Brüel & Kjær Vibro

uptime magazine

3·13

Service · Borealis (Part 1) · String Testing (Part 2) · Field News · Business Corner

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Our Service Team –
Delivering added value

The case stories in this issue of Uptime emphasize a critical requirement in machine condition monitoring – the key role played by the Service organisation. Our monitoring solution is well known for maximising uptime and minimising total life-cycle costs of machines. The hardware and software, an integral part of the solution, is relatively similar from one customer to the next, with maximum benefits achieved by balancing of the customer's expertise with B&K Vibro's service offering. Across customers, there is a large disparity in the amount of resources and experience levels in operating and maintaining machine monitoring systems. Therefore, we view this as an essential service offering of our global service organization, to provide the customised services necessary to fill these gaps and ultimately maximize the value of our customers' investment.

Some services are monitoring system specific, and are therefore intended to help customers with upgrading and maintaining their sensors, hardware, software, servers and IT integration. Other services provide monitoring and analysis expertise based on years of experience, such as diagnosis, root cause analysis, prognostics and training. Monitoring techniques such as performance monitoring inherently require services to optimize its effectiveness, since they are very machine and process specific. All of these services are customized to the client specific requirements in order they extract maximum benefit from the installed monitoring system. With an extensive global network of service engineers, B&K Vibro can provide a range of customized services and 1st, 2nd and 3rd level support agreements, both physically on-site and remotely.

Regardless of the service requirements, a customized frame agreement can be tailored to increase monitoring reliability, reduce system downtime and save money. Our Long Term Service Agreement (LTSA) is one such example currently being used successfully by numerous small, medium and large customers. We will talk more about this in our next issue of Uptime.

In launching this issue of Uptime, I would like to draw your attention to the invaluable impact that a strong service support program plays in the case stories contained in this and other issues of Uptime.

Shohan Seneviratne
Vice President

Brüel & Kjær Vibro

Uptime Megazine is a newsletter published by Brüel & Kjær Vibro to keep you up-to-date with new machine monitoring trends and technologies. This issue focuses on case stories where there is service.

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case story

LDPE Reactor mixer bearing faults – Part 1

This case story from the Porvoo low density polyethylene plant demonstrates the importance of online condition monitoring of the LDPE reactor mixer. This article is the first of a two-part series, providing insights in how the LDPE mixer was configured for monitoring. Part 2, will appear in the next issue of Uptime showing plots from three case stories.

End-user

Borealis, a leading provider of polyolefins, base chemicals and fertilizers, owns and operates the Porvoo petrochemical complex in Finland. The Porvoo complex consists of five plants that produce olefins (ethylene, propylene and butadiene), aromatics (phenol, acetone, benzene and cumene) and polyolefins (polyethylene, polypropylene). Low density polyethylene (LDPE) is currently produced in the plant with two lines delivering a total of 150k tonnes/year.

Machine monitored

One of the primary machines in the LDPE production plant is the autoclave reactor; the focus of this case story. It is a 6.5m long, 530mm diameter pressure vessel with a self-contained motor, which drives a long shaft with many mixer blades mounted on it (see Figure 3). The mixer portion of the reactor stirs the ethylene and peroxide mixture at high pressure to initiate and control the polymerization process (see a description of the LDPE

Figure 1. The Borealis Porvoo petrochemical complex, located 40 km east of Helsinki, Finland.

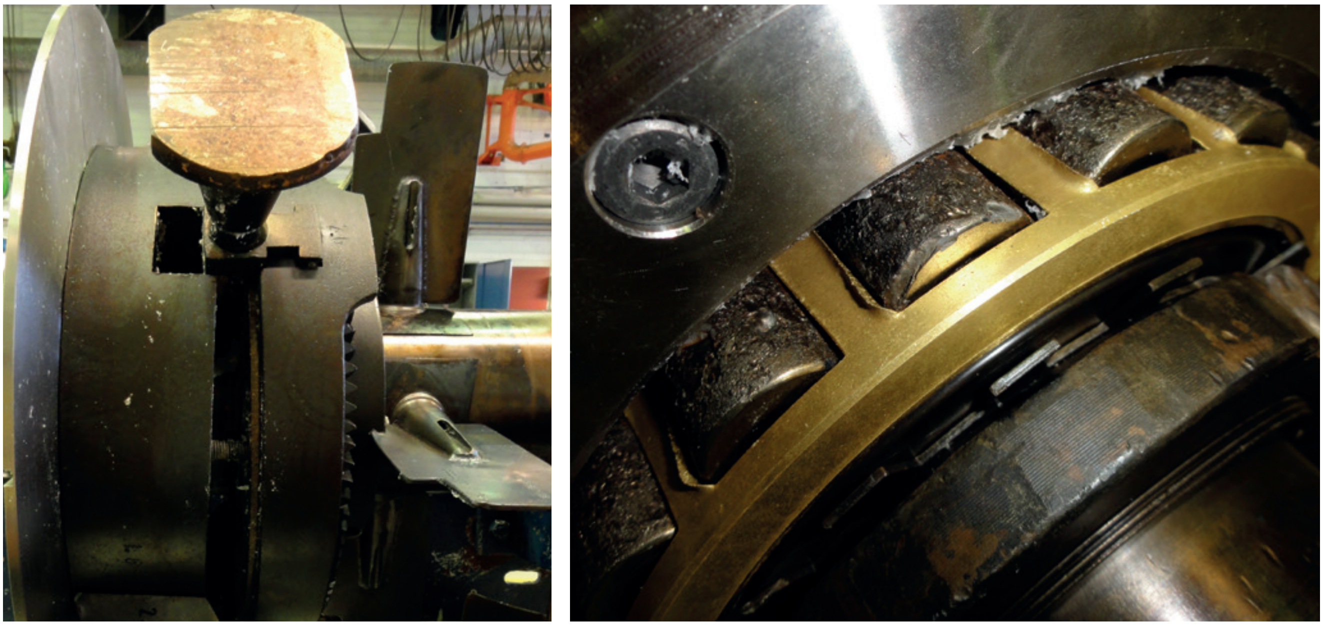


Figure 2. View of the damaged middle bearing of the reactor mixer, showing the fractured bearing housing (left) and the bearing rolling elements (right). The detection and diagnosis of this bearing fault is described in Part 2 of this article series.

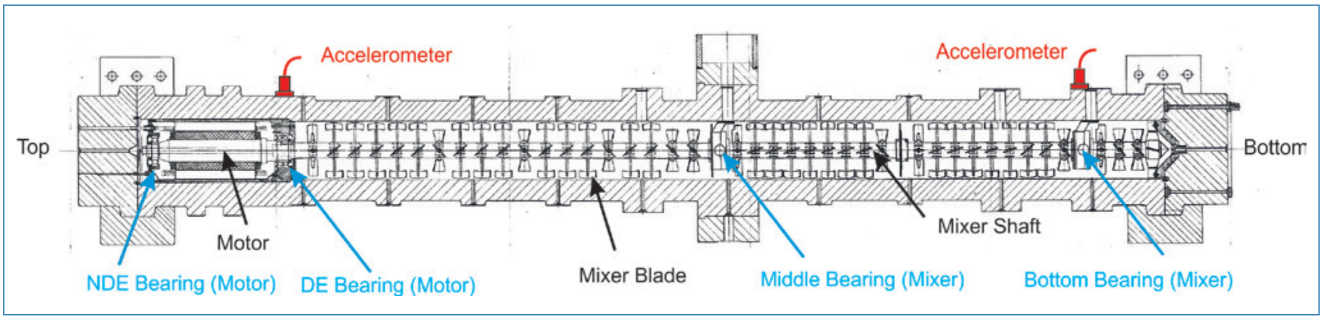


Figure 3. Autoclave reactor core showing location of the ATEX certified accelerometers and the bearings which are monitored by these accelerometers. The mixer shaft bearings are identical. (The reactor is shown on its side in this picture, normally it stands upright.)

process in the fact box). Given its criticality in the LDPE production process, any bearing failures in the mixer, will result in a plant shut down and lost production.

Temperature, pressure and the flow of peroxides are regulated in the reactor to control the LDPE properties. Because of the sensitivity of the polymerization process, this has to be carefully monitored and controlled. Any disturbances in the reactor, such as plugged output line or even a hot spot in a bearing, could trigger an uncontrolled reaction with the potential to increase the pressure extremely fast. There are two rupture disks installed on the reactor to prevent over-pressuring.

Decomposition (decomp) of ethylene can occur under certain pressure and temperature conditions and results in the formation of hydrogen and methane, which are highly explosive. If a decomp leads to a catastrophic failure, it takes one day to change the mixer. A day's production loss is approximately 205 tonnes, which is over €318,000 (at Jan 2013 LDPE spot prices). If there is secondary damage, it will take longer and incur increased maintenance cost to return the reactor back to service. Some plants change the mixer bearings frequently in order to avoid a failing bearing failure that can result in a decomp, but this causes unnecessary downtime.

Porvoo has adopted a condition monitoring strategy to carefully monitor the condition of the bearings and thereby extend the time between bearing replacement while preventing bearing failure and unplanned downtime.

LDPE Manufacturing Process

Low-density polyethylene (LDPE) is a thermoplastic polymer based on ethylene. The worldwide market for this plastic is approximately 18 million tons/year, €15.9 billion (2009). Around 65% of all LDPE production is extruded film, with plastic bags the most common product.

There are two different processes for making LDPE; autoclave and tubular method. Borealis uses the autoclave method at the Porvoo plant. The autoclave process uses two compressors to bring the ethylene up to reaction pressure; a primary compressor, normally a piston operated reciprocating compressor (typically four stages plus a booster stage, 250 bar), and the secondary compressor, normally a plunger operated hyper compressor (typically two stages, 1300-2000 bar). These compressors also take in unreacted recycle ethylene from the separators.

The autoclave reactor takes in the pressurized ethylene, to which organic peroxides are added to create free radicals, in order to initiate the polymerization process. This reaction propagates the formation of CH_2 polymer chains. The reactor mixer (shown with blades inside the reactor in Figure 4) ensures even distribution of the polymerization process in the reactor. LDPE properties such as density and melt index are regulated by a combination of controlling reaction temperature (160-310 ^{0}C), pressure (1300-2000 bar), and by adding comonomers and modifiers. This determines, among other things, the extent of branching of the polymer chains. The temperatures and pressures have to be carefully monitored, however, to avoid the risk of reaction decomposition. This occurs when the ethylene or polyethylene decomposes into H_2 and CH_4, which are highly explosive.

The reaction is terminated at the bottom of the reactor and the LDPE melt exits for the high pressure (HP) and low pressure (LP) separators, where it is cooled, and unreacted ethylene is re-compressed and recycled back to the autoclave reactor. Low molecular weight polymers (wax, oils) are removed in other separators. The purified LDPE exits the LP separator and is then sent to the extruders where the melt is homogenized, more property enhancing additives are added, and the final product is pelletized and de-gassed before packaging and delivery.

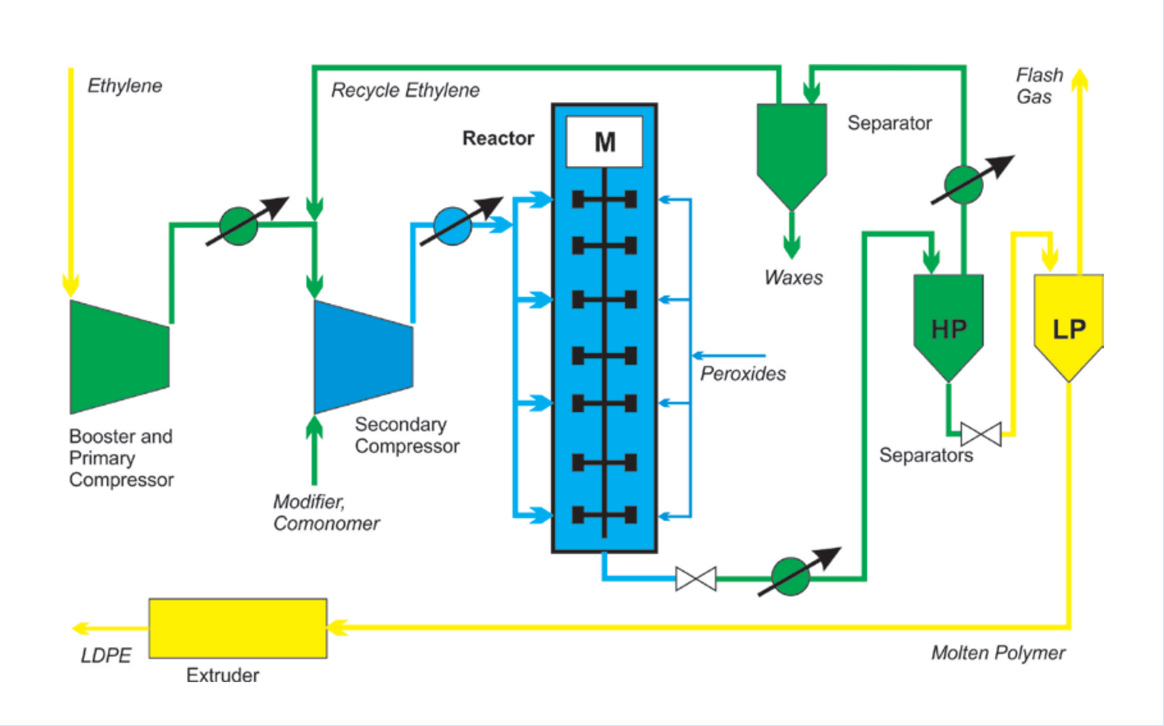


Figure 4. Simplified diagram of LDPE process, where blue denotes very high pressure (1400-2000 bar), green moderate pressure (40-250 bar) and yellow low pressure.

Monitoring Strategy

The Compass system, commissioned at Porvoo in 2001, is used for safety and condition monitoring of the reactor in the two LDPE lines at the plant. The same system is used to monitor the primary and secondary compressors and the extruders in the same plant, as well as other Borealis petrochemical complexes in Europe.

As shown in Figures 3 and 5, the four rolling element bearings in the reactor are monitored by two accelerometers. The primary fault detection measurement used is a bandpass acceleration measurement. The setting for signal response is nearly the same as that for a RMS and peak-peak measurement settings. The frequency range of 1-5 kHz captures the rolling element bearing resonance frequencies, providing accurate, early indication of a developing bearing fault.

Alarm limits for this measurement are normally established through experience. Generally, the first alarm indication (Alert) is set to occur approximately one month prior to the Danger alarm, which identifies a need to change the entire mixer (reconditioned unit).

After a bearing fault has been detected, Envelope analysis is used to identify the location of the bearing fault and determine its severity. A FFT velocity spectrum can also be used to identify the bearing fault frequencies if the noise floor is not too high. If a bearing fault further develops, it creates a secondary vibration signature which is visible in the velocity trend and spectrum. Sometimes the velocity spectrum identifies vibration at rotating frequency and its harmonics. These are generally process related and usually disappear in a short time.

If the polymer sticks to the blade, this results in unbalance. If the polymerization process is unstable, this creates a broad low frequency vibration. (See Figure 6.)

Conclusion

In this issue of Uptime, Part 1 of this article series presents general information concerning the monitoring strategy of an autoclave reactor in an LDPE plant. In the next issue of Uptime, Part 2 of this article series will present three actual case stories.

Acknowledgement

Brüel & Kjær Vibro would like to thank Marko Heinonen, for his contribution in making this article. ■

Marko Heinonen
Condition Monitoring Engineer, Borealis Polymers Oy

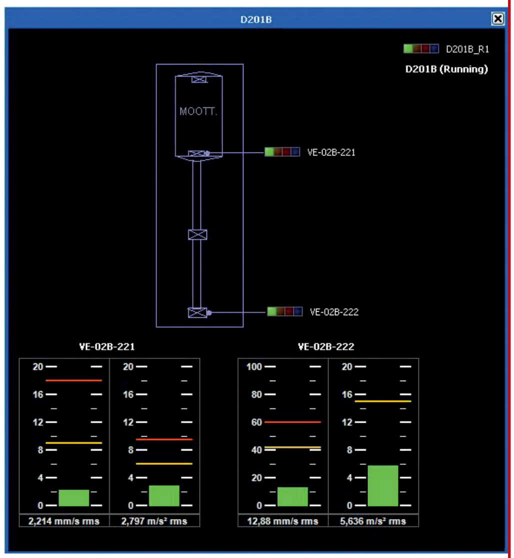


Figure 5. Machine view screen showing the traffic light status of the two measurement points and a real time acceleration bandpass vibration measurement display.

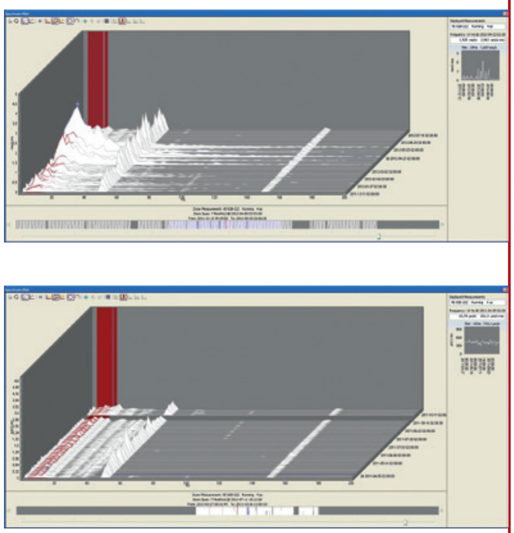


Figure 6. Process related low frequency vibration shown on the left. Normal plot shown on the right.

String Testing a Typical Machine Train – Part 2

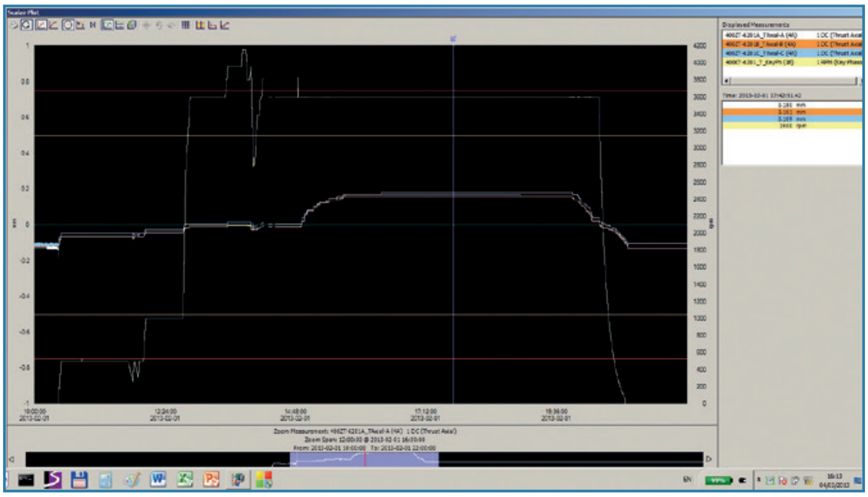
A string test is one of the important tests undertaken on critical machines prior to installation on-site, and Compass plays an important role in this testing process. This article is the second part of a two-part series that graphically demonstrates the kind of vibration measurements that are used for evaluating a typical machine train, as a completely assembled unit, prior to shipment to site. Part 1 appeared in the previous issue of Uptime (www.bkvibro.com).

Introduction

Part 1 of this article provided background information on a typical string test for a steam turbine generator machine train. In this issue, the final part of the article, examples of the actual plots used during the string test are presented.

Test Results (cont. from Part 1)

Plots are shown for the governor side of the steam turbine portion of the machine train.



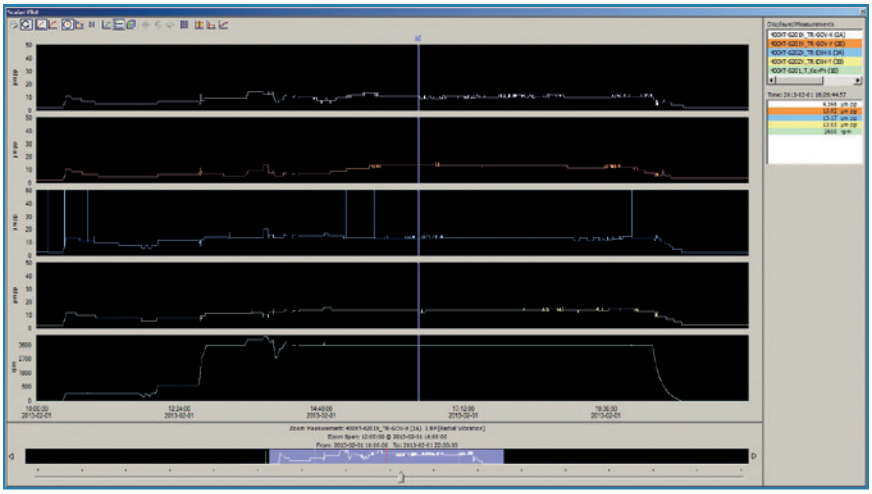


Figure 4. ***Axial position (top) and radial vibration (bottom).*** *These critical measurements are monitored across all machine states during the complete string test period. The axial displacement measurement is especially important since a thrust bearing rub could result in catastrophic damage to the machine within a few short moments.*

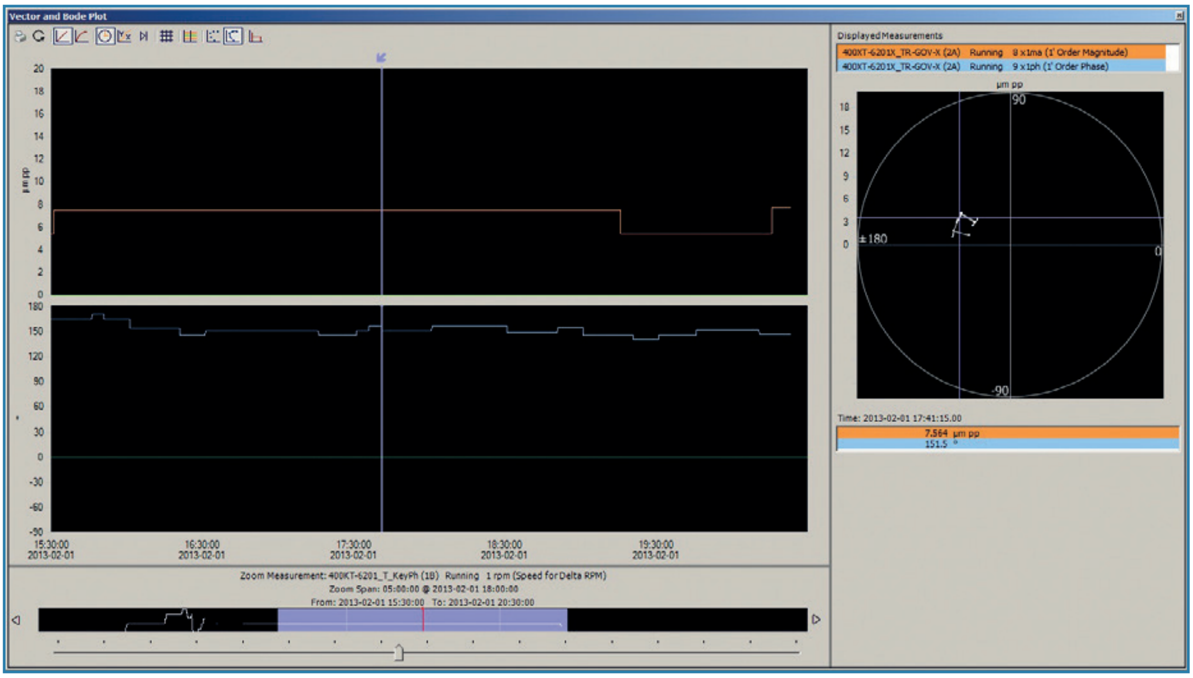


Figure 5. ***Vector plot (1x filtered) during running.*** *The first order vibration magnitude and phase at running speed provides a useful method for comparing the phase angle at different measurement points.*

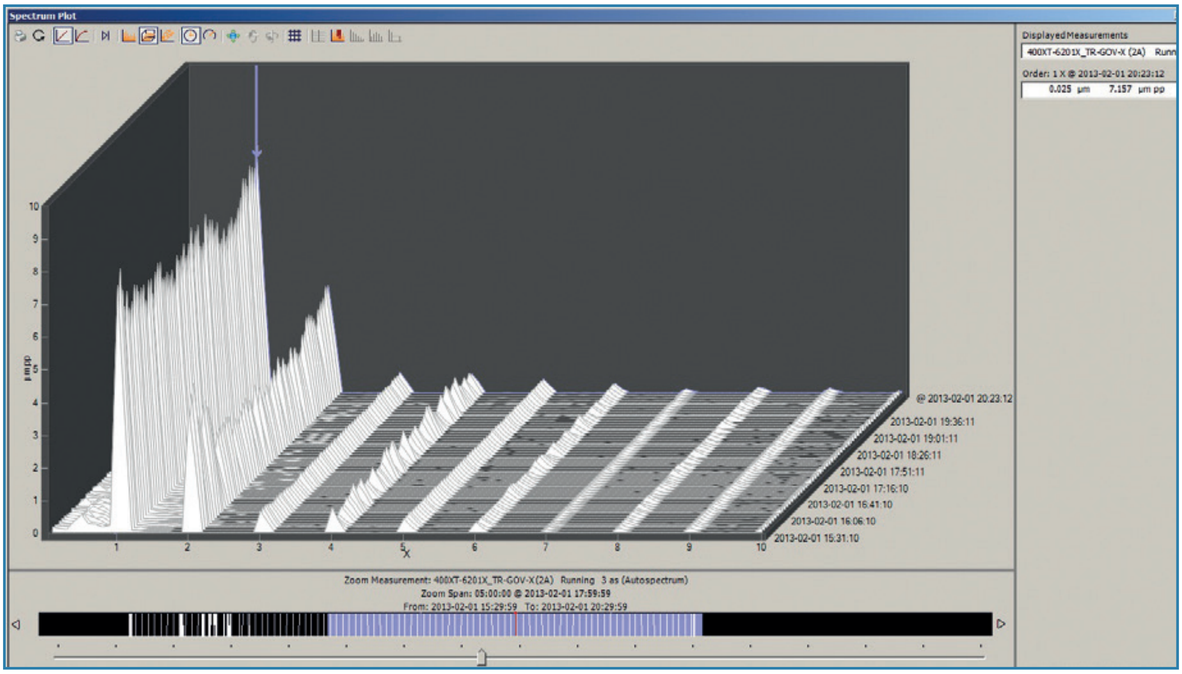


Figure 6. ***Spectrum waterfall plot (order scale) during running.*** *This plot can help identify faults in machine components that are synchronously related to the running speed during steady state operation.*

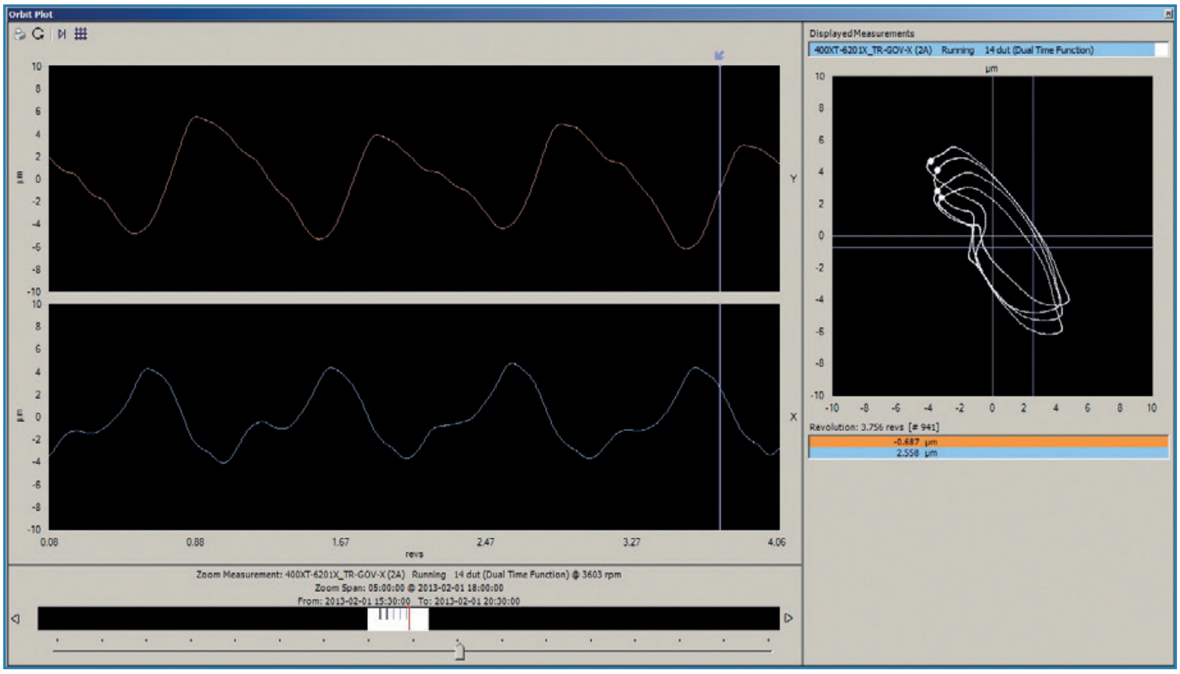


Figure 7. ***Orbit plot (unfiltered) during running****. The orbit represents the AC dynamic motion of the shaft within the journal bearing. While the Shaft centreline plot (Figure 9) gives an idea about shaft clearances in relation to the fixed part of the bearing, the orbit gives a better picture about the actual motion of the shaft. The plot shown was recorded unfiltered, which means all movement and running speed harmonics are displayed. The individual time signals from each sensor used to construct the orbit are also displayed for providing another graphical method of viewing all influences.*

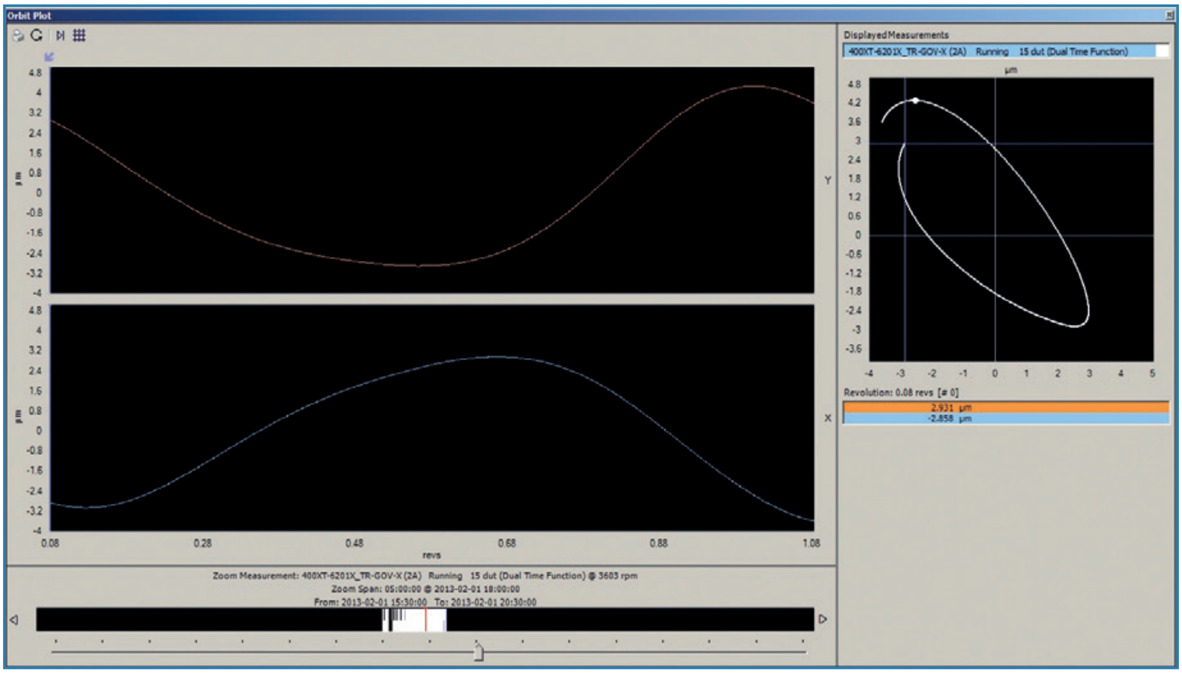


Figure 8. ***Orbit plot (1x filtered) during running.*** *This orbit plot is similar to that shown in Figure 7, except this one has been filtered to only show the shaft motion at running speed. This makes it easier to identify unbalance, misalignment, overloading, etc. The orbit plots can also be filtered to sub-harmonics to identify bearing stability problems, or other harmonics to detect various problems such as looseness.*

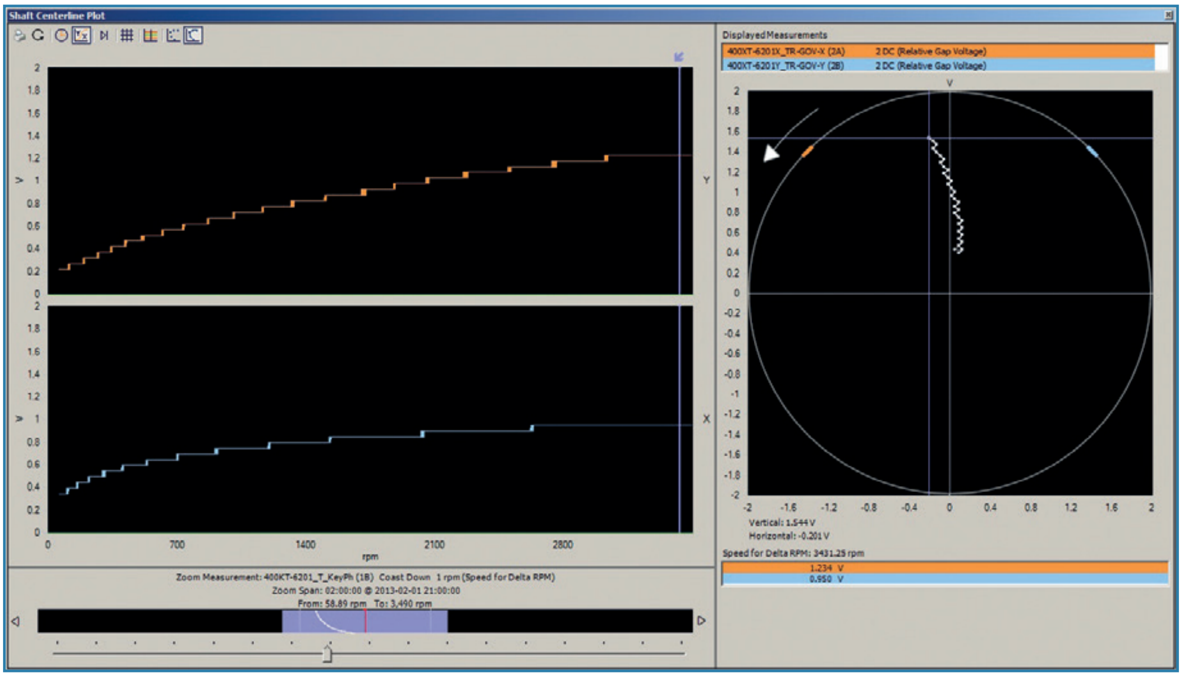


Figure 9. ***Shaft Centreline plot during coast down.*** *The shaft centreline plot, like the orbit, is based on an X-Y sensor configuration for displaying shaft motion within a journal bearing. The shaft centreline plot displays the shaft centre DC position changes within the bearing clearance range. This plot is typically recorded during a transient machine state, and represents the DC value of the shaft centreline. It determines how the shaft is positioning itself at different speeds or times, and how the bearing clearance is affected. The individual sensor DC gap values that are used for generating the shaft centreline plot are displayed in the linear plots.*

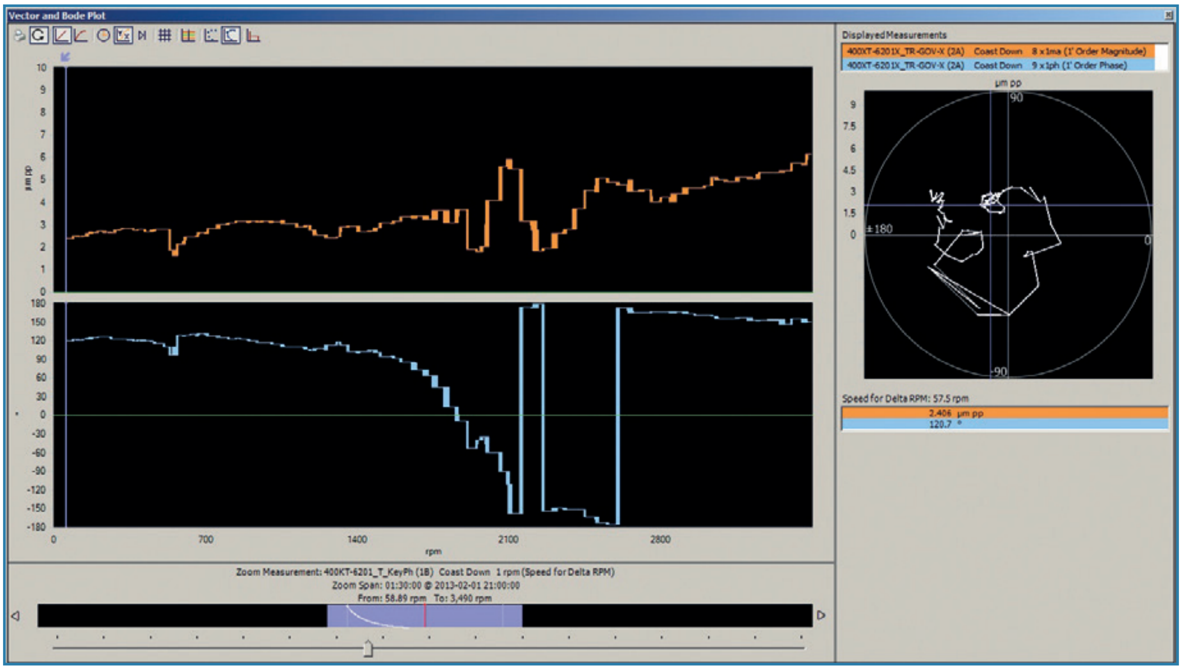


Figure 10. ***Bode and polar plot during coast down.*** *These plots display order magnitude and phase as a function of rotational speed or frequency. These are important tools in transient speed analysis (analysing non-stationary signals). The Bode plot is used to identify, confirm or monitor changes in the shaft resonant frequencies, or to examine the rotor dynamics on an order basis. It also enables changes in the damping properties of the shaft to be identified, caused by shaft cracks, etc. The polar plot presents the same information in polar coordinates.*

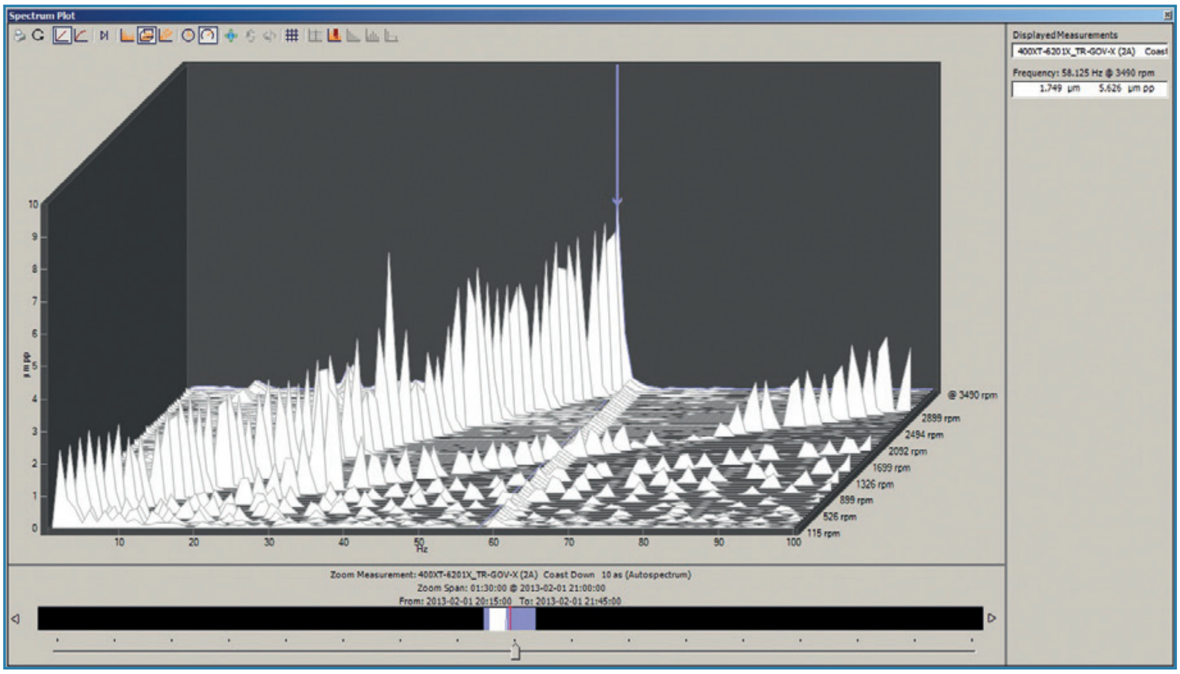


Figure 11. ***Spectrum waterfall plot (frequency scale) during coast down.*** *This plot is similar to that in Figure 6, except this is monitored during transient speed conditions and with respect to frequency. In addition to identifying the faults that can be detected during running speed, transient phenomena, such as passing critical speeds, can also be detected.*

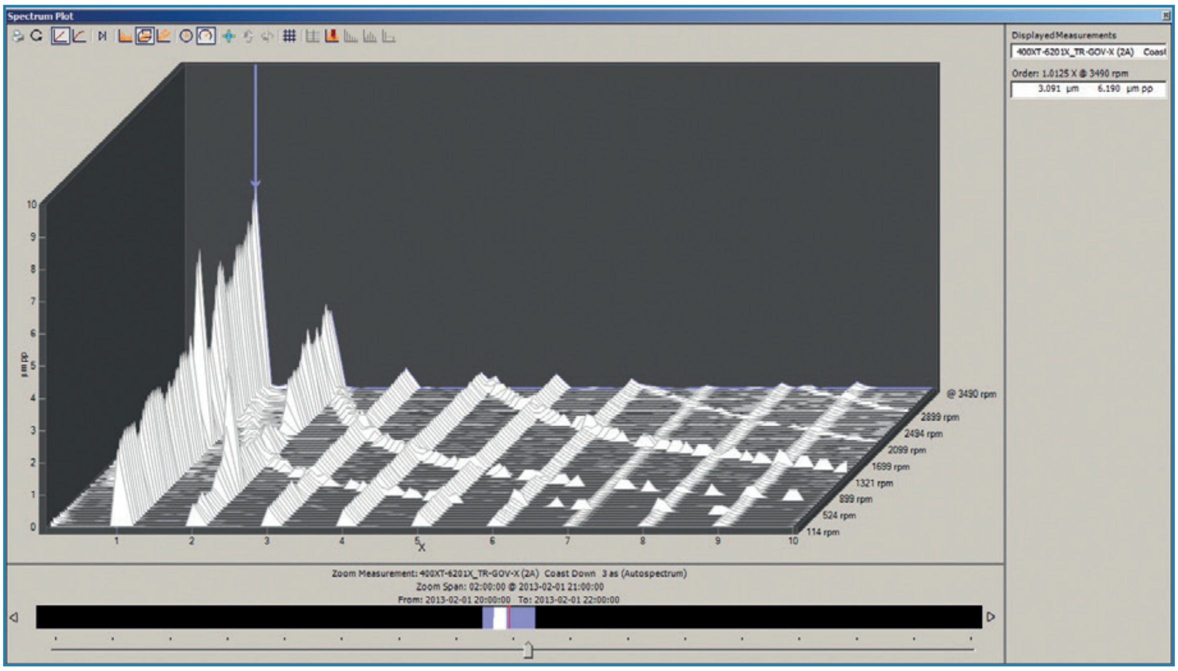


Figure 12. ***Spectrum waterfall plot (order scale) during coast down.*** *This plot is similar to that shown in Figure 11, except it is based on synchronous data (harmonics of the running speed) recorded during transient speed conditions. This plot can be used to detect changes in the running speed harmonics for the duration of the transient machine state.*

Conclusion

The comprehensive string testing process is an important part of machine commissioning and ensures the operational integrity of the machine train at the packager's facility where remedial actions can be performed easily, before shipping to site. This ensures a smooth on-site commissioning process and operation of the machine. Compass, together with Brüel & Kjær Vibro's service team play an important role in this process by monitoring all the important machine train vibration parameters and issuing a report that typically includes a list of potential failure modes that have been detected and recommendations to remedy these. For a few string tests, a consultant is contracted by the customer to evaluate the test information that we collect instead of us. In such a case it is the consultant who decides what is acceptable and if repairs or modifications are necessary. This is also the case for the example given in this article. We can report, however, that the string test revealed the machine to be operating within the design parameters specified by the customer.

Some test conclusions specific to the string test described in this article, as an example, are:

- The overall vibration level on the steam turbine was less than 20 μm peak-peak, even at maximum speed; well within the customer acceptance level of 25mm um peak-peak.
- There was no evidence of non-synchronous symptoms in the frequency spectrum plots (acceptance limit is 6 μm peak-peak).

Acknowledgement

We would like to thank Ajayan Madhavan from our international services organisation for his contribution in making this article. String tests are one of many value added services provided by our qualified service engineers located across the global network of Bruel & Kjaer Vibro sales and support centres. Contact your local sales representative for more information on this and other services.

Contact info@bkvibro.com if you would like the complete article as a single PDF document. ■

Compass to be installed on Colombia's largest hydropower station

Brüel & Kjær Vibro has been chosen to supply an integrated monitoring system on the 2456 MW Ituango hydroelectric power station in Colombia. Located on the Cauca River near Ituango in the Antioquia Region, construction began in 2011 with the plant expected to come online in 2018. The power station contains eight 307 MW Francis turbine-generators, operating under a 197 m head.

Compass 6000 has been selected to fulfill the comprehensive safety and condition monitoring strategy of all units. The extensive vibration monitoring system configuration includes X-Y displacement and velocity sensors at each bearing to monitor shaft and bearing problems, and accelerometers on the suction tube and turbine cover to detect cavitation, vortices and other potential failure modes. Fibre optic accelerometers installed on the stator core and stator end-windings will monitor loose laminations and slot wedges, respectively. Absolute and relative vibration and displacement will be monitored at the thrust bearings. In addition to vibration monitoring, the generator will also be monitored for air gap between the stator and rotor, magnetic flux of the passing rotor poles and partial discharge from the stator winding insulation. ■

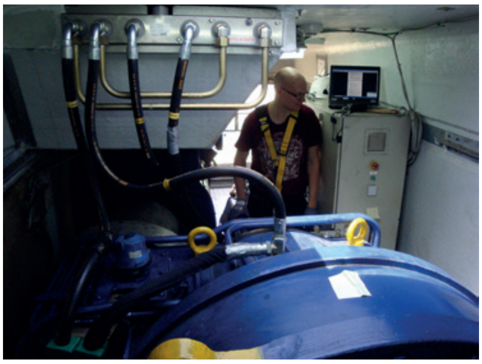
13% of Colombia's installed power capacity will be under the watchful eyes of Compass

Currently 70% of Colombia's total electricity production is hydroelectric, making it an important national energy source. There is approximately 14 GW of installed hydroelectric capacity in Colombia today. As a result of escalating environmental and social costs associated with large dams, and the El Niño-Southern Oscillation climatic phenomena (resulting in prolonged periods of drought for several years), the rate of hydroelectric development in the country has decreased somewhat since the mid-1990's. Ituango will be the country's largest hydroelectric dam, producing 13900 GWh each year. Compass will also be extensively monitoring another new hydroelectric project currently under construction, El Quimbo. With 400 MW installed capacity, it will be generating 2216 GWh per year when it enters service in 2015. Ituango and El Quimbo are the two largest hydroelectric projects in Colombia today.

field news

Leading European wind turbine operator choses Brüel & Kjær Vibro

Brüel and Kjær Vibro have been awarded a project to monitor 142 wind turbines at Enel Green Power (EGP) in Italy. “This order is of high strategic importance to both the operator and B&K Vibro” says Peter Allpass, Business Line Manager for the wind turbine monitoring group. “EGP is a major global operator of wind turbines with a diversified portfolio of assets that require a single monitoring solution to facilitate data correlation and improve asset reliability.” Peter continues: “Solution flexibility is core to our design concept and has enabled the successful implementation of monitoring systems on numerous wind turbine parks comprising a range of turbine and component manufacturers. This project will open doors to similar opportunities with this and other customers.”



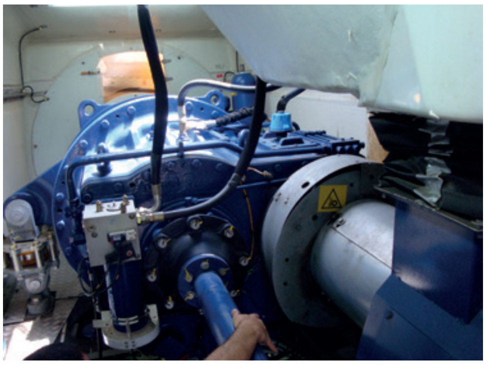


Figure 1. Site survey for installing the monitoring system hardware and sensors in the different types of wind turbines (left to right: Gamesa Type 1, Gamesa Type 2).

Extensive wind power installations

Enel Green Power (EGP) is currently a global market leader in renewable energy production, with an installed capacity of approximately 9GW in Europe and the Americas. 25,000 GW/h are generated each year from hydro, solar, wind and geothermal power sources. EGP meets the energy consumption of over 8 million families, thus avoiding 16 million tons of CO_2 emissions a year. More than half of the EPG plants are located in Italy (almost 380 plants), resulting in an installed capacity of 3,068 MW. Over the past decade wind power has seen the greatest growth at EPG, with 720 MW installed capacity in Italy spread out over a number of different wind farms.

System installation

Following a full site survey on four EGP wind parks, installation commenced on 142 wind turbines. Brüel & Kjær Vibro is training the customer to install the monitoring system themselves. The wind parks consist of the wind turbines shown in Table 1 on the next page.

There are two hardware installation packages provided:

- **Small Turbines** – This is for smaller wind turbines which are less than 1 MW, with monitoring confined to the high speed portion of the drive train.
- **Large Turbines** – This is for the larger wind turbines, where the entire drive train is monitored.

Monitoring services

Comprehensive monitoring and diagnostic services are provided to the operator from our global Surveillance and Diagnostics Service Cen-

Figure 2. Site survey for installing the monitoring system hardware and sensors in the different types of wind turbines (left to right: GE 1.5 S, Repower).

Wind Farm Name	Turbines	Model	MW
Frosolone	45	Gamesa G52	0.85
Caltavuturo	45	Vestas V52	0.85
Sedini	43	GE SL and SLE	1.5
Trapani	9	Repower MM92	2.05
Total	142		159.45

Table 1. List of wind turbines to be monitored by Brüel & Kjær Vibro at EGP.

tres. This includes around-the-clock fault monitoring, fault diagnostics, root-cause analysis, alarming and maintenance recommendations.

Future perspectives

Upon EGP gaining sufficient monitoring expertise and realising the full benefits of an online condition monitoring system, if interested, the new VibroSuite platform will enable a seamless transition towards undertaking their own diagnostics. It will provide EGP with all the flexibility needed to make decisions regarding their condition monitoring strategy today without necessarily knowing what direction they will take 3 years from now.

We are very proud of being selected by Enel Green Power for monitoring these wind turbines and are looking forward to providing them with our high quality diagnostic service, lead time to maintenance and increased uptime for the wind turbines in this project and future ones. The possibility also exists to integrate their hydroelectric power station monitoring with our hydro monitoring solution.

Acknowledgement

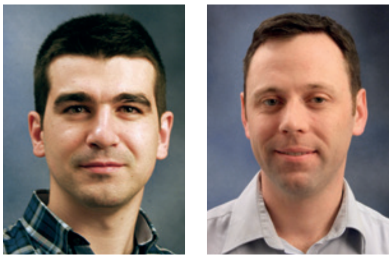
We would like to thank Tonino for his contribution in making this article. ■

Tonino Parente
Hydro, Wind and Solar Operation & Maintenance group in Italy
Enel Green Power

business corner

Collaboration in refining wind turbine monitoring techniques

The Technical University of Denmark and Brüel & Kjær Vibro are joining forces in a joint venture to find a holistic approach to monitoring, diagnosis and prognosis of faults in wind turbines.



Alexandros Skrimpas *and* **Christian W. Sweeney**

Wind turbines operate at low-speed under a wide range of operating conditions, and for this reason require a comprehensive range of monitoring techniques to effectively detect and diagnose developing faults in the drive train and other critical components. Normal monitoring techniques used for high-speed compressors, steam turbines and pumps are simply not applicable for effectively monitoring wind turbines. Using our experience from monitoring thousands of wind turbines world-wide over the past decade, Brüel & Kjær Vibro has developed and been refining the monitoring and measurement techniques for wind turbines. These monitoring techniques are currently being successfully implemented and there is an on-going development initiative to refine these, but the overall field of wind turbine condition monitoring is yet to be fully explored.

One of the vibration specialists at our Surveillance and Diagnostic Service Centre, Alexandros Skrimpas, is part of a joint research project between the Technical University of Denmark and Brüel & Kjær Vibro to develop a holistic approach to monitoring, diagnosis and prognosis of faults in wind turbines. Alexandros is undertaking this as part of his PhD studies with Christian Sweeney, group leader at the same Service Centre, who will be acting in a co-supervision role. The research project, with an expected duration of three years, is partly funded by Brüel & Kjær Vibro and the Danish Ministry of Science, Technology and Innovation.

The objective of the project is to carry out research into and development of a cost-effective condition monitoring system technology based on electrical, mechanical and thermal measurements. The new technology can be used in conventional wind turbines such as double fed induction generators as well as modern permanent magnet based wind turbines both geared and direct drive.

A number of monitoring and measurement techniques will be evaluated. Vibration monitoring and analysis is a proven and accepted technique for wind turbine monitoring, but there are a number of other lesser known techniques that will also be evaluated. These include air gap monitoring between the stator and rotor, magnetic flux of the passing rotor poles and partial discharge of the stator winding insulation. Electric signature analysis is an example of another technique that is not widely used in wind turbine monitoring but offers significant potential benefits. In this technique a demodulated current spectrum can be used for detecting loose or broken rotor bars, cracked end rings, rotor eccentricity, misalignment and coupling problems.

This project will shed new light on an integrated, multi-disciplinary approach to monitoring wind turbines using state-of-the-art simulation and testing techniques. ■

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