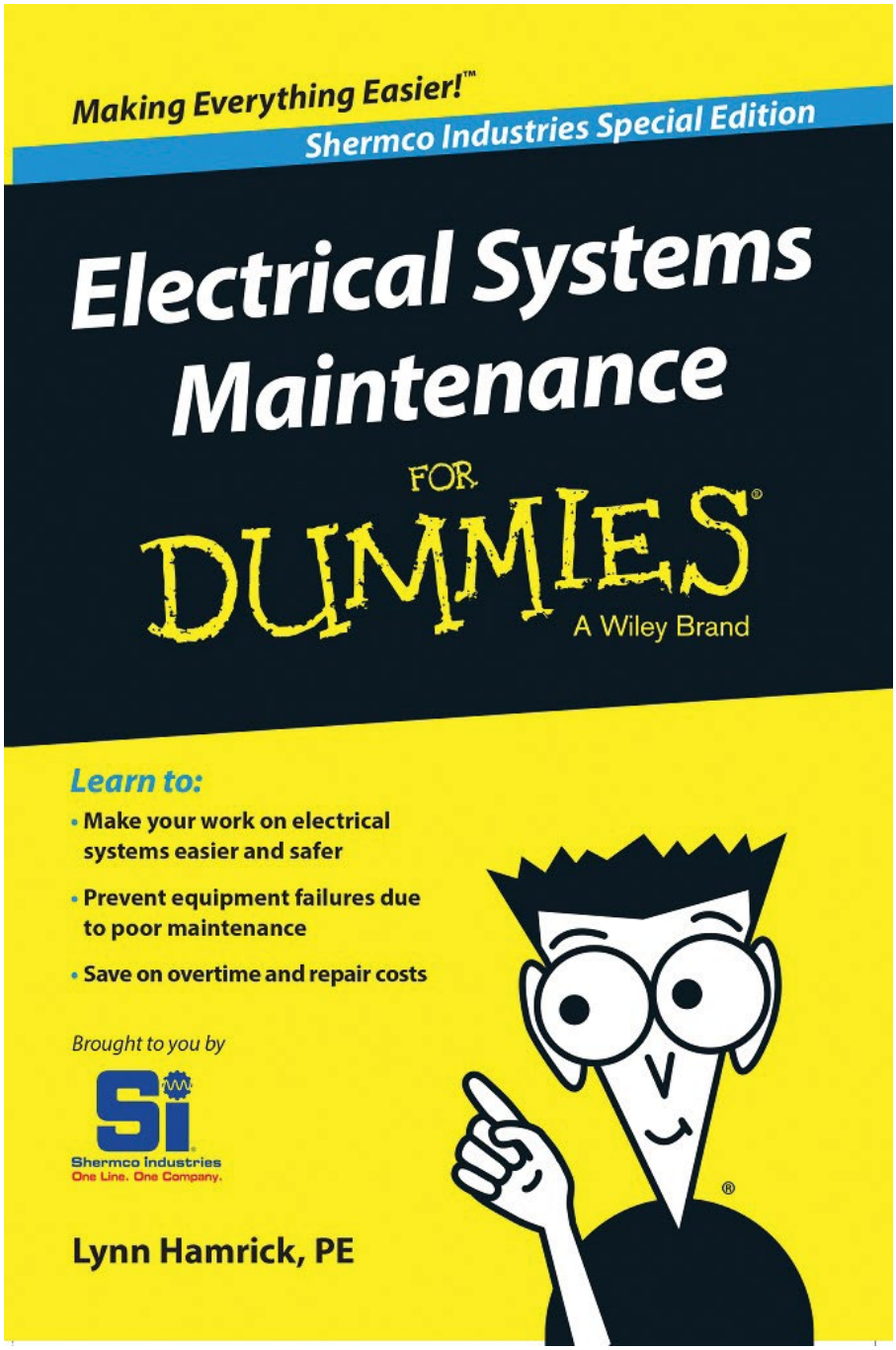
The book covers:

- Safety basics for working with electrical systems
- Testing and maintenance procedures to help avoid expensive equipment failures
- Maintenance tips for prolonging the life of expensive electrical systems
- How to put together a proper maintenance plan to train new employees and ensure consistency

Hamrick is the business development manager at Shermco Industries, where he is based in Marion, Iowa. He manages the development and implementation of NFPA 70E and NFPA 70B activities for clients, including electrical safety training, arc flash hazards analysis, and electrical preventative and predictive maintenance.

To download the free e-book, visit www.shermco.com/newsevents/shermcoinrint, or for a free printed copy, email info@shermco.com.

— Source: Shermco



PSI Repair Services ships 20,000th repaired wind part

PSI Repair Services, Inc., a subsidiary of Phillips Service Industries and an independent service provider to the wind energy industry, has announced that it recently shipped its 20,000th repaired wind turbine part to a prominent wind energy company. Since 2009, PSI has provided economical repairs, as well as industry-leading engineering services that include product upgrades, for the largest wind farms in the United States.

"PSI is very proud to be a trusted resource to the largest wind farms in the U.S.," said Mike Fitzpatrick, general manager of PSI Repair Services, Inc. "We are constantly adding new services and capabilities to meet the strong, ongoing demand from our wind energy customers, so come talk to us at the Windpower Conference."

PSI Repair Services offers component repair and engineering services for GE, Vestas, Gamesa, Siemens, RePower, and Clipper wind turbines. PSI covers the critical electronic, hydraulic and precision mechanical components that drive the turbines' pitch and yaw systems and down-tower electronics.

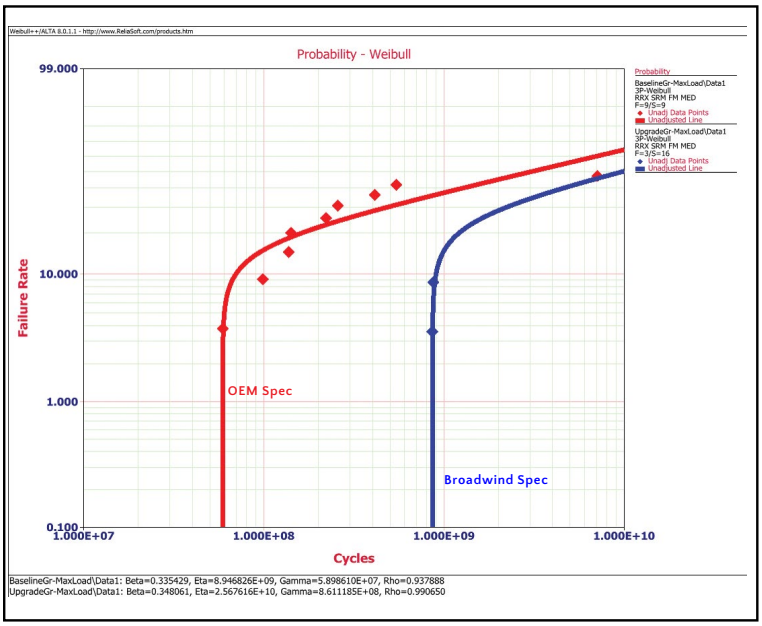
Commonly repaired components include printed circuit boards, pitch drive systems, inverters, IGBTs, PLCs, VRCC units, AEBIs, proportional valves, hydraulic pumps, pitch and yaw motors, encoders, slip rings, transducers, yaw modules, 3-phase bridge rectifiers, blade bearing automatic grease dispensers, active crowbars, line reactors, oil level sensors, battery chargers, cold climate converters, and more. PSI uses the latest diagnostic tools to detect failures down to the microchip level.

— Source: PSI Repair Services

CASE STUDY: BROADWIND ENERGY AND SENTIENT SCIENCE

LIFE EXTENSION OF A SINGLE-STAGE PLANETARY GEARBOX

Reduction in contact stresses due to geometry changes and improvements in material quality led to quantified fatigue performance improvement



The Weibull charts above shows rolling contact fatigue failure risk over time assessed with DigitalClone computational testing. The red line shows the OEM Spec and the blue line represents the Broadwind Spec. This Weibulls are representative of one of the 5 load cases run through the DigitalClone model. In the tables, the results of the 5 load cases are shown as L50 comparison.

SUMMARY

Challenge — Broadwind was seeking to quantify the effect of its DriveMAX® enhancements on a European single stage planetary design gearbox to help their customers calculate the value and ROI.

Solution — Broadwind turned to Sentient Science using the company's developed DigitalClone® prognostic models of the planetary stage to determine the effect on gearbox life due to DriveMAX® modifications under the same severe Class 1 site operating conditions.

Results — Early failures were predicted on the sun gear and planetary bearing on the OEM specification. The DriveMAX® upgrades were shown to improve the sun gear by a factor of 3x and improve the planetary bearing life by a factor of 1.65x.

CASE STUDY DETAILS

CHALLENGE

The goal was to quantify the effects of DriveMAX® enhancements for one of the largest deployed wind turbine gearboxes in the U.S.

> Sentient Science's prognostic modeling enabled us to quantify a 1.65x to 3x improvement in component life on remanufactured DriveMAX 4410 gearboxes. If an operator can add 5 years of production, this can yield up to $1M power production gain.
>
> -Jason Eddy, Broadwind Services, LLC

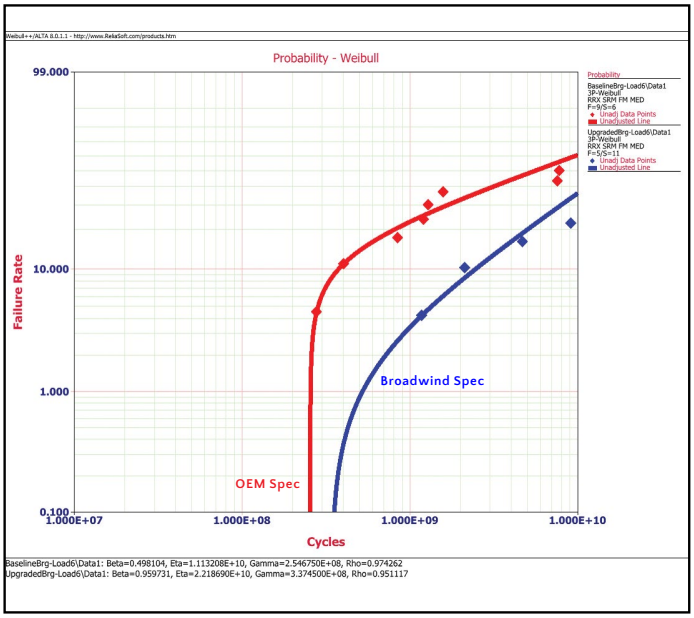
wind industry. As more wind turbines come off warranty, operators are seeking solutions to make decisions on how to service, maintain, and replace gearboxes in their fleet today to meet their long-term financial objectives.

The planetary stage is known to be a leading cause of premature failure in these gearbox models for 1.5MW wind turbines that can cost an operator up to $350,000.

To address this, Broadwind provides remanufacturing and upgrades of components to extend gearbox life. For example, Broadwind can complete full planetary stage remanufacturing up-tower. Wind turbine operators are increasing seeking to quantify the effect of remanufactured gearing enhancements on future expected component life and ROI before making a buying decision.

Solution

Broadwind provided Sentient Science with thereverse engineered design specifications on the original design and their updated configuration of sun gears, planetary gears, ring gears, and planetary bearings. Sentient Science developed DigitalClone models of each configuration under a severe Class



The Weibull charts above shows rolling contact fatigue failure risk over time assessed with DigitalClone computational testing. The red line shows the OEM Spec and the blue line represents the Broadwind Spec. This Weibulls are representative of one of the 5 load cases run through the DigitalClone model. In the tables, the results of the 5 load cases are shown as L50 comparison.

1 wind regime. Broadwind chose the DigitalClone models because they simulate material performance at the micro-structure level. With this level of fidelity, the model can accurately calculate crack initiation and small crack growth and perform "What If" comparisons considering geometry, operating conditions, lubricant properties, material microstructure, surface finish, and residual stresses among others. Recent validations in the marketplace have made Sentient the leading provider of predictive maintenance and decision support solutions for some of the largest wind operators who control over 40% of the US fleet.

Through a process of 'computational testing' - device testing done using computer simulations - Broadwind and Sentient Science assessed how the each planetary gearbox system would perform in the same 'apples-to-apples' severe Class 1 operational conditions.

Result

The computational testing results showed that, based on the severe turbine loading profile, early failures were predicted on sun gear and planetary bearing. Broadwind DriveMAX upgrades were shown to improve the sun gear fatigue performance by a factor of 3x and the planetary bearing life by a factor of 1.65X. These improvements in Broadwind gearbox components fatigue performance were mainly due to improvements in material quality and reduction in contact stresses due to geometry changes.

Life extension can provide a positive net present value if it eliminates a gearbox replacement before the expected end of life, or allows a wind turbine to operate for a few more years. This can add as much as $200k-$1M of power production if a PPA is extended by 1-5 years or eliminate the need for another $350K gearbox replacement before the wind farm end of life.

DigitalClone gearbox enhancement models can be made available to operators within DigitalClone Live so operators can quantify the expected life extension and ROI for specific turbines in their operating conditions. There is a varying response to life extension and ROI of enhancements based on the current turbine state, site wind regime, etc.

— Source: Broadwind Energy; Sentient Science

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