HYDRO
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THORDON
NEWSWORKS

Raanaasfoss 1 Hydro Plant in Norway

THE ***MOVE TO WATER PAYS*** FOR NORWAY'S *RAANAASFOSS* HYDRO PLANT OPERATOR

The water-lubricated SXL turbine guide bearings Thordon installed as part of the re-powering of Norway's Raanaasfoss 1 Hydro Plant have ***experienced almost zero wear after 23,887 hours*** of continuous operation on the first installed unit.

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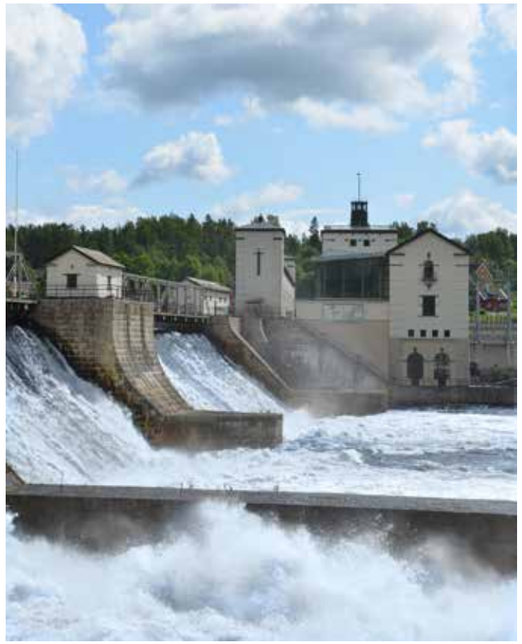
THE ***MOVE TO WATER PAYS*** FOR OPERATOR *...continued*



During routine inspections of the 13.5 MW turbines, commissioned by Voith Hydro in 2013, the guide bearings – the operator's first experience with water-lubricated bearings – showed "almost no wear at all", with a measured diametric bearing clearance less than 0.30mm (0.012") on the longest running Unit 1. All remaining turbines (Units 2 to 6) had very low measured diametric clearances of between 0.30 and 0.50mm (0.012" and 0.020").

When first installed, the SXL turbine guide bearings had an initial design clearance of 0.65mm (0.026"), allowing for up to 0.33mm (0.013") of water absorption into the bearing material, expected over the first months of operation. The fact that the measured clearance values are now lower than the starting clearances, confirms that the water absorption has taken place as predicted, and bearing wear from normal turbine operations is negligible.

Bjørnar Petersen, Mechanical Engineer, Akershus Energy, said: "We are very pleased with the performance of the Thordon technology, our first water-lubricated guide bearings. It's still early days, but we have noticed there is considerably less maintenance and monitoring to do compared with oil-lubricated systems. Operational costs have also been reduced as we no longer have to purchase lubricating oils."

When Akershus Energy embarked on a project to update the 1922-built plant, the first to provide electricity to the city of Oslo, water-lubricated bearings were not initially considerered.

"The Thordon technology was presented by Voith and we thought this was a good solution, not least for environmental reasons. We are pleased they recommended the system to us," said Petersen.

While turbine performance was a key driver in the decision to re-turbine, environmental consideration was also high on the agenda.

"The operator wanted the most environmentally-safe turbines possible," said Tommy Holmgren, Sales Director – Duwel Group, Thordon Bearings' Norwegian distributor. "The selection of a water-lubricated solution for the lower guide bearing instead of the more traditional oil-lubricated design allowed the bearing to be cooled and lubricated with the same river water that is powering the Voith turbine."

The water-lubricated bearings completely eliminate the risk of oil leakage contaminating the turbine's discharge or tail water, as can happen with older design oil/Babitt bearing assemblies. Not only does a water-lubricated bearing help protect the environment, it also delivers operational and maintenance advantages over the original oil-lubricated bearing system.

"The reduced maintenance requirement is largely due to the unique tapered keyset feature of the Thordon bearing, which reduces downtime during bearing inspection or replacement as it facilitates easy removal of the polymer bearing shells without removing the shaft or bearing housing," said Holmgren.

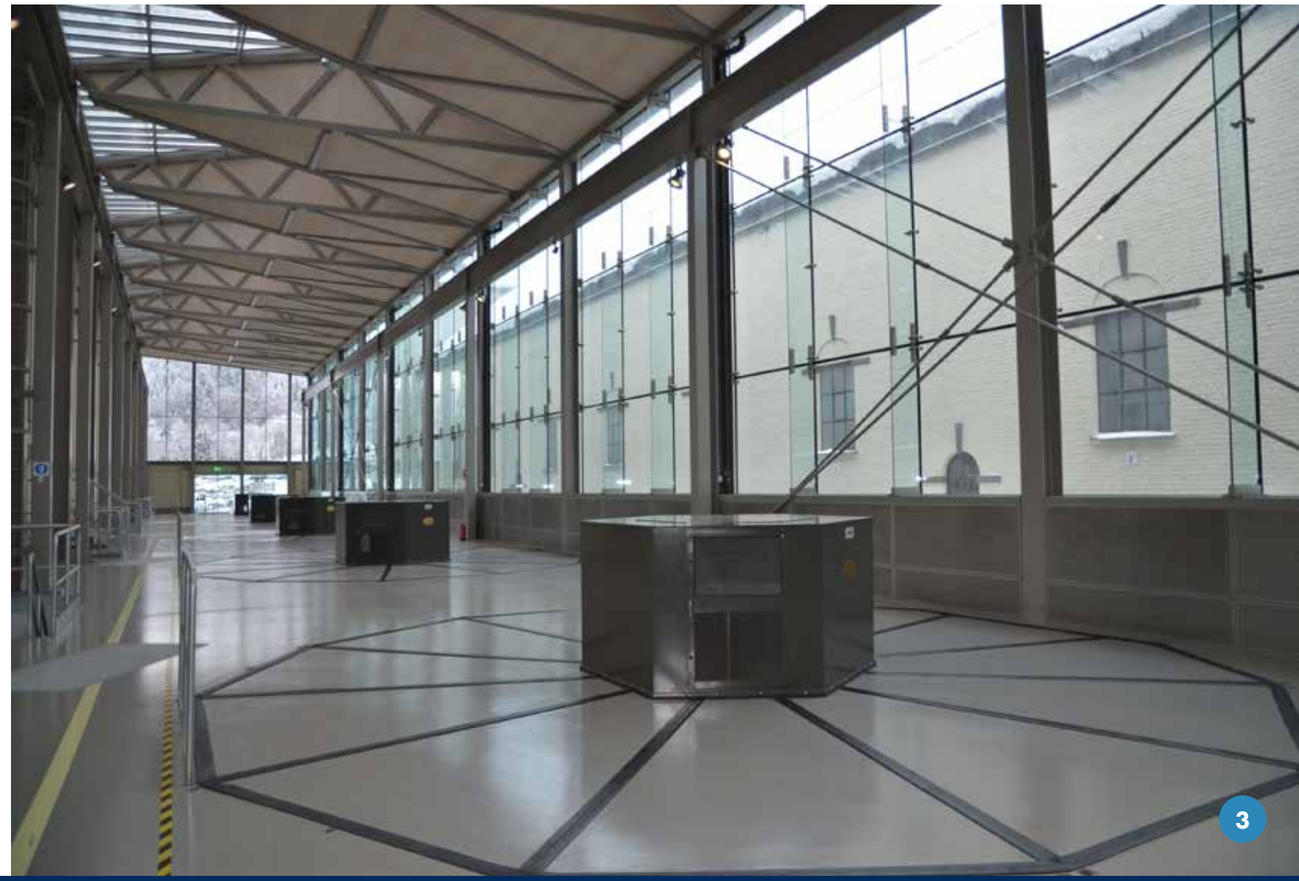
Greg Auger, Business Development Manager, Clean Power Generation, Thordon Bearings said: "We are delighted that Akershus Energy's first use of water-lubricated turbine guide bearings has proven a positive experience, commercially, technically and environmentally.

"The SXL bearings installed in the plant are currently showing extremely low wear rates and will hopefully be able to last even longer than the oil bearing designs in the original configuration."

Based on the bearing installation projects Thordon has been involved with to date, operators that have converted to a hydrodynamic water-lubricated main guide bearing have not only taken the environmental lead over competitors but found that the solution pays commercially.

Indeed, Bjørnar Petersen acknowledged that the re-powering project of Raanaasfoss 1 came under budget by about NOK10 million (USD1.15 million), due to "the smoothness of the installation". The first unit was commissioned in December 2013, with the sixth and final unit following in spring 2016.

Thordon Bearings is now discussing projects to retrofit the turbine guide and wicket gate bearings of other hydro plants in the Akershus Energy portfolio.



THORDON BEARINGS PROVIDES ***NEW LEASE ON LIFE*** FOR ***FORTUM HYDROPOWER PLANTS***

Fortum's 10MW hydropower plant at Vässinkoski, Sweden, is now successfully operating with Thordon Bearings' polymer SXL turbine guide bearing following the completion of the plant's extensive renovation and recommissioning work.

Thordon's involvement in the project followed the retrofit installation in 2013 of its water-lubricated bearings to the slightly larger Noppikoski plant, also in Sweden. Both refurbishment projects were overseen by ČKD Blansko Holding, the largest turbine manufacturer based in the Czech Republic.

For both plants, ČKD Blansko specified Thordon's SXL polymer bearings, each with a bronze tapered keyset, in addition to SXL axial sealing face rings.

Greg Auger, Thordon Bearings' Hydro & Clean Power Business Unit Manager, said: "When we were first approached by ČKD Blansko to supply the new turbine guide bearing for the 1967-commissioned Noppikoski turbine, we were faced with a particular design challenge: the Francis turbine is connected to the generator by a 45m long shaft supported by seven individual bearing positions. The scope of the project was so extensive, it made sense for ČKD Blansko to replace all of these bearings to achieve the best control of shaft position and vibration."

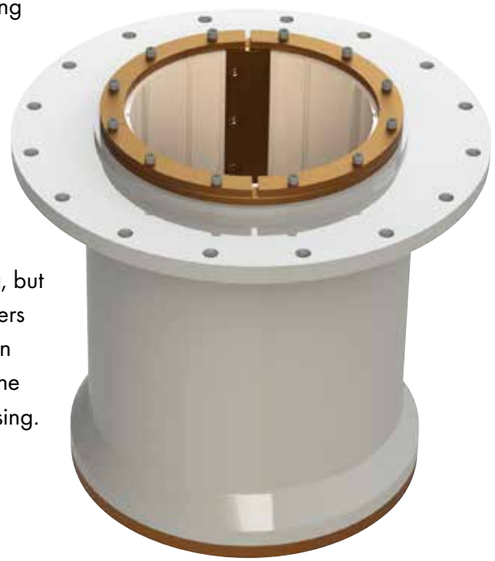
The six intermediate bearings were refurbished by ČKD Blansko, and the seventh water lubricated bearing was replaced with a Thordon SXL guide bearing to support the 420mm (16.53") diameter shaft. Thordon also supplied a longer wearing SXL seal face material for the axial seal assembly that was installed. This was Fortum's first experience with Thordon's water-lubricated guide bearings supplied as part of a major upgrade project.

Based on the success of the retrofit and subsequent five-years of seamless operation, Fortum and ČKD Blansko specified a similar scope of supply for the Vässinkoski plant, which also operates a 1967-commisioned Francis turbine and generator.

"Aside from the obvious environmental advantages, the Thordon solution provides for a longer operating life and, due to the unique tapered keyset design, optimises in-service maintenance since the SXL polymer can be removed without having to split the bearing's metal housing," added Auger.

Commenting on the installation, Jan Piroutek from Eribos, Thordon's distributor for Czech Republic and Slovakia, said: "We worked closely with the OEM on the final design and material selection and supplied the SXL bearing with a bronze tapered keyset along with an SXL axial seal ring."

Working with ČKD Blansko to help design and build all the metal components, the companies were able to use parts of the original bearing casing but replaced the rubber element with the Thordon SXL polymer. During assembly, the bearing was submerged in liquid nitrogen at -196°C (-321°F) to ensure a perfect fit into the housing, but this meant engineers had only about ten minutes to install the bearing in its housing.



"Everything went very smoothly, indeed," said Piroutek. "We anticipate the Noppikoski and Vässinkoski plants will now be operating for another 30-years before their bearings need to be replaced.

"During the commisioning ČKD Blansko technicians confirmed very negligible water leakage through the axial seal – even less than Thordon calculated during the design stage," said Piroutek.

The Vässinkoski and Noppikoski Hydropower Plants, both located on Sweden's Oreälven river, each operate one 10MW vertical Francis unit rated at 333rpm and are connected to the turbine runner by a 45m long shaft.

Following extensive tests, the Vässinkoski plant upgrade was commissioned in March 2018.

The 1967-comissioned Noppikoski Hydropower Plant operates on the Oreälven river in central Sweden with an installed capacity of 10MW and annual power output of 33GWh.

The plant operates power generation equipment in an atypical arrangement in that the 1620mm diameter Francis runner of the Francis turbine is connected to the generator by a 45m long hollow shaft and the entire rotating assembly is supported by seven individual bearings.

In early, 2013, the plant successfully commissioned an upgraded turbine and generator following an extensive refurbishment by ČKD Blansko Holding. The sister Vässinkoski plant, refurbished in 2018, also features one 10MW Francis turbine, operating with 62m of head at a nominal speed of 333rpm.

In both stations, the generator hall is located below ground level, while the turbine can be found at the bottom end of a deep tubular pit, 4.0m in diameter. Water flows through the units at a rate of 20m3/s via the penstock and into a 6.0m diameter bulb which contains the distributor mechanism and water lubricated turbine guide bearing.

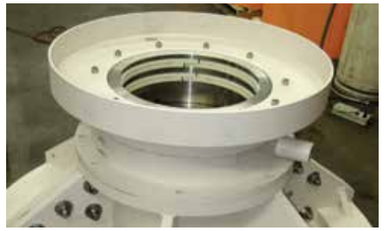
The rotating mass is quite complex as it includes eleven individual shafts coupled together (1 turbine shaft, 4 intermediate shafts, 4 hollow shafts, 1 lower generator and 1 upper generator shaft). Before the refurbishment began ČKD Blankso studied the rotor-dynamic behaviour of the system in order to fully understand the system, including the influence of the Thordon SXL water lubricated turbine guide bearing.

The original radial type shaft seal using carbon segments was upgraded to use an axial-type seal including the Thordon SXL sealing face.

The COME BACK of Water Lubricated Turbine Guide Bearings

Hydro-electric turbines operating in remote areas all over the world are producing enormous amounts of clean energy. Nonetheless, a large number of these generating stations have the potential of posing an environmental threat to local ecosystems. Oil and grease have long been considered as one of the primary methods of lubricating the lower turbine guide bearing. As environmental regulations become more stringent, any accidental or operational loss of oil or grease to the environment is not acceptable and can have grave repercussions. This can be a serious issue in remote areas where detection, monitoring and spill clean-up can be very difficult due to the poor accessibility or un-manned operation of the power station.

To eliminate any risk of oil leakage, Thordon Bearings can prepare custom designed solutions of water lubricated lower turbine guide bearings. Solutions can range from a simple bearing supply to a complete bearing, supplied with the support housing and integrated shaft seal housing package. Working with hydroelectric turbine equipment manufacturers and power station operators around the world, Thordon Bearings is not just providing bearings to fit an application, but developing bearing solutions to resolve and overcome bearing application challenges. Listed below are some examples of hydropower plants around the world using Thordon water lubricated turbine guide bearings.



Spaulding I & Spaulding II

Working perfectly since 2012, the conversion of 2 turbine guide bearings on vertical Francis turbines at the Spaulding power stations located in the US Pacific northwest from oil/white metal bearings to Thordon's water lubricated SXL bearings has been a great success.

In this application the bronze tapered keyset is covered with SXL flaps, which eliminates a large groove in the front of the key that could direct cooling and lubrication water away from the running face of the bearing during certain operating conditions.

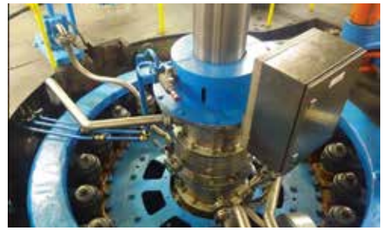
Saratov

In 2014, Thordon was selected to supply the turbine guide bearings for 21 large vertical Kaplan turbines, each with an output of 60 megawatts for a large power station in Russia. With 1350 mm shaft diameters, these are among the largest water lubricated turbine guide bearings that Thordon has manufactured for the hydro industry so far. Thordon SXL elastomer was specified for the water lubricated bearing system. The turbine guide bearing housing was split into 4 segments to allow it to be more easily maneuvered in the location where it was to be assembled. This bearing system also featured 2 tapered keysets to facilitate easy future bearing replacements.

Raanaasfoss Power Plant

Originally built in 1922, the Raanaasfoss Power Plant in Norway began a project in 2012 to maximize performance and to render it more environmentally friendly. This project included six vertical propeller turbines, each with a maximal output of 15.5 megawatts. Thordon supplied the turbine guide bearing for the first unit in December 2012 and the final unit was up and running in spring 2016. Thordon was tasked with providing a design solution for the complete bearing and seal assembly that used water as the lubricant instead of oil. As one of the concerns for the project was environmental impact, Thordon's water-lubricated bearings were the right fit for both the technical requirements and environmental mindset.

The design focused on providing a fully hydrodynamic bearing design with adequate support to carry the expected loading while integrating Thordon's unique tapered keyset feature for fixing the polymer bearing directly into the fabricated stainless steel bearing housing, without the use of adhesives or additional mechanical fastening. The reduction in the complexity and total number of components in the assembly resulted in substantial cost savings. The use of the Thordon tapered keyset greatly reduces downtime during bearing inspection or replacement as it facilitates easy removal of the polymer bearing shells without removing the shaft or bearing housing.



Centrale di Fabbriche

Owned by a large utility in Italy, the Centrale di Fabbriche power station was originally built in 1955. Discussions began in 2014, and were primarily focused on improving access to the shaft seal and eliminating risk of water entering the existing oil lubricated Babbitt bearing assembly on this vertical Kaplan turbine. In the original design of this 15 megawatt unit, any problems encountered with the shaft seal were very difficult and time consuming to resolve as complete disassembly of the oil lubricated turbine guide bearing would be required. A water lubricated bearing would be the solution to this problem with complete elimination of the existing oil bearing and shaft seal, being replaced by a new Thordon SXL bearing and shaft seal mounted above the bearing assembly. In early 2016, a new stainless steel bearing housing was fitted, with Thordon's SXL bearing and tapered keyset supporting the 400mm diameter shaft. The original carbon graphite shaft seal was also replaced with a new radial type seal that utilized Thordon's SXL elastomeric seal segments for improved seal wear life.

Ruskin Power Station

The Ruskin powerhouse was built in 1930 located in British Columbia, Canada. The original vertical Francis turbines were designed using water lubricated stave type wooden turbine guide bearings. Thordon SXL staves had been used to upgrade the original wooden bearings and keep the units running for the past 10 years. When the decision was made in 2013 to completely replace the ageing turbines, it was a logical solution to continue using Thordon to provide a modern approach to the original water lubricated design. Three new 35MW vertical Francis units were installed to replace the original turbines, starting in 2014 and Thordon supplied the complete water lubricated bearings in stainless steel housings, together with the radial type shaft seals and water filtration systems to supply the water for cooling & lubrication of the bearings.

About THORDON

THORDON BEARINGS INC.

Thordon SXL has a proven track record and has been used in Hydro, Marine and Industrial applications for over 35 years. Thordon SXL offers a low coefficient of friction, superior adhesive wear performance and good resistance to wear resulting from third particle abrasion. SXL offers minimal to no maintenance requirements and eliminates the pollution risk associated with oil-lubricated bearing alternatives.

Thordon turbine guide bearing designs allow easy installation and replacement without removing the split steel bearing housings or shaft. Thordon has over 35 years' experience supplying water lubricated turbine guide bearings, for rehabilitation and new projects.

For more information check out our video at: thordonbearings.com/hydro-power/new-hydro-video

OIL-TO-WATER BEARING CONVERSION COMPLETE FOR ***JALDHAKA STAGE-1 TURBINE***

A member of the Global Service & Support team installing an SXL guide bearing in a split stainless-steel housing

The Jaldhaka Stage-1 Hydropower Station operated by the West Bengal State Electricity Distribution Company (WBSEDCL) is back online following the successful completion of a project to convert its oil lubricated turbine guide bearing to Thordon's water lubricated SXL bearing solution.

Thordon Bearings' Global Service & Support division completed the bearing conversion of the 10MW Francis turbine in June 2018 together with Andritz Hydro, after the existing white metal bearing was damaged due to water ingress from a faulty shaft seal.

Through its regional distributor in India, Soneji Engineering, Thordon supplied a complete guide bearing package for the turbine's 355mm (14in) diameter shaft. The scope of supply included an SXL guide bearing with tapered key set in a split stainless-steel housing, a SXL segmented radial shaft seal with split housing, a Thordon Water Quality Package (WQP) to deliver clean lubricating water to the bearing, and a comprehensive instrumentation package for monitoring bearing condition.

Greg Auger, Thordon Bearings' Hydro Business Development Manager, provides a backdrop to the story: "We were initially approached in 2016 to replace a problematic oil-lubricated bearing with a water-lubricated system. After initial design discussion with the turbine engineers in France, we began working with the turbine manufacturer's Indian office team to optimise the design, and the order was placed in January 2017 for the Thordon solution. Six months later we were able to ship the package to India for installation."

But despite best laid plans, political strife and port strikes in India meant the onward shipment to the remote site was delayed until November, 2017.

By the following January, 2018, project teams from Thordon GSS and Soneji Engineering, alongside engineering teams from the turbine manufacturer and plant operator, the bearing and seal was successfully installed and commissioned.

Commenting on the installation, Anil Singh, Vice-President, Soneji Engineering, said: "The oil bearing and associated systems were removed entirely to eliminate pollution risk. We first installed the WQP before retrofitting a new Thordon SXL bearing bonded in a split stainless steel bearing housing. The original shaft was sufficiently protected with a split and welded stainless steel sleeve, and machined to the finished size. Finally, the existing shaft seal was replaced with a new radial type seal using Thordon SXL seal segments."

The Jaldhaka Stage-I Hydropower Plant, owned by the WBSEDCL and located in the Darjeeling District of West Bengal, northeast India, was fully modernised in 2017-2018.

The 28-month renovation work included the installation of new stators and poles and the electrical auxiliaries were refurbished. For the turbines and mechanical auxiliaries, new runners, MIV and governors were installed.

"The decision to replace problematic oil-lubricated guide bearings with water-lubricated ones, made complete sense following the recent investments WBSEDCL has made in the facility," said Auger.

"Through our distributor Soneji Engineering, Andritz Hydro and WBSEDCL were aware that Thordon had expertise converting turbine bearings to water lubricated designs, so we are obviously delighted to have put this expertise into tangible form with this project."

The Stage-1 turbine began operations in March 2018 with the new water lubricated bearing and shaft seal assembly. Since no additional oil lubricating system is needed, Andritz Hydro and WBSEDCL will benefit from a reduction in operational costs, while the maintenance requirement will be optimised with a Thordon shaft seal positioned above the bearing for easier access.

T-G DNALOP PURCHASES POLISH HYDROPOWER PLANT TO ***DEVELOP NEW TURBINE TECHNOLOGY***

Struzyska Hydro Plant in Pila, Poland

Thordon Bearings' sister company T-G DNALOP has purchased the small Struzyska Hydro Plant in Pila, Poland, 180km south of its bearing and seal production facility, in Slupsk. The Struzyska plant operates three small turbines capable of generating 67kW of electrical power.

Once two of the turbines have been refurbished and are back onsite, the Canada-headquartered company will operate the plant commercially, supplying electricity back to the grid. The intention is to overhaul the 37kW-capacity No. 3 turbine, scrap the 17kW No.2 turbine and redesign and upgrade the 13kW third unit. All the turbines are Francis type.

Thordon Bearings' founder and polymer bearing and seal innovator, George A. (Sandy) Thomson, said: "The Struzyska power plant is located on the Gwda River in a beautiful part of northwest Poland noted for its lush parks and forests. When we heard the plant was available we took the opportunity to invest as part of a wider strategy to increase our market presence in the European hydropower sector."

While the primary reason behind the investment is to use the Struzyska plant as a demonstration site for Thordon's water-lubricated turbine guide bearing, wicket gate bearing and shaft seal technologies, the facility will also be used to develop a series of low noise, zero pollution Kaplan-type turbines.

Turbine manufacturing marks a new market for the company, the global leader in industrial and marine polymer bearings.

"While we do not wish to encroach on the business activities of the main turbine suppliers and plant operators, many of whom are valued customers of Thordon, we do see a market for a small, efficient turbines in the 5kW to 75kW capacity range," said Thomson.

"We aim to start working on the design with local partners within the next few weeks. The Thordon turbine will likely utilize Permanent Magnet (PM) technology to deliver a quiet, environmentally-efficient, high efficiency, low-risk hydro-turbine."

Thordon Bearings has applied for EU funding to develop the new turbine on the premise that it will be designed and manufactured in Poland for the world hydropower market.

Greg Auger, Thordon Bearings' Hydro & Clean Power Business Unit Manager, said: "Once overhauled, we will run two of the existing three turbines and use the area freed up by scrapping the No.2 turbine as a test bed for the prototype unit.

> ***When they realize that environmental conservation pays dividends, those that continue to operate oil-lubricated systems will be easily swayed***

No. 3 Turbine before refurbishment efforts began

"At least one of the refurbished turbines will be onstream this year. We have already designed new face seals for the smaller unit and our production plant at Slupsk is working on refurbishing components as required, and producing the new wicket gate and turbine guide bearings for both units."

Thordon Bearings, which has been supplying water-lubricated turbine guide bearings and shaft seals to hydropower plants for more than three decades, has seen a steady increase in oil-to-water lubricated bearing conversions.

"Once the Struzyska facility is fully up and running we will invite potential customers to see the benefits first hand, of converting from oil or grease to a water-lubricated bearing solution. When they realize that environmental conservation pays dividends, those that continue to operate oil-lubricated systems will be easily swayed," said Auger , adding "a fully water lubricated plant needs less attention; you'll never worry about replenishing oil or grease."

Aside from the obvious environmental benefits of converting to water-lubricated bearings, operational costs are reduced since the purchase of costly lubricating oils is eliminated and the fear of polluting the river, disappears.

THORDON BEARINGS ***TURNS THE TIDE*** WITH COMPAC ON OCEAN_2G

Thordon Bearings proposed a seawater lubricated bearing solution to support the main turbine shafts on the OCEAN_2G tidal energy platform being developed by Magallanes Renovables, Spain. With 40+ years of experience supplying seawater lubricated bearings for propeller shafts on thousands of ships worldwide, Thordon was the logical choice having expertise running large underwater machinery reliably in an open ocean environment.

Thordon Engineering undertook a careful review of the design loads and expected shaft speeds which would vary through the range of expected tidal currents, at a depth of up to 16m. The biggest technical challenge on this project was to ensure that the design would establish a stable hydrodynamic water film to lift and support the shaft with minimal running friction and maximum bearing wear life. Although the operating profile of a tidal energy platform is arguably more predictable than a typical ocean going ship, it has the added challenge of starting and stopping four times per day with each reversal of the tide. If the bearing is not correctly sized in this application, the starts and stops may shorten the bearing life.

In addition, careful consideration was given to protecting the rotating shafts against sea water corrosion. A specialized stainless steel cladding solution was chosen to protect the 600mm diameter shaft, and Thordon's COMPAC elastomeric polymer alloy bearings were selected to ensure the longest possible life in an unpredictable and demanding open ocean environment.

In order to establish a reliable flow of seawater for cooling and lubrication of the bearing system, a pumped water supply was incorporated in an open-loop configuration to deliver 100 L/min of water flow to the forward end of the bearing assembly. The forced water supply has the added benefit of slightly pressurizing the bearing space to prevent entry of abrasives and debris.

After a straightforward installation of the bearings in 2017, the OCEAN_2G platform was launched in Vigo, Spain and went through a series of preliminary tow tests. After successful completion of these trials, this exciting new technology will now be deployed for full scale testing and development work at EMEC in Scotland.

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