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Journal

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Front cover photos:
Main Image: Staff at Hidrostal.
Top Right: A Permanent Magnet Motor from Kolmer.
Bottom Right: Axflow Drainage Pumping Solution.

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AEMT COMMENT

Embracing Innovation

The culture at the heart of AEMT Members is their ability to use their ingenuity and expertise in order to solve engineering problems where many would not be able. It's this talent that makes true innovators out of member companies, whether there is a large power company with a melted generator rotor, or a local council with a pump problem, members have been able to offer a solution.

In this edition of the Journal a white paper by Quartzelec looks at the benefits of repair over scrappage when it comes to damaged generator rotors. Looking at a specific case study, engineers at Quartzelec used new repair techniques and stress analysis to extend the feasibility of a repair further than traditionally thought.

In another case of ingenuity, the East India Dock area of London had trouble with a fountain offering nearby cars a free carwash on windy days. The obvious answer would be to switch the pump off, but Wilson Electric came up with a more elaborate way of controlling the fountain's pressure, meaning it could still be enjoyed on the windier days.

Siemens, who have remained pioneers in innovation for decades, have achieved another milestone recently by creating the world's first battery driven car ferry. The current advances in battery and electric motor technology has allowed them to do this, however the clever part comes in keeping the 1,000kWh batteries charged without crippling the power grid.

Submersible motors and permanent magnet motors are not particularly unique these days, but the combination of both types by Kolmer Electric Motors and Dutch company Marotechniek has proved to be very successful when applying the motor to a dredging pump on the swing arm of a hopper/cutter.

Finally AEMT members got to witness the cutting edge of innovation coming out of ABB in March, with a visit to their Milton Keynes Robotics facility. They met YuMi, the collaborative human/machine robot aimed at the consumer electronic industry and learned of a new robotic air gap inspector which can easily crawl through a 10mm airgap of a large motor or generator.

Thomas Marks
Editor and Marketing Manager

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PROCESS TECHNOLOGY






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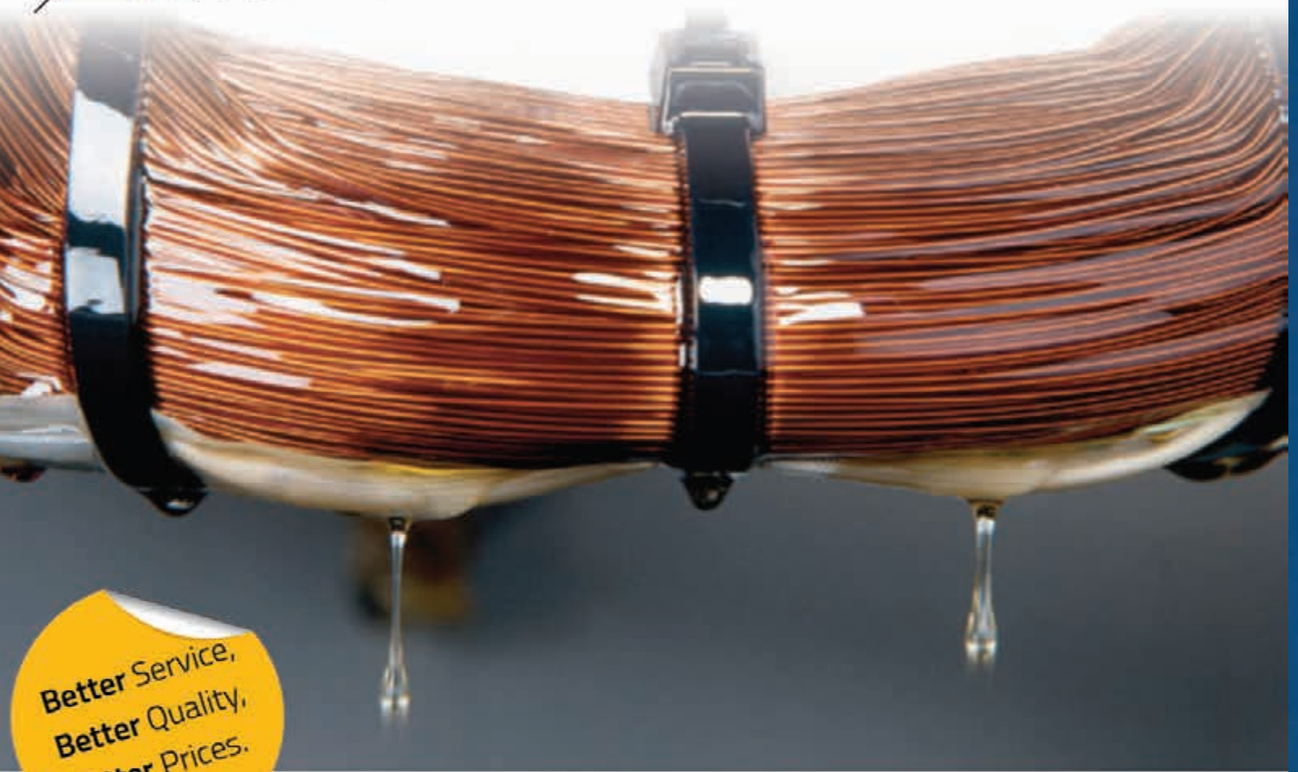

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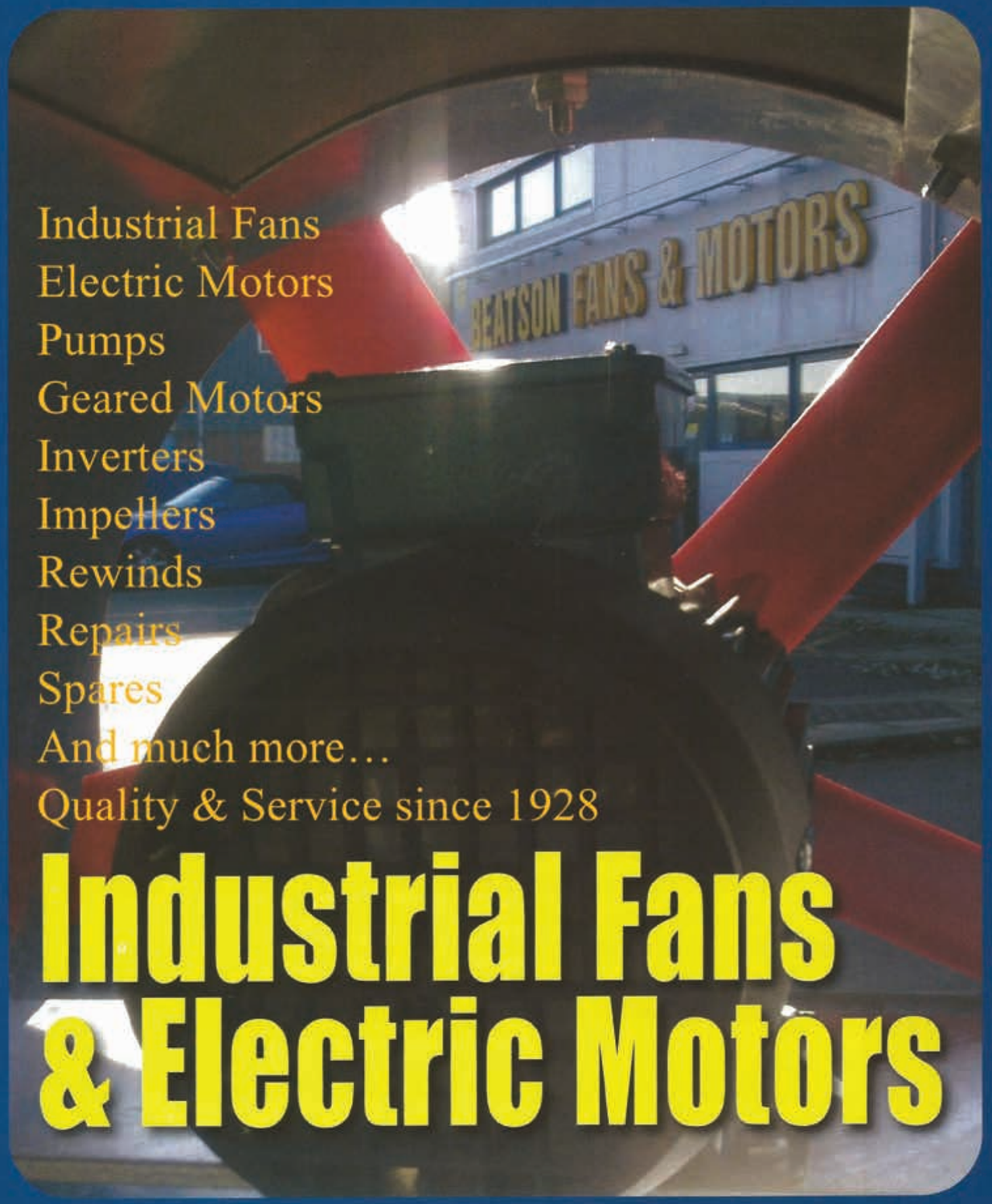

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The East India Dock Fountain splashed passing cars until Wilson Electric Engineers solved the problem.

The answer is blowing in the wind

When drivers on a road near an ornamental lake and fountain in London's docklands complained that they were getting an unexpected and unwanted free car wash, Carillion PME, the company in charge of maintaining the site, called in automation expert Wilson Electric for help with eliminating the problem. Two Vacon NXL AC variable speed drives proved to be the key to an efficient and cost-effective solution.

The fountain that forms the centrepiece of the ornamental lake on the Funeven Business Estate in the East India Dock area of London undoubtedly looks attractive. However, even in moderate wind conditions spray from the fountain affected vehicles on the adjacent busy roadway, a situation which was not only inconvenient for the drivers of the vehicles, but also a potential safety hazard.

One solution would have been to switch off the fountain on windy days but, as only a small amount of wind was needed to trigger the problem, this would have meant that the fountain would spend much of its time out of use. Carillion PME wanted a better solution and, following discussions with Wilson Electric, a company that regularly works on the site, it was agreed that a system would be put in place that would regulate the height of the fountain according to the prevailing wind speed.

The fountain is fed by two pumps, each with an 11 kW motor. The pumps run in parallel and, in the original arrangement, the pump motors were provided with standard direct-on-line starters. There was no provision for speed control and there was no space within the existing control panel for the addition of the variable speed drives that would be needed to control the height of the fountain.

However, after looking closely at the application, engineers from Wilson Electric found that there was just sufficient space to accommodate two of Vacon's exceptionally compact NXL drives within the enclosure that houses the control panel.

"The small size of the NXL drives was a key advantage in this application," said John Brooker, Technical Services Supervisor for Wilson Electric, "but they also had other benefits including, for example, ease of use, enclosed construction and built-in EMC filters. In addition, we've been using Vacon drives for many years, so we knew that we could depend totally on their performance and reliability."

To sense the wind speed, Wilson Electric fitted an anemometer that has a standard 4 to 20 mA analogue output. As might be expected, the anemometer provides a 4 mA signal at zero wind speed, increasing linearly to 20 mA for wind speeds of 30 knots or greater. However, the speed of the pumps is required to be highest at zero wind speed, decreasing as the wind speed increases. The flexible software of the NXL drives was therefore used to configure them for an inverse response to the signal from the anemometer.

"The drives were very easy to install and set up," said John Brooker, "and the new arrangement works very well – the fountain responds almost instantly to changes in wind speed, which means that it runs at full height, giving maximum visual impact, whenever possible, but there is no longer any risk of passing vehicles being affected by spray. It's an effective solution, it was easy and inexpensive to implement, and it satisfies the requirements of everyone involved."

The Vacon NXL drives used in this application have now been operating continuously for more than eighteen months. They are installed in an outdoor freestanding enclosure that is heated in winter to prevent condensation, but reaches high temperatures in the summer when it is exposed to direct sunlight for long periods. In spite of these demanding operating conditions, the drives have proved completely reliable and have delivered faultless performance. ■

"The drives were very easy to install and set up, and the new arrangement works very well – the fountain responds almost instantly to changes in wind speed, which means that it runs at full height, giving maximum visual impact, whenever possible, but there is no longer any risk of passing vehicles being affected by spray."

Power Transformer Testing

Condition Monitoring of Power Transformers – Issues with Repeatability of Sweep Frequency Response Analysis (SFRA)

By Dr Andrey A. Reykherdt, Senior Condition Monitoring Engineer.

One major issue with the SFRA measurements is their repeatability on-site in the range of high frequencies when it comes to periodic condition monitoring of transformer windings. SFRA measurements can be affected by a number of factors such as layout and grounding resistance of the ground extensions of SFRA cables which may lead to misinterpretation of the test results.

Power transformers are a key element of power networks and therefore their periodic condition assessment becomes essential. One of the most important aspects of the transformer assessment is the detection of mechanical deformations of transformer windings which can result in short circuits in the network as well as reduced clamping pressure due to insulation aging.

1

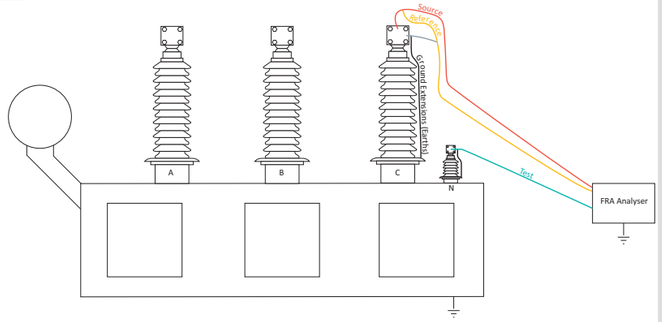

Figure 1: A common method of connecting test cables and their ground extensions to a power transformer for SFRA measurements.

Several methods exist for the detection of displacement or deformation of transformer windings. Among all the most popular are three phase and single phase leakage inductance or impedance measurements. However, these measurements utilise a fixed frequency of 50 Hz or 60 Hz, so the detection sensitivity is much lower in comparison with the SFRA method, whereby the measurements are typically performed at frequencies from a few Hertz up to 2 MHz.

As a result diagnostic frequencies in SFRA can be divided into the following three frequency ranges:

- 5 Hz up to about 5 kHz, this range shows the effect on the transformer core, including core magnetization and residual flux;
- 5 kHz up to about 500 kHz, indicates the effect of winding relationships including radial geometrical movements of windings relative to each other and
- Above 500 kHz, indicates the effect of axial movements of windings, internal leads and tapping circuits.

The SFRA method is very sensitive to any mechanical movements in transformer windings due to the changes occurring in the distributed winding inductance and capacitance, which in turn can influence the characteristic frequencies of the input and output signal measured in terms of the magnitude and phase of its admittance.

However a number of different factors may influence the SFRA measurements; among the most common factors are: (i) the layout of ground extensions of SFRA test cables across high voltage bushings, (ii) the type of ground extension in the measurements (round type or flat ground extensions) and (iii) the resistance between ground extensions and the transformer tank.

Figure 1 shows a common connection of the test cables and their ground extensions during SFRA measurements on a transformer while testing one of the phases. Figure 2 demonstrates two ways commonly used for connections of the ground extensions across the bushings with the ground extension away from the bushing (A - not recommended) and along the bushing (B - preferred).

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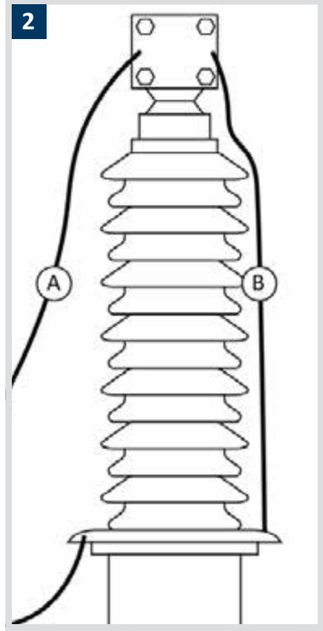

Figure 2: Ground extensions of SFRA test cables. Earth away from HV bushing (A) is not recommended.

As can be seen from Figure 2, the ground extensions can be connected in different ways along the bushing from the test cables at the top of the bushing to a flange base. It is important that the length of the ground extension corresponds to the length of the bushing every time the FRA measurements are performed. The

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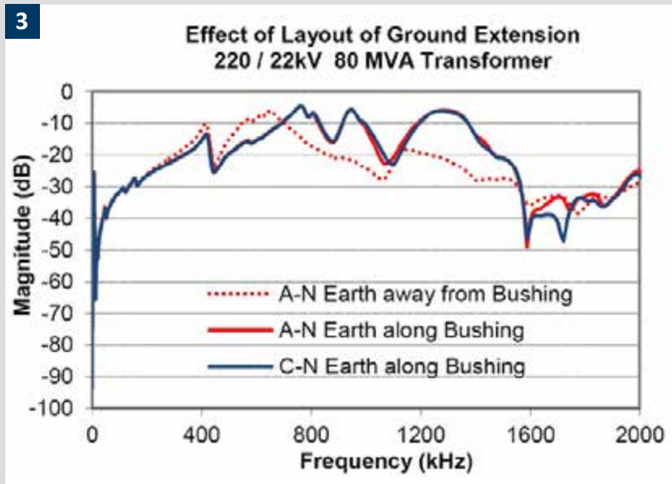

Figure 3: Effect of the different earth point and layout of ground extensions on FRA measurements; C phase to Neutral (C-N) measurement shows good correlation with A-N when using similar layout of ground extensions.

The SFRA method is very sensitive to any mechanical movements in transformer windings due to the changes occurring in the distributed winding inductance and capacitance, which in turn can influence the characteristic frequencies of the input and output signal measured in terms of the magnitude and phase of its admittance.

repeatability of the SFRA measurements in the high frequency range depend strongly on the layout of these ground extensions and the selected grounding points around turrets and flanges.

Figure 3 demonstrates a possible effect of the layout of the ground extensions with two different earthing points. The first measurement was performed with the ground extension “away from the HV bushing” (A phase to Neutral) and then the earth position was corrected to “along the bushing”. Similar SFRA response was received on other phases providing good correlation of SFRA signatures (only C-N measurement is shown in Figure 3 for comparison purpose).

Likewise when earthing the ground braids to the transformer tank (turret or flange) ground resistance also plays a very important role as many old transformers have painted or rusted surfaces which should be cleaned to make a lower ground resistance for the ground extensions. Figure 4 shows this effect of grounding resistance between the ground extensions and the transformer tank on SFRA signatures.

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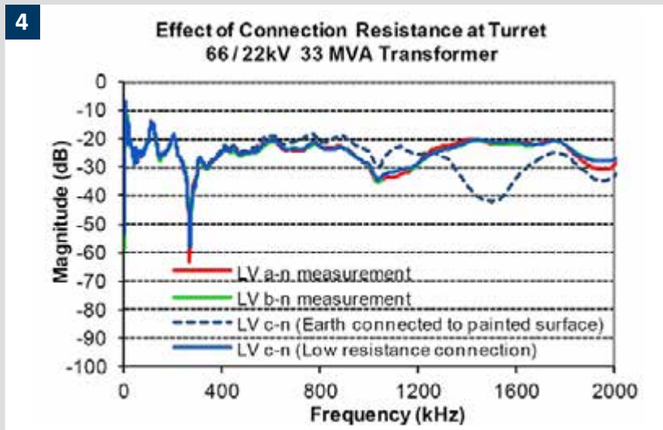

Figure 4: Poor ground resistance at transformer tank when earthing ground extensions resulted in higher deviation of LV C-N measurement, which was successfully repeated with lower earthing resistance of ground extensions

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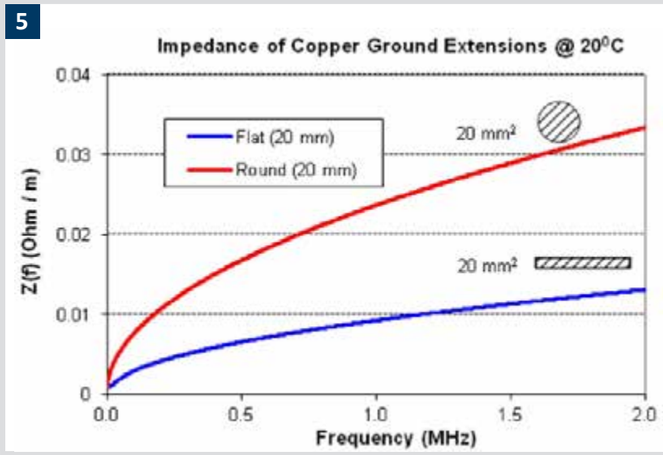

Figure 5: Calculated internal impedance of two types of ground extensions (round & flat) versus frequency for the same size of their cross section (20 mm2)

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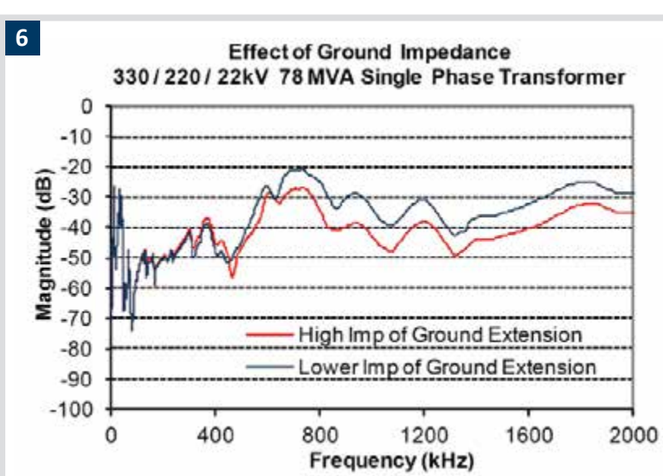


Figure 6: SFRA measurements using two ground extensions with high (round type) and lower impedance (wide flat type) of ground extensions

As mentioned before, a different type of ground extension can also affect the FRA measurements. Figure 5 demonstrates the calculated internal impedance of the round and flat type ground extensions according to. A flat (braid type) ground extension of the measurement cables has the lowest internal inductance and as a result provides smaller influence on SFRA test results. Figure 6 shows the FRA results from a 330 kV winding performed using two different ground extensions providing higher and lower test cable ground impedance.

SFRA results can be adversely affected if many aspects of the measurements are neglected. Misleading diagnostic results can be obtained at the frequencies as low as around 400 kHz possibly leading to a wrong conclusion on the condition of the transformer. ■

Conclusion

Experience of Select Solutions with SFRA measurements demonstrates that the SFRA results can be adversely affected if many aspects of the measurements are neglected. Misleading diagnostic results can be obtained at the frequencies as low as around 400 kHz possibly leading to a wrong conclusion on the condition of the transformer.

To achieve high repeatability of SFRA measurements the following practices are recommended:

1. Keep the ground extensions straight along the bushings and make them as short as possible.
2. Perform the measurements using only flat type ground extensions with low impedance.
3. Make sure connections are made to bare metal not to painted nor rusted surfaces.
4. Before starting SFRA measurements, connect the source, reference and test clamps together clamped on the highest voltage HV bushing with the ground extensions along the bushing. The resulting graphs should be a straight line of zero magnitude across the whole range of measurement frequencies. On completion of all SFRA measurements, perform another calibration check in the same way it was done initially. This will determine the highest repeatable frequency by comparison of the initial and the final SFRA measurements.
5. Perform the SFRA measurements in a consistent way to minimise external interferences.

The first electric car and passenger ferry in the world, equipped by Siemens in cooperation with shipbuilder Fjellstrand, has been taken into operation. With three battery packs, one on board and one at each pier, it functions completely emission free.

Setting a Course for Carbon-Free Shipping

As silently as a crocodile, the white giant approaches the shore. It opens its "mouth," which is several meters across. Suddenly the silence is broken by the roar of engines as a stream of trucks and people emerge from the opening. Odd Moen, an engineer who is responsible for ship solution sales at Siemens Norway, smiles. His vision of an electrically powered ferry sailing across Norway's Fjords just became a reality. Making hardly a sound and producing absolutely no emissions, it's the first and only ferry of its kind in the world.

A Century of Battery Powered Service

"For more than 100 years, there have been battery powered submarines that run solely on electricity," says Moen. "That got us wondering why we couldn't bring such a drive system concept to the surface, so to speak."

Experts began to work on developing this idea as early as 1999, but the technology needed was still too new for the market at that point, Moen recalls. Since then, however, technologies have improved, and lifecycle assessment issues have become more important.

Indeed, it was the environmental aspect of the project that won over Norway's Ministry of Transport and Communications, which oversees the country's waterways.

Five years ago the Ministry launched a competition to develop the most environmentally friendly ferry. The Ministry announced that the winner would be awarded the concession for the ferry link between the villages of Lavik and Oppedal in the Sognefjord. Diesel operated ships continue to serve this connection, but the concession license expires in 2015. The Ministry decided it wanted to use ships whose low noise and emissions would disturb the idyllic surroundings as little as possible.

We got together with the Fjellstrand shipyard and the ship owner Norled and developed an old idea further," Moen explains. "We pooled our expertise – Fjellstrand's knowledge of energy efficient shipbuilding and Siemens' electric propulsion expertise." The result is a sophisticated concept that's unparalleled anywhere in the world and unrivalled in terms of environmental compatibility. "That's what ultimately convinced the Ministry officials," says Moen.

The cooperative effort led to the creation of a fully electric ferry that travels across the fjord 34 times per day, with each trip requiring around 20 minutes to make the six kilometre crossing. The 80 meters long ferry is driven by two electric motors, each with an output of 450 kilowatts. Both are powered by lithiumion batteries.

The batteries have a combined capacity of 1,000 kilowatthours (kWh), which is enough to make a few trips between the two fjord communities. After that the batteries need to be recharged.

The ship's batteries will be recharged directly from the grid at night after the ferry stops operating.

Fjellstrand and Siemens engineers have come up with a simple idea to address the batteries' range problem. "We want to recharge the batteries at the docks after each trip," Moen explains. Still, this will give the ferry operator only ten minutes for recharging while passengers and vehicles disembark. The problem is that the power grid in the region is relatively weak, as it was designed to provide electricity only to small villages. "Briefly consuming so much energy from the medium voltage system to recharge the ferry batteries would cause the washing machines in all the houses in the area to stop running. Obviously we can't do that to the residents here," Moen explains.

Green Power Mix

Siemens' experts therefore installed one lithiumion battery at each pier to serve as a buffer. The 260kWh unit supplies electricity to the ferry while it waits. Afterward, the battery slowly recoups all of this energy from the grid until the ship comes back again to drop off passengers and recharge. The charging stations are housed in a small building about the size of a newsstand. The ship's batteries are recharged directly from the grid at night after the ferry stops operating. This solution is both simple and ingenious. "Under the prevailing conditions, it was the only feasible way of building and operating a battery powered ferry," says Moen. "Otherwise we would have had to expand the entire grid, and that would not have been possible due to the high costs of such a project."

It isn't just its drive system that makes the new ferry so environmentally friendly. Its electric motors are of course virtually silent and don't burn any fossil fuels. They also don't produce any pollutants. By contrast, a conventional

ferry travelling the same route consumes around one million litres of diesel fuel and emits 2,680 tons of carbon dioxide and 37 tons of nitrogen oxide each year. Nevertheless, the real reason for the positive environmental balance is the electricity mix. “The electricity in this area is generated exclusively by hydroelectric plants,” says Moen. “This makes the energy the ferry uses cheaper than diesel. It also means the ship doesn’t emit even one gram of carbon dioxide, directly or indirectly.”

Project specialists have also adopted a new approach for the ferry’s design. After all, unlike most electric cars, this ship was developed from the ground up as an electrically powered vessel. This has had a noticeable effect on its weight in particular. Despite its 10 ton batteries and capacity for 360 passengers and 120 vehicles, the ship is only half as heavy as a conventional ferry. That’s because it’s made exclusively of aluminium rather than the steel normally used in shipbuilding. The ship’s corrosion resistant structure also means it doesn’t require the special coat of paint that’s used to protect steel ships against rust.

Its robust aluminium hull needs far less maintenance, says Moen. That too lowers the ferry’s operating costs. In addition, the ship’s designers searched for the most energy efficient systems available.

The energy management system (EMS) is pre-programmed with curves giving engine fuel consumption under different load conditions. The EMS interfaces with sub-controllers for gensets, thrusters and remote controls to monitor and set optimal engine speed.

The ship’s genset, switchboard, propulsion and thruster control systems are fully integrated to ensure seamless ship operation.

Electric Ferries could Serve 50 Routes in Norway

Moen believes the great potential offered by electric ships can already be exploited. “There are 50 routes in Norway alone where battery powered ferries could operate profitably,” he says. “And we expect that batteries will become considerably more efficient and less expensive over the next five years.”

He also points out that Norwegians are very enthusiastic about innovations. In this respect, Moen, who rides an electric bicycle to work three times a week and likes to go snowboarding in the winter, is no exception. Still, although he is an enthusiastic fan of progress, Moen also likes continuity. For example, he has been working at Siemens for more than 30 years.

He also regularly spends time in his garage, where he restores vintage automobiles. Those vehicles, at least, are still allowed to keep their combustion engines. ■

The batteries are charged from hydro power. This battery pack onboard, like the ones on each pier, corresponds to the effect of 1600 standard car batteries. The charging at each peer takes only ten minutes.

The pumping station is positioned over the discharge pit and comprises of: two Wemco WSP6 self-priming pumps, galvanised Mild Steel pipework, heated jackets for cold weather protection and a control panel c/w pulsar ultrasonic level control.

Drainage pumping problem solved at the Port of Immingham

Article by Bryan Orchard for Axflow

Like many industrial sites that contain large areas of open space, surface water build up can prove to be a problem. At the Port of Immingham surface water has always been removed from the 1,230 acre site by a tidal flap (valve) that drained water from a series of inter-connecting chambers and discharge pit directly into the Humber Estuary. However, due to recurrent blockages ABP's engineers were keen to find a permanent solution to the problem.

The Port of Immingham is the largest by tonnage in the UK, handling some 50 million tonnes annually, and can accommodate vessels of up to 130,000 tonnes, so maintaining full operation at all times is essential. Whilst surface water build-up was not a major threat to the Port's operations, it was seen as a recurring problem that had to be resolved. In mid-2015, engineers at the port called in the service of pump distribution and engineering specialist AxFlow Limited, asking them to devise a solution that would eliminate the problem. AxFlow's proposal was to build a surface-mounted pumping station that would drain the interconnecting chambers and pump the water into the dock.

The new surface water pumping station was commissioned in the final quarter of 2015 and Mark Redgrove says that initial reports received indicate that it is working well.

AxFlow Technical Support Manager Mark Redgrove explains why this solution was arrived at. "The existing drainage system consisted of a series of underground chambers that collected the water, which then drained into a main discharge pit on the lock side of the port. From there the water was discharged through the tidal flap located on a mud bank in the estuary. However, due to the regular build up of silt, divers were having to manually clear away the silt and mud," explains Redgrove.

The pumping station is positioned over the discharge pit and comprises of: two Wemco WSP6 self-priming pumps, galvanised Mild Steel pipework, heated jackets for cold weather protection and a control panel c/w pulsar ultrasonic level control. "The discharge pit is approximately 1m.sq so a surface mounted self-priming pump was selected as there was insufficient space in the pit to use submersible pumps," continues Redgrove. "We also had to take into account the issue of pump maintenance, which is much easier with surface-mounted pumps. The decision to use Wemco WSP6 pumps was made on the grounds that the run-off water contains grit and solids that collect on the docks, these pump would easily handle them as they are not affected by solids."

The Wemco WSP heavy duty self-priming pump is equally at ease with clean and solids laden liquids due to its open type two-vane impeller. The pump is suitable across a broad spectrum of applications for water and wastewater handling, it has a differential head capability range of 3-42m and can deliver flowrates between 10-700m^3/h. The two-vane impeller is manufactured in a choice of cast iron or CD4MCu with the wear plate also made from cast iron and the casings in ductile iron. It is this build quality that enables the pump to handle both clean and aggressive fluids, plus the solids handling capability proving excellent for this range.

Self priming pumps are ideally suited to any duty with a suction lift where ease of access to the pump is necessary for maintenance purposes. Whereas submersible pumps have the benefit of being primed by the liquid in which they are submerged, access can be difficult when maintenance is required.

The two 6-inch Wemco pumps have been installed by AxFlow on the edge of the pit and have suction legs descending 7.5m into the pit. The run-off water is pumped through 30m of discharge pipework that takes the water away to a point where it drops into a dummy sluice, this being a small chamber that is parallel to the lock, as the level of the water in the lock rises and falls, so does the dummy sluice. The water run-off passes out of the dummy sluice into the lock and enters the estuary when the lock gates are opened.

The discharge pit has the capacity to hold between 6- and 7m³ of water, and once it is empty it soon fills up as water from the interlinked chambers drains into it. The design flow is 200m³/hr, which provides the dock with plenty of surplus capacity, with emptying times being between four and five minutes. Once the chamber is empty it can fill up relatively quickly depending on the rainfall. Due to the fluctuations in the volume of surface water run-off, the pumps are not operating continuously. The pumps are on duty/standby configuration so that both pumps share the workload. When one pump has run for a period, the ultrasonic control system will switch operation to the standby pump, which then becomes the duty pump. Should there be very high rainfall both pumps can operate at the same time to keep the flow at optimum capacity.

Installing the suction legs into the 7.5m deep pit.

AxFlow has undertaken a number of pump projects for ABP over the years. "This is not our first project at the Port of Immingham," says Redgrove. "Back in 2014 we were asked by ABP engineers to produce a pumping solution for emptying a grit chamber in a settling pit at the coal terminal where the water separates out from the grit. We installed two sets of 4-inch submersible pumps and these have worked very well."

The new surface water pumping station was commissioned in the final quarter of 2015 and Mark Redgrove says that initial reports received indicate that it is working well. ■

Damaged Generator Rotors: The economic and logistical benefits of repair over scrappage

A Quartzelec white paper explores new advances in repair techniques and stress analysis to extend the feasibility of a repair further than traditionally thought.

Produced by: Wojciech Betlej, Tony Croucher, Bernhard Fruth and Dominic Buse.

ABSTRACT

Many would agree that one of the worst possible electrical failure mechanisms on a generator rotor is a motoring event while the rotor is at standstill. The resulting damage can be extremely severe – including a melted rotor body and double earth faults. In many cases, this renders salvage impossible and the rotor has to be scrapped.

This paper describes extensive repairs recently carried out by Quartzelec to a generator rotor following such an occurrence whilst the rotor was at standstill.

The failure resulted in a double earth fault and severe arcing damage, which included deep excavations within the forging slots, almost 20% of the copper winding on the rotor melting away or becoming severely distorted, and severe damage to the retaining rings, snap rings and wedges.

It is believed that the repairs carried out by Quartzelec to save the rotor rather than scrapping it, were a first and that they could well replace current practice: rotor bodies which would normally be condemned can now be successfully repaired.

INTRODUCTION

During steady-state condition, the main magnetic field set up by a generator's rotor winding and that produced by the current flow in the stator winding are aligned, so no unwanted voltages are induced in the rotor. During transient conditions, however, the magnitude of both magnetic fields changes causing negative sequence currents to flow in rotor components such as the body, damper cage and field winding.

International standards for new generators specify requirements which must be met whilst in the transient state, including the ability to sustain certain abnormal conditions such as external faults in the transmission system, or minor voltage and frequency variations which would induce negative-sequence currents on the rotor surface. Most new units incorporate leading edge protection systems to guard against most major faults. Unfortunately, however, neither malfunction of these protection systems nor human error can be fully controlled. The objective of this article is to reveal the consequences of a motoring incident, and the repair methods used by Quartzelec to tackle the resulting severe rotor damage, including weld repairing the melted rotor forging and altering the geometry of the slot dovetails section supported by precedent stress analysis.

Can a synchronous generator work as an induction motor?

Loss of excitation whilst a generator is under full load effectively turns a synchronous generator into an induction motor. The rotor speed rises until the prime mover governor reduces the steam input to inhibit the speed increase.

This induces low frequency currents in all conductive components such as the rotor body, wedges, damper cage and winding. The time for which the rotor can sustain this asynchronous condition depends on many considerations – but principally upon the induced currents flowing through rotor components that have not been designed to sustain them for prolonged periods.

Due to centrifugal force present whilst the generator is under load, contact between all of these components is very good, resulting in low resistance. So normally, no harm is done to the rotor before the generator trips. This phenomenon – known as reverse current, reverse power or motoring, is not normally allowed to persist for any period of time. However, until the generator breaker is opened, the generator will act as a motor with current from the grid, keeping the prime mover spinning at slip frequency. This can be very destructive to rotor wedges and rotor-retaining ring contact areas if allowed to continue for any length of time. Most generator units are protected from this by reverse power relays or loss of excitation protection.

The situation changes dramatically if the generator rotor is running at low speed or standstill and the main circuit breaker has been inadvertently closed. Under such conditions, the generator attempts to run as a squirrel-cage motor, using a damper circuit (Figure 1). High currents flowing through the stator winding induce a 50Hz current flowing in the rotor components. Due to lack of centrifugal force, high resistance is created between squirrel-cage components, generating excessive heat.

The rotor will try to accelerate, but the presence of rectification diodes within the excitation system will allow only half cycle current to flow through the damper circuit, successfully reducing the rotor speed. Bitter experience shows that generators exposed to this condition can be permanently damaged in a matter of seconds.

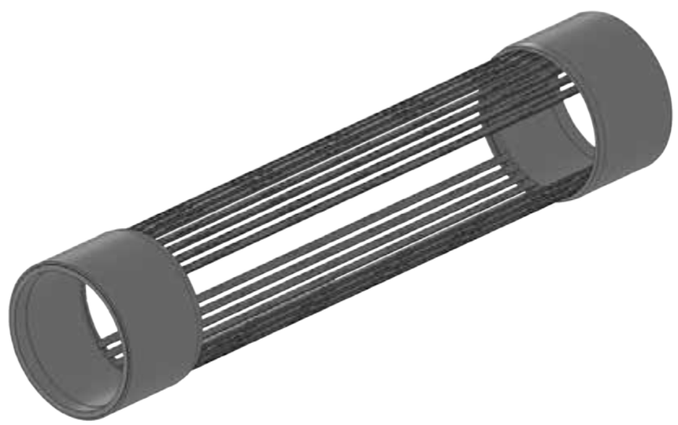


Figure 1. Rotor damper circuit made from wedges and retaining ring

CASE STUDY

Repair time: < 5 months
Repair cost: 50% lower than replacement

The following scenario occurred on a 140 MVA generator in a Ghanaian power station, causing severe damage to several rotor components. The customer report confirmed that undefined issues with one of the circuit breakers may have occurred, tripping the generator during run-up. Subsequent attempts to start the machine were unsuccessful and the decision was made to remove the rotor and conduct the appropriate investigation.

Investigative findings

Investigation revealed damage consistent with a motoring incident. The damper circuit on the Ghanaian generator rotor was comprised of aluminium wedges shorted by retaining rings shrunk onto both sides of the rotor. By design, the circuit does not become fully active until the rotor's speed exceeds 2000rpm, when the damper components create a low resistance path, preventing negative sequence currents induced from causing any damage.

Figure 2 & Figure 3 (above right) clearly show severe damage caused by high currents flowing in the damper circuit during the motoring incident. When the rotor is stationary, there are no centrifugal forces to load the slot content against the rotor to cause full contact between the ends of the rotor slot wedges and the end winding retaining rings. Full contact between the slot wedge flanks and wedge slot flanks also becomes intermittent.

The majority of induced currents flow through the aluminum wedges and rotor body surface, causing substantial heat to be produced when a high resistance joint occurs between two damper circuit components. This explains the severe arcing damage on wedge tips, flanks and retaining rings. Similar damage was found in every slot dovetail.

In addition, almost 20% of the copper winding on the rotor had either been melted away or suffered severe distortion. See Figure 4 & Figure 5 below.

Later investigation confirmed the presence of a double earth fault, resulting in severe arcing damage. Two deep excavations (250mm and 300mm axially, up to 20mm deep) were found within two of the forging slots where material had vaporized at the site of the earth faults. It is believed that an earth fault had occurred during attempts to run the generator after the motoring incident. See Figure 6 & Figure 7 below.

Figure 2. Molten retaining ring fit area.

Figure 3. Molten wedges.

Figure 4. Molten copper from slot 24.

Figure 5. Molten copper from slot 11.

Figure 6. Molten tooth in slot 11.

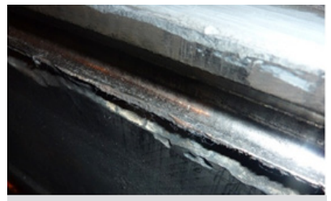


Figure 7. Molten tooth in slot 24.

Figure 8. Earth fault location recovery process.

QUARTZELEC'S SOLUTION

The component with potentially the longest lead time and highest cost to replace was the rotor forging; preliminary engineering work was focused here to make sure that it was salvageable. This involved the following:

STEP 1: Rotor body inertial slots

- During the motoring incident, the highest currents flowed through the wedges as well as the rotor body, with the highest density around the inertial slot teardrops.
- A hardness test was conducted to confirm that heat damage had not occurred in those locations.

STEP 2: Rotor slot dovetails

- Severe arcing damage was confirmed in all rotor dovetails. The depth of the most severe damage was measured.
- It was identified that it was necessary to open every slot by 1mm in order to remove all damage.
- Stress analysis of the rotor teeth was conducted to prove the mechanical integrity of the new dovetail and wedge design (see Figure 8).

STEP 3: Deep excavations in slot 11 and 24

- The locations of the earth fault on the rotor body were dressed out.
- Metallographic replicas to make sure that the heat affected zone was completely removed.
- Additional hardness tests were conducted in multiple locations around the damaged area.
- A weld repair to the rotor body was subsequently carried out (See Figure 8).

STEP 4: Rotor body

- The forging itself required the standard set of non destructive tests (NDT) including dye penetration test, magnetic particle test and ultrasonic test to all high stress locations.
- On confirmation that the rotor body could be salvaged, all remaining components were checked and revalidated.

STEP 5: Rotor wedges

- All aluminium wedges showed evidence of severe arcing damage along their entire length and were deemed unfit for use.
- Because the rotor slot dovetails were opened to remove arcing damage, new wedges were required.
- Existing aluminium wedges were reverse engineered.
- New wedges were manufactured to incorporate new modified shape and original vent hole configuration.

STEP 6: Rotor retaining rings

- Both retaining rings showed evidence of severe arcing damage and were scrapped.
- Existing retaining rings were reverse engineered. New retaining rings were manufactured from 18/18 material to ASTM A289.

STEP 7: Rotor snap rings

- Both snap rings showed evidence of severe arcing damage and were scrapped.
- Existing snap rings were reverse engineered to enable new ones to be manufactured.

STEP 8: Rotor copper

- The rotor copper was thoroughly inspected to identify damaged turns.
- Hardness tests were conducted to review the condition of coils affected by high temperatures.
- Collapsed copper corners were found on every top turn, prompting the decision to replace every coil.
- Approximately 20% of the winding was deemed unsuitable for re-use.
- New copper turns were manufactured using silver bearing copper, drawn to incorporate the contraflow cooling system.

STEP 9: Rotor field lead

- The field lead wedges were NDT tested and passed acceptable.
- The field lead dovetail was NDT tested and passed acceptable.
- The existing field lead wedge insulation was replaced.

STEP 10: Radial stalks and upshaft

- Radial stalks were cleaned and replaced.
- The connection was removed, cleaned and HV tested to ascertain the electrical integrity of the upshaft.
- The existing upshaft was found to be acceptable, and reused.

Following the rewind, the rotor was tested at 120% overspeed for two minutes to confirm mechanical and electrical integrity. Insulation resistance, RSO, search coil and HV testing were carried out at 3000 rpm. A heat stability run was also carried out at a mean winding temperature of 80°C to ensure acceptable rotor vibration response at temperature.

Rotor teeth stress analysis

The rotor is machined from a low alloy steel Ni, Cr, M having 0.2% proof stress of 600-700MPa. The rotor has longitudinal slots to give the correct location for the copper stack to be positioned as Figure 9 below.

The copper coil group is made up from a series of copper turns in an 'E' cross section, separated from the forging by an insulated slot liner and placed together to form cooling air passages with alternate turns electrically isolated by an insulation layer. A final top packer provides the final barrier between the current carrying conductors and the wedges.

The forces generated by rotation are restrained against radial movement by the aluminium wedge that locates in the dovetail profile of each rotor slot, see Figure 9.

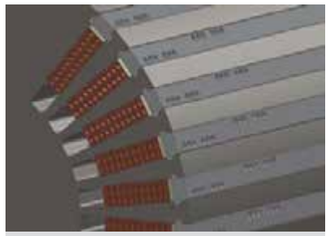


Figure 9. Rotor slot content.

To determine if machining the profile to remove the damaged material was a viable option, an FEA study was undertaken of the original profile and of the new profile, see Figure 10.

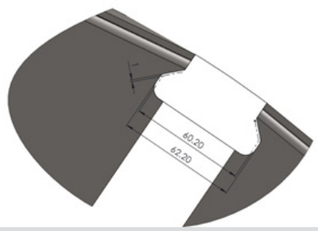


Figure 10. New profile dimensions and the old in chain dotted

The rotor had not been damaged by a failure with the slot profile, the exact material properties were not known, therefore, the change in stress level was of more interest. This contrasts with the approach used for new designs of

Figure 11. Rotor forging – general view.

rotor where the mechanical properties are known and the stress level is of paramount importance.

The rotor slots are distributed symmetrically about the rotor's Z axis – a feature used to reduce the FEA model down to two slots. The slot was also loaded uniformly along the length of the wedge due to the mass of the copper and the aluminium wedge acting on the dovetail profile. This enabled a 100mm section to be taken to represent the rotor length, see Figure 11 & Figure 12.

The model was restrained against movement in the Z axis (axis of rotation) on the faces – and normal to the radial faces – leaving the section free to move in the radial directions.

Loads representing the copper and aluminium mass were applied to the dovetail flanks, orientated normally to a plane in the centre of the slot and reducing the FEA model to a single component. The applied centrifugal force was calculated using the restrained masses, their centre of gravity and the rotor speed, thus:

Where,

m = (Cu) 3.67 + 0.402 (Al) = 4.075kg

ω2 = 3600rpm 120% overspeed, = 388 radians/sec R = 0.4m
CF = mω2R= 4.075 x 3882 x 0.4 = 245,206N

In addition to this load a centrifugal load was applied to the rotor segment along the Z axis, using a speed factor of 120% of the running speed to simulate the centrifugal loads from the rotor's mass.

The overspeed value (3600rpm) was used because the centrifugal force increases with the square of the

Figure 12. Rotor forging cross section through rotor body

speed. If the change in stress is low at overspeed levels, it follows that it will be even lower at normal running speed.

The FEA model was run for both slot profiles in a basic mesh configuration, then with successive mesh refinement around the dovetail profile to increase the accuracy in the relevant area and demonstrate convergence in the stress level as required by NAFEMS (the International Association of the Engineering Modelling, Analysis and Simulation Community). Also, following the association's guidance on convergence to determine whether a good quality mesh had been designed, the displacement for all meshes was checked and found to be independent of the mesh quality.

The results shown in Table 1 (opposite) show a converging solution for all simulations, other than the final refinement for the original profile where there is a divergent. For comparison the medium mesh refinement is used as a convergent point on all simulations.

The Von Mises stress between the two profiles changes by only 8.7% for the increase in width.

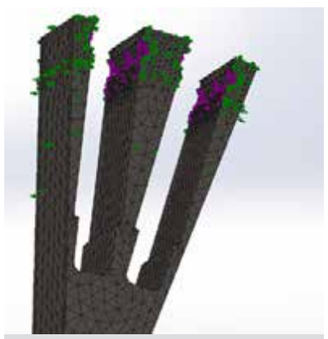


Figure 13. Restraints and applied load to profile flanks.

FEA profile	Mesh size	Von Mises stress (MPa)	Deflection (mm)
Original	8mm 5mm 2mm	516 516 548	0.331 0.331 0.331
New	8mm 5mm 2mm	533 565 564	0.318 0.318 0.310
New profile, with wedge surface contact	8mm 5mm 2mm	281 361 339	0.230 0.236 0.233

Table 1. Simulation results summary.

Whilst not the deciding factor, the predicted stress for the groove was higher than expected, for both profiles. To check that the FEA model had not been over simplified, an additional simulation was conducted with the wedge included in the model and loaded against the slot flank profile.

The meshing and restraints used the same symmetry principle as for the simple FEA model, with the contacting flanks of the wedge mated to the rotor slot profile for a no penetration contact. This contact allows for sliding motion between the two faces and more realistic simulation; NB the figures overleaf show the model in an exploded view.

This also confirmed that the bending stress on the aluminium wedge remained within a reasonable level, despite the slight increase in span.

All the simulations confirm that an increase in profile results in a minor increase in stress, but would not be detrimental to the rotor stress, or wedge, even at overspeed.

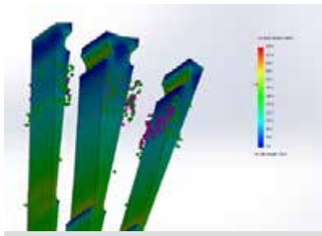


Figure 14. Stress pattern, original slot profile

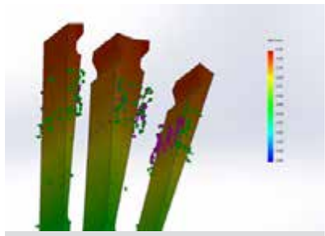


Figure 15. Displacement pattern, original slot profile

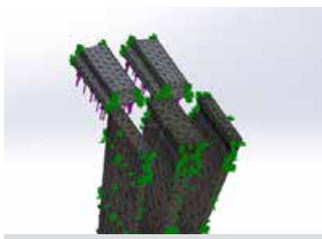


Figure 16. Medium mesh with wedges in exploded view.

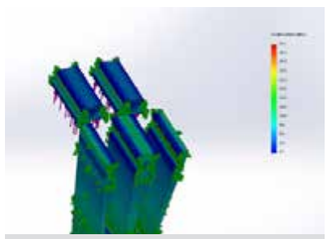


Figure 17. Stress pattern.

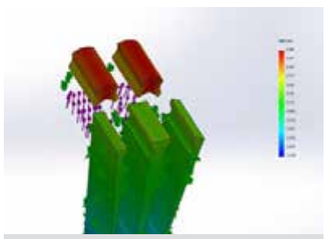


Figure 18. Displacement pattern.

Rotor weld repair

Once the excavations had been prepared by the removal of heat-affected areas – confirmed by performing a set of material replicas and additional hardness tests – preparation for TIG welding commenced. The rotor forging was preheated to increase the strength of the weld and provide finer weld structure by full martensite transformation using highly accurate temperatures.

The welding was then carried out in accordance with internal processes at previously agreed parameters by highly experienced welders specialising in this procedure. The welding locations were then carefully dressed to allow NDT inspection. Both magnetic particle and ultrasonic tests were carried out by a specialist NDT technician with over 35 years experience to confirm effective fusion between materials. Finally, both weld locations were hand-polished and the forging stress relieved in accordance with company internal specifications.

Rotor body stress relief

The elevated temperatures generated during the welding process leave high residual stresses in the welded location, potentially causing unacceptable metallurgical changes in the alloy and in turn, stress corrosion cracking and increased risk of brittle fracture. To minimise the risk of this happening, high temperature was applied to the affected location, reducing proof strength and allowing deformation to take place and residual stresses to fall, until the required level was achieved. This in itself is a stringently controlled process, as relief time and temperature level are dependent on the alloy in question.

Figure 19. Slot 24 ready for weld repair.

Figure 20. Slot 11 ready for weld repair.

CONCLUSION

With today's power generation sector under intense pressure to reduce maintenance costs and times, the question of component repair verses replacement has become crucial to economic viability. Quartzelec has effectively demonstrated that a severely damaged rotor with vaporised forging and molten components can be recovered if bold engineering solutions are applied and skillful craftsmen deployed.

In this case, the severely damaged rotor was repaired in less than five months, and at a cost 50% lower than the cost of a new rotor. ■

Hidrostal changes up a gear with EMiR

Investment in targeted ERP pays dividends in performance

In early 2013 Hidrostal found itself with a very common yet difficult decision. The software that it was using to run its business (that had been built as a bespoke tool) was not meeting the changing needs of the organisation. At the very least a major overhaul if not an entire rebuild was required in order to allow the improved processes identified by the management team to be implemented.

Hidrostal Ltd is the UK based sales company for Hidrostal AG, a Swiss pump manufacturing business that was formed in 1987. Hidrostal Ltd bring bare shaft pumps from Switzerland to the UK and customise them to specification. This includes the fitting of seals, local manufacture of drive assemblies for vertical sump pumps, fabrication of baseplates for horizontal units and assembly to UK procured motors and couplings. The complete customised pumps are then shipped to the final customer.

The company remains one of the few dedicated and specialist waste water pumping businesses left in the UK, alongside its sister company, Bedford Pumps Ltd, a specialist manufacturer of large submersible and conventional pumps to the water and wastewater market, acquired by Hidrostal in 2014. From standard off the shelf products to complex bespoke design solutions, the combined specialist engineering knowledge from the two companies

ensure that any pumping need within the water, wastewater and industrial markets can be fulfilled with a complementary range of pumping solutions from 0 to 12,000 litres per second.

Hidrostal Ltd operates as a supplier, designer and installer of fit for purpose pumping solutions. In addition the company also offers workshop repair, site maintenance, pump hire, and support services.

Faced with an investment of over £100k to get the existing IT just to a position where new programming could be started, Hidrostal started to look to other packages and alternatives. It quickly became clear that the business did not fit neatly with any of the tools on the market. “The high end ERP (Enterprise Resource Planning), tools such as SAP were clearly a step too far and without massive customisation would never have fit our business needs.” explains Finance Director Annette Boulter. “The smaller tools on the other hand were just not up to the complexity needed”. A routine visit to another AEMT member that Hidrostal works closely with, WGM Engineering, introduced Hidrostal to EMIR ERP (Electro-Mechanical Information Resource ERP), which is specifically targeted at companies in the pump and motor industries.

Targeted Software

The main attraction to EMIR is the fact it is purpose built for companies in the same industry. “What we saw was a programme that fitted with our business needs and could be made to fit our operational needs with virtually no modification. This is what appealed to us the most, given our previous experience of a bespoke system where a lot of modifications were required and where those modifications sometimes took months to implement.

The plug and play nature of the tool was the main draw. This enabled us to make real changes from the very moment that we started using the system.” Annette explains.

Hidrostal made the decision to invest in EMIR Pro, complete with the full Finance and CRM modules. The software is specifically built for the pump and motor industry and most of the modifications that would be needed to fit Hidrostal’s business processes were already inbuilt.

As companies in similar trades were working with EMIR to continually develop the programme, it represented combined best practice throughout the industry.

The Hidrostal stock part system now holds over 20,000 parts, each of which can be configured to have a specific price for a given customer. This has been invaluable in setting up framework agreements with customers who require fixed pricing for a number of years where standard sales prices may change from year to year.

EMiR
Electro-Mechanical Information Resource

Instant Efficiency

Hidrostal’s EMIR system replaced not only the old bespoke ERP system but also Sage Accounts and ACT contact database. The move to a single IT system significantly improved efficiency in removing duplication of entry and also increased the integrity of the business information. The system went live in January 2014 and after the initial bedding in period the effect of having single data entry and one data repository could be seen. “Headcount savings were able to be made almost immediately, but more importantly all of our other staff could be freed up from administration and focus on value added activities, improving quality and timeliness of service to our customers”.

In addition a single source of data entry, from the original quote all the way through to final delivery ensures that the errors which can occur from multiple data entry is eradicated.

Hidrostal Flexibility

Hidrostal’s product range is extremely flexible. The company founder, Martin Stähle, invented and patented the single vane screw centrifugal impeller almost 50 years ago. This impeller offers the best free ball passage without a compromise on efficiency, and a variation of this impeller is incorporated into every pump the company makes in order to solve specific pumping problems.

Due to the extended product range the company is famous (if not infamous) for the length of the part code for the pumps it sells and this is because of the configurability of the range. With over 10,000 combinations of components it was historically almost impossible to create pricelists. Before the system was implemented Solutions in IT were able to make fast changes that allowed Hidrostal to work with part numbers of up to 50 characters, easily encompassing the pump codes needed. In addition to this the EMIR stock system allowed individual parts to be easily added as an upload from a csv file.

The Hidrostal stock part system now holds over 20,000 parts, each of which can be configured to have a specific price for a given customer. This has been invaluable in setting up framework agreements with customers who require fixed pricing for a number of years where standard sales prices may change from year to year. In a standard system this would be an administrative nightmare, in EMIR it is a simple update.

Data no longer for ransom

In Hidrostal’s previous ERP, reporting was limited and because each of the accounting, CRM and job management systems were separate it was a full time job ensuring that the data in each was consistent. This made reporting and analysis a very difficult task.

“The problem with so many systems is that whilst they operate efficiently in their own right they only produce reports that are in pdf format or even worse just screen shots that cannot

What we found was that the enquiries within EMIR were so straight forward that the auditors simply figured out where to get the information themselves, without having constantly to ask for evidence and copies of invoices. This saved hours of time on our part. So much so that we are even considering undertaking the audit remotely next year."

be used elsewhere. The joy of EMIR is that virtually every screen can be downloaded to Excel or csv and then used for further analysis. This has provided Hidrostal with some real advantages in understanding trends and in providing key business insights."

Paperless Finance

The Holy Grail of Finance has always been to move to a paperless department. With EMIR, Hidrostal has been able to achieve this in just 12 months.

Throughout history Finance Departments have been a hub for paperwork and endless rows of files, mostly of purchase and sales invoices. In this day and age many, if not most, suppliers prefer to invoice electronically, saving paper, printing and post and ensuring that the invoice actually reaches who it needs to. Many Finance Departments however still find themselves carrying on in the old way of doing things, which actually means printing out the invoice as it arrives to allow it to be processed and filed. At Hidrostal, with EMIR, this has been eradicated.

All suppliers are encouraged to send invoices in electronic pdf format, and for the few who cannot the paper invoice is simply scanned to pdf then recycled. Data entry is simple with a dual screen workstation (simple to set up on most PCs) with the invoice on one screen and the EMIR data entry on the other. EMIR assigns an internal invoice number under which the pdf is then saved (in designated folders) at which point the invoice is available to see within EMIR and the pdf can be opened from EMIR itself to view the invoice whenever needed.

In this scenario the Purchase Order drives the process and the person setting the order decides the nominal code to which the expenditure will be assigned (confirmed when the PO is authorised). The invoice is only cleared for payment when it completely matches the PO. A weekly team meeting is all that is needed to check which invoices have not been cleared and to agree the actions to ensure they are matched and subsequently paid.

Where many companies use their paper invoices (filed under the date to be paid) to manually create their payment runs, this is done automatically in EMIR. Hidrostal pay their suppliers weekly and EMIR proposes the payments to be made based on the agreed terms with the supplier and the date of the invoice. Of course invoices can be put on hold and suggested payments changed, but Hidrostal find little need to do this because all problems are dealt with as soon as the invoice arrives, rather than when payment is actually due. In addition EMIR knows that the Hidrostal payment run is on a Friday and will suggest all invoices with a due date before the following Friday should be paid, ensuring that all supplier invoices are paid on or before their due date.

This instils both trust and predictability into the organisation's relationship with their suppliers, and helps create the basis for a real working partnership as opposed to withholding payment until the paper reminder comes through, as so many firms do.

What enables this is the excellent credit control in place at Hidrostal, enabling Cashflow to be fed down to the supply chain. This is achieved through excellent staff but enabled by the debt chasing facilities and the data provision in EMIR. It is very easy to see which customer's invoices are overdue and customers who have gone over a set number of days late are put on stop immediately. This ensures that bad debt is almost unknown and old debt is tiny.

With electronic sales invoicing, purchase invoices held as pdfs, and online banking, Hidrostal had its first all-electronic audit at the start of 2016. Instead of vast amounts of time spent finding paper evidence the auditors were instead given access to the Hidrostal Cloud Server and access to EMIR itself. This allowed them to pull their own evidence from the accounts system with minimal input from Hidrostal's staff.

"What we found was that the enquiries within EMIR were so straight forward that the auditors simply figured out where to get the information themselves, without having constantly to ask for evidence and copies of invoices. This saved hours of time on our part. So much so that we are even considering undertaking the audit remotely next year." confirmed Annette Boulter FD.

"The move to an electronic Finance Department has not made us completely paperless but has led to 99% less paper, which in turn has led to less storage space being required and the ability to outsource much of the transactional Finance activity. The efficiency of the department and the happiness of our suppliers has increased tenfold."

Hidrostal Ltd is delighted with the way that EMIR has revolutionised their business. In today's busy world the importance of efficiency cannot be underestimated. The time that has been saved by streamlining Hidrostal's business process with EMIR frees up more time to focus on the company's main strength, ensuring that any pumping need within the water, wastewater and industrial markets can be fulfilled. ■

Deritend's FREEFLOW thermodynamic instrumentation helped the customer with their reservoir pump situation.

Detailed analysis at a reservoir pumping station reveals solutions to lasting problems

Out of three pumps installed at a customer's reservoir, two pumps had different manufacturers to the third and as such could not be assumed to operate in the same way.

The variable drives were also obsolete and, prior to the project being carried out by Deritend, it had not been possible to obtain any information about the electro-mechanical efficiency of the motor and variable speed drive arrangement.

Informally it had become known that pump three consumed more energy, while station Supervisory Control and Data Acquisition data (SCADA) showed confusing variations in cost per mega-litre. The reservoir operators had been unable to pinpoint what was happening and why.

Testing the pumps as part of a wider programme across many sites, Deritend used innovative measurement techniques and a patented software algorithm to gather data and identify solutions.

To monitor all three pumps over an eight-week period a conventional pump testing system called ECOFLOW was used and FREEFLOW, a thermodynamic instrumentation.

Being able to deploy both methods together has meant measurements could be made to the motor and drive efficiency, essential to solving the lasting problem at the reservoir.

Patented software algorithm at work

Due to the physical setup of pipework at the reservoir, a flow meter could not be placed on each pump. Using a patented algorithm Deritend were able to use one flow meter on the common suction pipe work and, with 100% accuracy, divide this measurement into the contributing flow rates for each individual pump; essentially placing a virtual flow meter on each pump. As a solution, it was decided to use one flow metre, connected to the common inlet main that was able to measure total flow.

The central flow meter synched with the software to effectively create a virtual flow metre – the algorithm for which was able to take the total flow and divide this amongst all of the pumps to give an accurate reading for each one.

Specific measurements taken:

- Electrical power to drive
- Suction pressure
- Discharge pressure
- Differential temperature
- Rotational speed
- Total station flow rate

The calculated parameters for each pump:

- Total differential head
- Electrical power
- Hydraulic efficiency
- Motor drive efficiency
- Volumetric flow rate

Importantly, the data showed that the acquired information about pump three was not at all accurate. In fact, Deritend were able to reveal specific characteristics of the variable speed drive, showing its designed efficient operating region did not coincide with the best efficiency point for the pumps. There was a fundamental mismatch in characteristics and an inefficient design.

Data showed that when demand was met using parallel pumping operations (with two pumps) the hydraulic efficiency of the station was around 85% (compared with the solo pumping operations where the hydraulic efficiency is around 70%). This suggested that the solo pumping operations result in a 15% decrease in hydraulic efficiency.

By analysing the specific power of the station revealed the opposite result, however. This showed that parallel pumping operations result in around a 34% rise in operating cost of the station. Evaluating the electro-mechanical drive efficiency of the variable speed drives and the motors the engineers were also able to demonstrate a significant increase in cost when running motors at lower speeds.

Deritend demonstrate the Freeflow monitoring system to a customer.

The above data offered some quite dramatic revelations – all of which then needed to be acted upon. So, to evaluate the optimum trade-off between hydraulic efficiency and electro-mechanical drive efficiency, a scheduling analysis was performed. The data collected from the pump monitoring period enabled the engineers to calculate variable speed drive efficiency and identify some peculiar points in the way the station's pumps worked.

The results in full

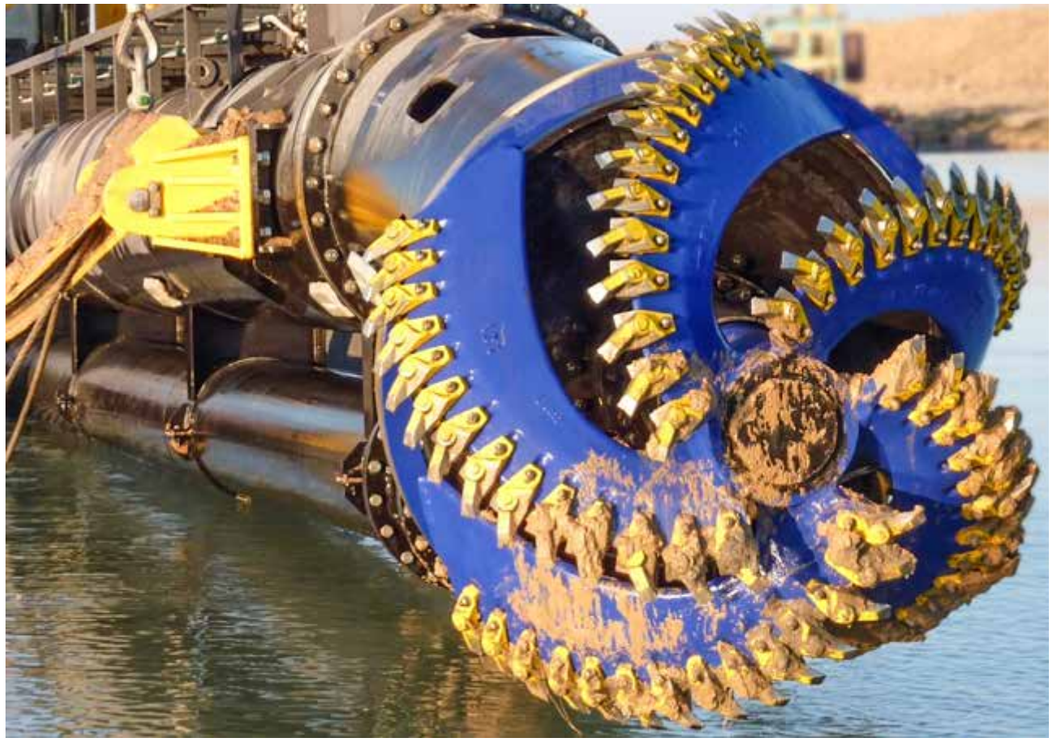
Running a scheduling analysis of existing practices revealed the best way of working across all pumps:

- Pump 1 operating solo needed to be run up to 850 rpm.
- Pump 3 operating solo should only be run up to a max of 714 rpm.
- Any flow required (below that delivered by pump 1 solo at 850 rpm, which during the data capture period was 1112 l/s), should be met with solo pumping operations only. Any parallel combination operation at flows below this threshold would result in higher running cost.
- Any flow required above the aforementioned threshold should be met using a parallel combination of two pumps, as operating a solo pump above this would result in higher operating costs.
- Parallel operation of all three pumps at the same time should never be used as this would yield higher running costs
- Using the above recommendations it was calculated that the result would be an annual saving of £56,070 (21.7%).

Furthermore, pump 2 had shown signs of wear and warranted refurbishment, which would result in an estimated annual saving of £8,293 (10.7%). The cost of refurbishment was estimated to be £30,000, a pay back of 3.6years.

The resulting next phase of work:

While the above results signalled the end of pump testing at the reservoir, the revelations initiated a further phase of work to more closely examine how the best efficiency points of the pump and drive could be aligned through remedial engineering works. To devise the work programme to achieve this, the pumps are being analysed as part of the entire network that the reservoir is a part of. Deritend are currently instrumenting the network to conclude on engineering changes and adjustments to pump impellers, estimated to achieve 49% in savings. ■



New improved uses developed with permanent magnet motors

Submersible motors are not unique, and neither are permanent magnet motors. The combination of both types however is hardly available. In co-operation with Marotechniek, a Dutch drive and control specialist for dredging vessels, the Electric motors specialist Kolmer has developed a submersible permanent magnet motor, intended to drive the dredging pump on the swing arm of a hopper or cutter.

Energy consumption

In terms of energy consumption the Permanent Magnet (PM) Motor controlled by a frequency converter is the best technical solution available. A highly efficient partial load is realised, however in many applications the flange, shaft and shaft height dimensions of the machine would have to be adapted as a PM motor is typically 1 to 2 frame sizes smaller than a standard AC induction motor. Modifications to the PM motor often make sense, as other more energy efficient outcomes in the machine may result.

By removing the gear box or belt transmission one can achieve further improvements to the overall transmission efficiency.

In terms of the initial investment a permanent magnet motor is not the cheapest solution but by taking the total cost of ownership into consideration it becomes more affordable.

Before installing a motor, Kolmer engineers are able to carry out the necessary calculations in order to let their customers know the return-on-investment possible.

Squirrel cage or permanent magnet?

From the outset Kolmer provides its customers with the best solutions for the situation. A good example has been the development of the submersible permanent magnet motor.

Together with Marotechniek, Kolmer started developing several submersible motors for under water applications. Among others, Marotechniek was using a 1500 rpm squirrel cage induction motor combined with a gear box; an effective but relatively heavy solution. Weight reduction on the swing arm of a hopper was wanted so, one option was to eliminate the gearbox. An eight pole AC induction motor would be an alternative solution, but would result in driving the pump at an undesirable speed range and present a larger motor size. Choosing a permanent magnet motor however would lead to a smaller motor size and foot print, resulting in a motor similar to the original four pole squirrel cage induction motor without the gearbox.

In comparison to a squirrel cage induction motor, the permanent magnet motor has an inherent high efficiency. An eight pole squirrel cage motor would show a lower energy efficiency and worse power factor. Yet a permanent magnet motor will show a better power factor and has a better energy efficiency depending on the number of poles.

In co-operation with CG Drives & Automation (previously known as Emotron and who developed a special software for its frequency converter), Kolmer and Marotechniek designed a 500 kW twelve pole submersible permanent magnet motor. Working together they achieved a motor design without a gearbox, which delivered the desired performance (rpm and torque) for the intended applications, and produced a fully optimised, energy efficient, drive system.

Using a motor without a gear box requires less maintenance in comparison with a squirrel cage induction motor setup. The new drive system also requires less space and has lower mass, enabling a lighter swing arm to be constructed thereby reducing manufacturing & material cost in its construction.

The payback period is also relatively short since the additional investment in a gear box has become unnecessary. In some cases smaller cabling might also be achievable.

The joint development of the submersible permanent magnet motor was completed last summer and it has since been successfully tested.

Marotechniek has had the motor in continuous operation for some months now on a high profile cutter dredger in Germany, with continuous monitoring being applied. Both Kolmer and Marotechniek introduced the motor during the Europort international marine trade fair last November in Rotterdam. Both companies can now offer the submersible permanent magnet motor worldwide.

The next step

Kolmer is in discussion with several other clients in order to jointly investigate possible applications. At this moment various projects are investigating and developing permanent magnet motors, including for:

- hybrid propulsion systems and thrusters for vessels,
- several applications in water and waste water plants (e.g. pumps, mixers),
- attractions in amusement parks, and
- in air treatment systems and the pumping industry.

Submersible motor cleaned after testing & Commissioning.

There has even been a request for a 2.2 MW permanent magnet motor.

David Ede of Kolmer Electric Motors says, “We are now working on a project to replace a hydraulic motor for a permanent magnet motor within the same housing.

“In every single application you must be able to justify the decision; in other words, you need to have a business case.”

“It also takes another perspective for client engineers; when selecting a squirrel cage induction motor the engineer will normally be looking for power and rpm. However, when choosing a permanent magnet motor, torque is more important.” ■

...and the same motor after a few weeks running.

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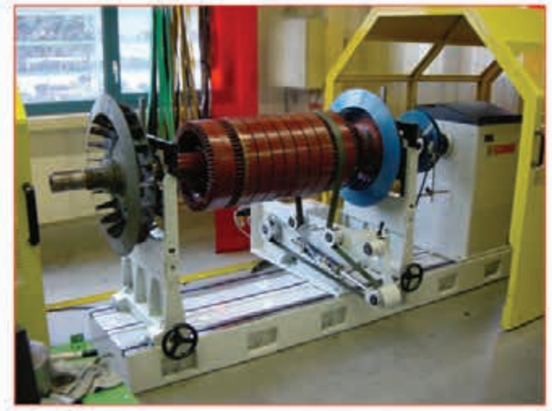

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WES 25th Year Gala Dinner

Singing waiters and a WES Dollar Casino provided guests of WES's 25th Year Gala Dinner Celebrations with a sensational evening at the end of last year.

Mike Robinson gave an emotional speech looking back over 25 years of the Robinson family company. In 2012 Mike handed over the mantle to his son Mark who has since taken the company from strength to strength and welcomed guests with a warm speech of thanks. Mark's wife Faye was to thank for the organisation of the glamorous evening and speeches were also given by WES's longest supporting customer; Deritend's MD Richard Hale. ■


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1. Mark Robinson.
2. Mike & Angela Robinson (right) plus (daughter-in-laws) Faye Robinson & Kellie Robinson.
3. Mike & Angela Robinson plus Richard Hale.
4. Mick & Kate Richmond Quartzelec plus Mark Robinson.
5. WES 25th Gala Dinner.
6. Thomas Marks and fiancée Gaëlle Claire.
7. Trevor & Carolyn Rice plus Richard & Shirley Hale.

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ABB Robotics Meeting, Milton Keynes

In 2010, ABB geared up to meet the growth of the manufacturing industry with a dedicated Robotics facility in Milton Keynes. AEMT members were invited to a day hosted by ABB to look at the emerging technologies available in motor efficiencies as well as what the future holds for manufacturing with robotic technologies.

Please visit the theaemt.com/calendar/past-events to download copies of the presentations outlined below.

EU MEPS Directive

Richard Gee, Channel Manager for ABB Motors and Generators UK took members through a comprehensive overview of where LV motor efficiencies are heading. In 2015 we saw Stage 2 of the EU MEPS directive come into play and in another year we will see Stage 3, where motors with rated output of 0.75-375kW must meet either IE3 efficiency or IE2 efficiency when fitted and used with a VSD. From 2018 it is proposed that Ex n & Ex d machines should be included in the Ecodesign regulations. Ex e equipment will be excluded, as changing their designs could infringe on their safety aspects. High voltage motors could also be regulated from 2018. ABB welcomes these changes, and even though undefined yet, they believe they already have products available for a potential IE6 market. Richard ended his presentation with a perfect segue for Andy Preston, UK Drives Product Manager, to present on ABB's SynRM motor-drive packages.

SynRM Motor-Drives

In the synchronous reluctance technology of SynRM motor-drives, the rotor laminations are designed to follow the magnetic flux field, as this field rotates, the rotor is kept in harmony due to the design with zero slippage and 100% torque. Andy outlined the consequences as being; a higher energy efficiency, higher power density, lower bearing temperatures, longer bearing lifetime, accurate speed control even without sensors and they're also easy to use, maintain and repair for re-winders. Induction motors are so similar in design to SynRM motors, that they can easily be upgraded. Even re-winders can be faced with a SynRM motor and without any additional knowledge be able to repair the machine. The only caveat is that SynRMs must be installed with a VSD, meaning repair shops will also have to have a range of VSDs lined up in order to test the machines. The efficiency of SynRM motors has already managed to reach a conceptual IE6 limit (ie, 20% less losses than IE5 ultra-efficient motors), and with so many advantages over permanent magnet motors, they are likely to become more common place.

Robotics

Mike Wilson, Robotic Sales Manager at ABB, gave members an overview of where robotic technology is heading, before touring the ABB Robotics facility and the meeting of YuMi, ABB's innovative collaborative dual-arm robot. The UK currently invests far less in robots than other EU members; Germany has 161 robots per 10,000 employees whereas the UK, only 31(these figures exclude the car industry). Without automating manufacturing processes across all UK sectors, production will never match competing countries. The perceptions that hold the industry back are not necessarily founded: niche business needing flexibility, variable workloads, robots are too expensive and the workforce will not accept them. By automating processes, yields are increased, quality is consistent, less wastage produced, and ultimately a workforce that is being used to create more value than when they were on a production line. There may be significant upfront costs, but as Henry Ford put it, "If you need a machine and don't buy it, then you will ultimately find that you have paid for it, but don't have it."

YuMi

The driver for human/machine collaboration comes down to 4 influencing factors: productivity, variation of product, lot sizes and flexibility. Where there are high lot sizes and productivity, automatic assembly lines are already common practise, such as in car manufacturing plants. When there are a high number of variants and greater flexibility is needed humans still outweigh machines, and that's where the charm of the artisan comes for decorative and luxurious items. In between these two setups comes collaborative assembly, and this is where the secret of YuMi lies. YuMi is easy to setup, offsets increasing labour costs, maximises worker productivity and upskills the workforce among other benefits. The two most redeeming features about the robot are its safety features, meaning there are no dangers to nearby humans while in operation, and the ease of which it can be programmed by the current workforce without the need for intensive training.

Expect to see YuMi excel in the consumer electronics industry and any small parts assembly environments. ■

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1. ABB Speakers (L-R) Richard Gee, Mike Wilson, Andy Preston, Patrick Wright, David Hawley and Rob Wood.
2. George Ibrahim (Biraf, Eygpt) with Tony Ruane (SKF).
3. An ABB FlexPicker Robot in Action.
4. YuMi at work.
5. David Hawley (ABB) with Mike Smith (Deritend).
6. David Manton (Quartzelec) with Andy Preston (ABB Speaker).
7. Richard Hale (Deritend).
8. Tim Marks (AEMT) with Jennie Gordon (MGC Systems).
9. Robert Shoebridge (WH Shoebridge).

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