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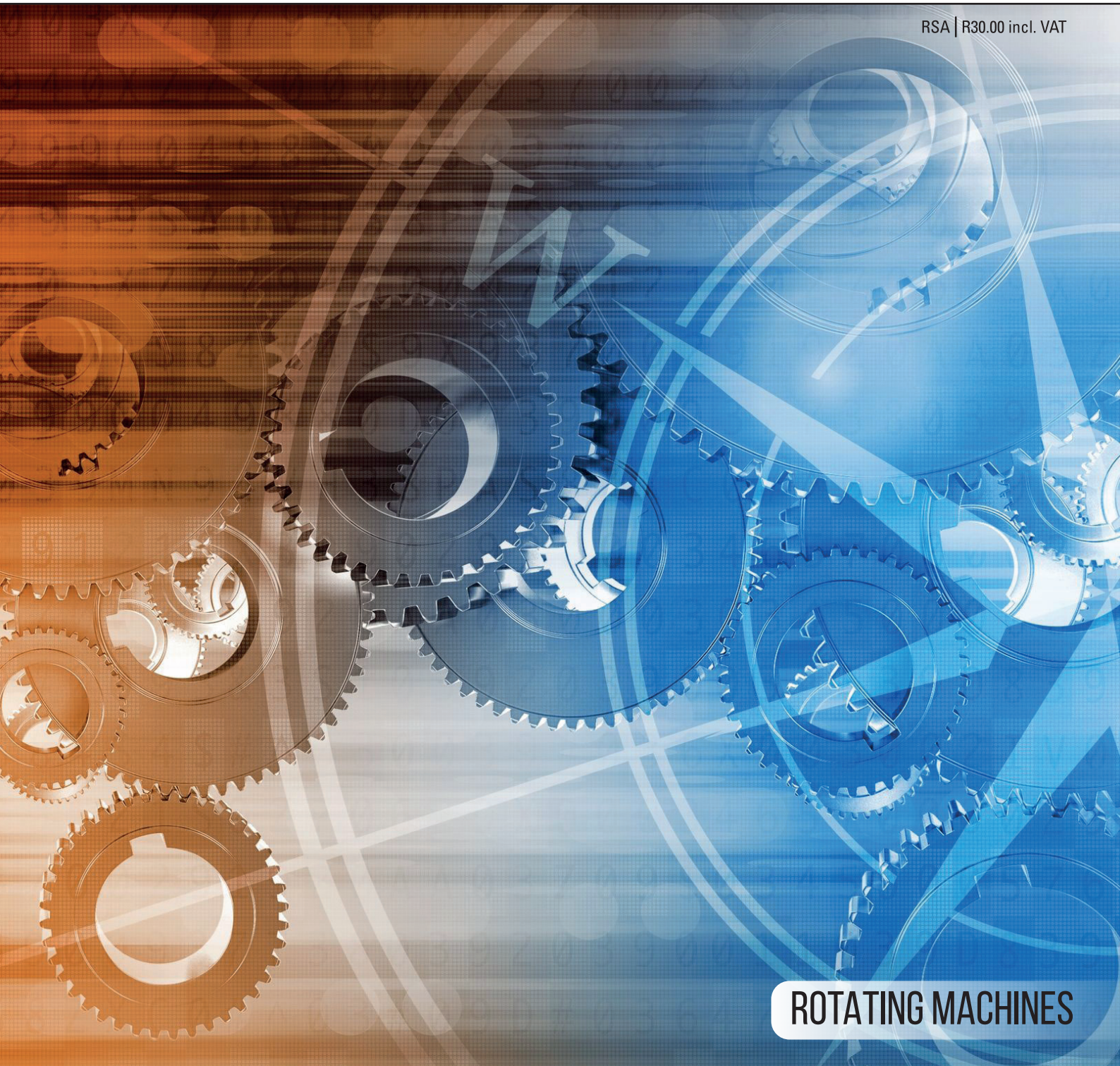

ROTATING MACHINES

SAIEE THE OFFICIAL PUBLICATION OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS | APRIL 2021

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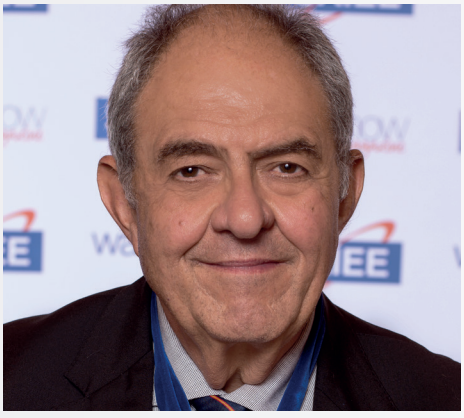
2020 SAIEE President

PROF SUNIL MAHARAJ
Deputy President

PRINCE MOYO
Senior Vice President

PROF JAN DE KOCK
Junior Vice President



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CONTENTS

FEATURES

GENERAL

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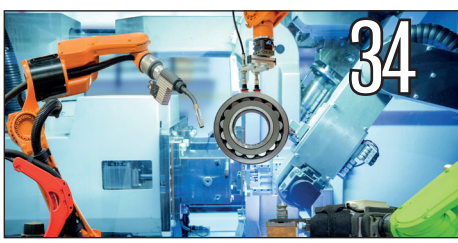

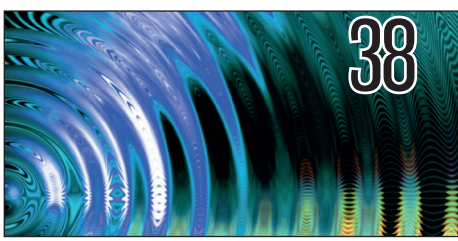

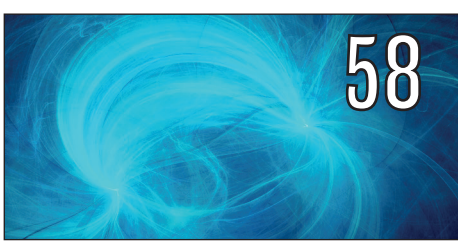

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Dear Valued Reader

This issue features Rotating Machines.
On page 34, our first feature article on "Sustaining the Life span of Rotating Equipment in Plants" discusses the fact that you are 17 times more likely to introduce defects during equipment start-up than during regular equipment operation.

Our second feature article, "Magnetoresistive Sensors and Piezo-resistive Accelerometers for Vibration Measurements: a comparative study", explains that this study focuses on comparing two different sensors for vibration signals: a magnetoresistive sensor and an accelerometer as a calibrated reference. Find it on page 38.

In our Historical part of this issue, Mr Hendri Du Preez wrote an article "History of Rotating Motors" and explains that a few electrical engineers know when the initial concept for electric motors started, about 280 years ago. Read it on page 52.

Dudley Basson didn't disappoint with his historical article on page 58 - "Halbach Magnets and Reluctance Motors", which discuss Halbach magnetised PM brushless machines, which are novel in their magnetisation is self-shielding.

The month of March produced ±10 webinars, including the SAIEE AGM and the SAIEE Presidential inauguration lecture. I willl, in the next issue of **watt**now, introduce our new Office Bearers and Council members and sport the SAIEE President's inaugural lecture in article format, which took place on the 31st of March, "Future of Work".

Herewith the April issue; enjoy the read - and happy Easter.

Minx

SAIEE Coffee table book

Second Edition

In 2001 the SAIEE published a coffee table book titled "Sparkling Achievements". The book was compiled and edited by Michael Crouch, a Past President of the Institute and published for the SAIEE by Chris van Rensburg (Pty) Ltd.

This first book surveyed Electrical Engineering in South Africa and included material from 43 local organisations. The second edition's objective is to include new companies and their history and achievements during the past two decades from 2001 to 2021.

Work contacting organisations started in February 2019 and went well until the onset of the Covid 19 pandemic, after which it gradually became challenging to entice companies to participate. Numerous companies had retrenched staff and were in serious financial difficulties. However, we eventually gathered together sufficient material to make the book viable.

One of the most outstanding inputs is from the Square Kilometre Array (SKA) Radio Telescope organisation in the Western Cape. All inputs are exciting, and we feel confident that the book will be an outstanding success.

This softcover book will be available at R350 (incl. VAT) from the Institute and uploaded onto the SAIEE website. The book will be ideal to grace the company entrance foyer and CEO's office and will go to press during April 2021. The cover of the book is shown here.

To order your book, please contact Dudu Madondo either via email: reception@saiee.org.za or contact her on 011 487 3003.

Reflection on my Presidency

SY GOURRAH
2020 SAIEE PRESIDENT

As I draw towards the end of my term as President, it is with mixed feelings that I write my last letter. What an unbelievable year it has been; who would have thought that COVID would impact our lives as much as it has?

One of the first challenges the SAIEE was faced with was the physical 2020 AGM which we eventually held virtually. Since then, SAIEE has embraced the technology, resulting in most committee, section and chapter meetings being 'held' using this medium.

As an institution, we have not had any face-to-face engagements, meetings or events since the 15th of March 2020, which has been somewhat unusual for our association (and others like us). The focus is our members, and therefore networking. I have not had the pleasure of meeting our new council members in person, which is rather strange and which indeed illustrates the importance of 'in person' meetings to grow relationships and networks. So, I have come to the last month of my term without a single face-to-face meeting or event, which is unbelievable. Thankfully, we are now set up to use online platforms (e.g. webinars and zoom) to communicate, educate and conduct business remotely. This has been a significant change in how we do things and has involved many changes that many of us have learned about and adapted to. The result is that we have been thoroughly catapulted into the digital age.

With the recent announcement that South Africa has been moved back to Level 1, we hope to see more activity around the CPD courses and Training Academy, which has had slower online registrations. People seem to prefer face-to-face training and are experiencing online webinar fatigue.

Throughout the Lockdown, the SAIEE has launched numerous new sections and chapters, which has seen increased member participation in our many diverse webinar topics. There has been an upside to Lockdown!

The AGM will be held on the 25th of March 2021, followed by Professor Maharaj's Inaugural Presidential address on the 31st of March 2021.

The partnership between the Association of Municipal Electrical Utilities (AMEU) and the SAIEE has gained traction. We will publish the details of these joint webinars soon.

Talks with the GIZ SAGEN program to build Power System Planning and Operation capacity in South Africa are ongoing.

The Ministerial RE Sector Engagement Forum (RESEF) has held three workshops and is gaining momentum.

The Engineering Council of SA (ECSA) has recognised the SAIEE as part of its CPD licensing body. Further, ECSA has also approved the Overarching

Code of Practise for the Performance of Engineering Work, a document to which SAIEE submitted input.

The incapability to meet physically has not hindered the advancement of our contribution to the engineering fraternity, and we continue to enrich our members through different webinars and ongoing online interactions.

Before I end off, I would like to take this opportunity to thank the Office Bearers, EXCO, Council and staff of the SAIEE for my online year of Presidency and the constant support you have all given me. I would like to wish the incoming President Prof Sunil Maharaj an exceptional year ahead and the incoming office bearers the very best for their journey to Presidency.

It has been a privilege to serve you as the first online President, and I look forward to our new digitisation world.

Please continue to practise safe social distancing, wear a mask in public, sanitise and keep safe.

S Gourrah | SAIEE President 2020
Pr. Eng | FSAIEE

PRESIDENTIAL LEGACY PROJECT

PEP LAY-BY BUDDY INITIATIVE

The outgoing SAIEE President, Ms Sy Gourrah, has selected the PEP Lay-By Buddy Initiative as the legacy project for her Presidential term. The PEP Lay-By Buddy Initiative helps those in need by making their life a bit easier in the following way:

Donors can make a payment towards settling randomly selected customers' PEP lay-by's on their behalf.

Contribute as little as R20 on the PEP website.

Any payment made gets deposited into the PEP lay-by fund for the purpose of settling lay-by customers' purchases.

Each month randomly selected beneficiaries will receive a voucher via sms that they can then redeem against the outstanding balance of their PEP lay-by.

Beneficiaries are selected at random by the system and sent a voucher number that they then use in store to settle their lay-by. Specific beneficiaries cannot be specified or selected.

SAIEE members are urged to contribute to this initiative by going directly to this initiative's website and entering their name, mobile number (both optional) and **info@saiee.org.za** in the email address field (compulsory for SAIEE generated donors in order to be able to identify SAIEE members who make a donation). Anyone anywhere in the world can make a contribution that will go towards the cause via the PEP website. Contributions received via lay-by buddy go towards settling lay-by's in South Africa.

www.saiee.org.za

SAIEE

Dear Valuable SAIEE member,

SAIEE CHARGE REWARD PROGRAMME

Compliments of the new season to you and your family. 2021 is finally here, and we all look forward to a productive and healthy year ahead. As the second wave of Covid-19 continues to proceed unabated, 2021 is set to become another year of keeping safe and healthy by working from home. This, however, does not have to spell doom for your self-empowerment requirements as we are set to continue the trend of providing you with informative webinars to help with your professional development needs. As an added caveat to that, full attendance and participation in these technical engagements earn you as a member Charge Reward Programme points.

The Charge Reward Programme runs in cycles of 5 years. As a member, you have an opportunity period of 5 years (starting from December 2019) to earn these points, after which a new cycle begins, and all unused points are forfeited. Accumulated Charge points can be redeemed on various SAIEE activities like Training Academy courses and membership fees. To find out the amount of Charge point allocated to you, one needs to click on the unique link that was sent out to all members in good standing recently. That link is unique to each member and is not transferable. As a member, you are therefore encouraged to keep your membership in good standing by paying your membership fees for 2021.

Do not forget that now you can pay membership fees in instalments. If your fees are paid in full by the 31st of March 2021, the discounted membership fee is applicable.

As a parting shot, I encourage you to keep safe and earn those Charge Reward Points!
Please forward any comments/suggestions to improve to leanetse@saiee.org.za, and let's get the SAIEE working for you!

For more information, on how this programme works, click here. wn

Yours faithfully,

Leanetse Matutoane
Acting CEO

CHARGE REWARD PROGRAMME





MEMBER LOYALTY

We appreciate our Member's support for 110 years

REWARD

A unique reward programme exclusive to SAIEE Members

FEEDBACK

We received your feedback and we listened to added benefits

EARN POINTS

Earn Charge Rewards by attending events, courses or writing articles

SATISFACTION

We want you, our Valued Member to feel satisfied when working with us





LOYALTY PROGRAM

Redeem your Charge Points towards CPD credits

QUALITY

We guarantee top quality events, courses, and services

SERVICE

We are here to serve you, our Valued Member better

RESPECT

We respect you and want to see value for your hard-earned money

SUPPORT

We are here to answer any queries you might have

For more information:

Visit your Membership Porthole on the SAIEE Website:
www.saiee.org.za

Alternatively, call Connie on 011 487 3003.

SAIEE
CHARGE
rewards programme

BI rolls out countrywide stock of IE1 motors from ABB Africa

Leading supplier Bearings International (BI) now has sufficient stock of IE1 motors from ABB Africa to be able to supply the local market in accordance with the new partnership between the two companies, reports BI Offer Marketing Manager Victor Strobel.

Already a distributor of ABB Dodge gearboxes, BI has been an ABB Mechanical Power Transmission (MPT) partner since 2011.

Given the existing close working relationship with ABB, it was a natural step to extend this. As a result, BI has expanded its motor range in size to include a 400 V and 525 V offering, now allowing it to supply projects in the mining industry.

Customers will benefit from dealing with a local supplier versus direct imports, plus the availability of quick technical back-up and support. BI's extensive 42-branch network across South Africa covers all the major mining and industrial areas.

BI is ensuring that its branch network has sufficient stock of the IE1 motors. First-level customer support will be provided by BI's own sales team and product managers, while second-level support for technical issues will be provided by ABB itself. wn

BI Offer Marketing Manager Victor Strobel

SCREW-IN TEMP SENSORS

- A wide range of measurements – always in view!

INSTROTECH offers Kobold's MMA range of industrial temperature probes, or insertion resistance thermometers (with/without transmitter).

The MMA is engineered using 316 stainless steel and incorporates high accuracy Pt100 resistance sensors with analogue output options. The MMA is delivered standard with M12 or DIN 43650 plug electrical connections, as well as a wide variety of popular process connections.

INTEGRATED TRANSMITTER

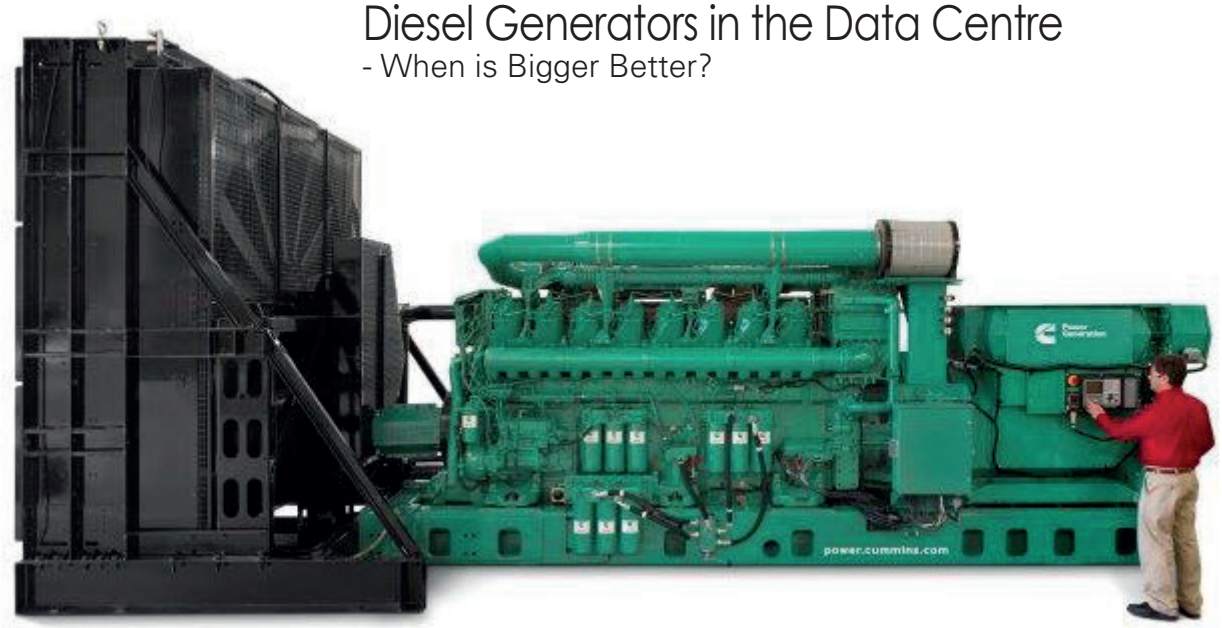
Temperature sensors with transmitter are capable of transmitting measuring signals noise-free over long distances. The two-wire transmitter is integrated in the resistance thermometer. The output-signal is 4-20mA. The transmitter range is configurable from PC through the KM-HART interface and the KM-Soft software.

This quality range of economically priced temperature instrument is suitable for a wide range of industrial applications such as: heating installations, furnace and apparatus construction; machine construction and building installations; marine engineering; general industrial applications; food, and pharmaceutical industry.

Contact INSTROTECH for more information on Kobold's MMA range of industrial temperature probes on sales@instrotech.co.za wn

KOBOLD MMA Temperature sensor transmits long-distance, noise-free signals.

Diesel Generators in the Data Centre
- When is Bigger Better?



Paralleling generators in a data centre design can have many advantages

Finding the best combination of generator size and system architecture is a goal for all data centre designers. Many times, a larger generator can provide unique advantages. When you combine large generators into a paralleling system, you can achieve a whole new level of benefits. The data centre designer should carefully analyse all options to optimise the generator system design.

There are many factors to consider when designing the generator system for your data centre. Two of the most essential items to consider in your design are the optimal size of the generator and the architecture of how your generators integrate into the overall power system. In some installations, you have no choice but to go with a larger generator due to the site's size constraints.

This can be especially true when installing additional power generation into an existing building. Using a more significant number of smaller generators would not have been a good option in this example. The higher power density of large generators was the better choice. In addition to the unique challenges in metropolitan areas, sometimes the footprint advantages of large generators are also desired in new construction.

Paralleling generators in a data centre design can have many advantages. It does not fit every situation, but paralleling does provide many benefits over a single generator design. The advantages have varying degrees of importance in a data centre application, but efficiency (reducing your stranded generator power capacity) can be the most attractive. The generator system is one of the more expensive systems to procure, install and maintain. Making this system as efficient as possible will have a significant effect on reducing data centre cost.

An essential challenge in a paralleling system architecture is achieving concurrent maintainability. This is due to the common paralleling bus required in a generator paralleling system. Various system architectures have been developed to address this challenge. One of the more common architectures is adding tiebreakers (or sometimes tie switches) to the paralleling bus. These tiebreakers provide segments in the bus that allow you to shut down the switchgear for maintenance partially.

For example, if you have an N+2 design, you can completely isolate one switchgear segment for maintenance or repair. This design is also used in an N+1 design with tie-breakers in-between each generator on the paralleling bus. The protective relaying on a segmented bus can be designed to eliminate the paralleling bus as a single point of failure. This is most commonly achieved with a current differential scheme.

Another way to achieve concurrent maintainability is that each generator can be switched from one paralleling bus to an alternative paralleling bus. In an N+1 design, there would be one additional generator and corresponding transfer switch. Any one component, including the paralleling bus, can be shut down for maintenance, and there will still be the full 'N' capacity available from the generator system. There is another architecture for paralleling generators being used in data centres. This is sometimes called '3 to make 2' (or '4 to make 3', etc.) wn

NOW, MAINTENANCE CAN BE PROACTIVE INSTEAD OF REACTIVE!

Fluke's new TiS75+ Thermal Imager, great for preventative maintenance programs

COMTEST, local representative of Fluke, has their new TiS55+ and TiS75+ thermal imagers, easy-to-use series of infrared cameras that easily transform plans for preventive maintenance (PM) programs into reality. These cameras offer technicians and contractors who need quality images and feature-rich cameras, an option for their troubleshooting, intermittent inspection, and preventive maintenance needs.

Technicians make many inspections daily, and it can be hard to remember what was seen and the inspection location. Clipboards to jot down notes are old-school! The new technology Fluke TiS55+ and TiS75+ come with built-in personal assistants, meaning the old clipboard can finally be ditched and technicians can have all the information needed, embedded in the images saved, including:

Voice annotation - Record up to 60 seconds per thermal image - Identify exactly what is seen, in real time

IR-PhotoNotes - Take photos of asset numbers and other identifiers, and use as a reference when looking at the thermal image on a computer

Asset Tagging* - Sort the thermal images by asset, scan a QR code on the asset, then start capturing thermal images. Images will automatically be sorted by asset, simply connect the camera to a computer to view them.

Focus is one of the most important parts of a thermal image so whether users are seasoned thermographers or new to thermal cameras, Fluke has:

- Manual focus: Seasoned thermographers can use the manual focus wheel to adjust the image based off how far they are from the target.
- Fixed focus: For quick scans or for users new to thermography, simply use fixed focus position. Now take images at 1m from the target and images will be in focus every single time.

Building Health matters: Building inspectors always look for moisture - that's why Fluke includes a dew-point calculation in the TiS75+ thermal camera. When air is cooled to the temperature where it is saturated with water, moisture develops and wreaks havoc on buildings. Once dew point is calculated, the camera will display the Dew Point Colour Alarm. Everything the camera displays that is at the dew point temperature and below, will display as a thermal image. Everything above will display as a visual light image. This allows users to see where in the image condensation is occurring, and a scale of how far objects are below the dew point. wn

Beware fly-by-night online auctions

Covid-19 lockdown restrictions have led to an unprecedented migration to online auctions as a means of selling anything from properties and cars to office furniture and even household goods.

New companies are emerging using social media marketing to encourage buyers to bid or make offers on goods and buyers in the electrical and electronic industry can be duped into participating in a sale process or so-called auction that is not transparent, legal or safe.

As a result, the South African Institute of Auctioneers (SAIA), has noticed an uptick in complaints leveled at fly-by-night auctioneers who do not fulfill their obligations to deliver goods or choose to provide alternative goods that are not what the customers bid for. There have also been reports of problems associated with the refunding of deposits where these are required.

"Unfortunately, it is only when problems arise that the bidder realizes they are dealing with unprofessional sellers purporting to be Bonafede auctioneers and this should send a clear signal to the public to only deal with professional, registered auctioneers who are members of SAIA. Before committing to purchase on a so-called auction site, a simple check on the SAIA webpage will dispel any concerns you may have. Our members have remained resilient in the face of the virus and are among the leaders in online auctioneering," says SAIA chairman, John Cowing.

He continues that the institute's members comply with all requirement and legal requirements to ensure honest and fair auctions. Most will display their membership credentials on their website which can be verified by our office if the bidder has any doubt. "Our members are responsible custodians of assets who prescribe to our code of conduct. You are well advised to establish who in fact you are dealing with before parting with money. These auctions are putting a stain on our industry and we hope in time with legislation we will be able to eradicate these illicit traders.

"While we actively promote the growth of the industry and the uptake of new technologies, we do not support these

John Cowing
SAIA Chairman

organised crime syndicates. You can often find bargains at auction but put simply, if it sounds too good to be true, it probably isn't true. It also pays to go to the institute's website www.auctioneering.co.za to explore member offerings or phone the Hotline on 021 813 6342 or WhatsApp 067 117 7049 with any queries," concludes John. wn

EXACT DETERMINATION OF FUEL CONSUMPTION

INSTROTECH has KOBOLD DOE, an oval gear flowmeter, categorised as positive displacement flow technology. When liquid flows through this positive displacement flowmeter, two oval geared rotors measure a constant volume per rotation, within a precisely machined measuring chamber. With each rotation, a constant volume of liquid is measured. The rotation of the oval gears is sensed via magnets embedded within the rotors.

The meter can be used with a wide range of media and chemicals. The aluminium version in particular is suitable for applications with motor and heating fuels or lubricating liquids. These magnets transmit a high-resolution pulse output. The output signal can be process externally via a remote display controller or PLC, or via a variety of output/display options available as accessories attached to the flowmeters. wn

Space-Age Challenge For Concor At Meerkat

Scientists will soon gain even further insights into the evolution of galaxies in the universe as the MeerKAT telescope array is expanded. This is an exciting project presenting some unique challenges for leading South African contractor Concor.

In partnership with OptiPower, Concor has been awarded the R202-million infrastructure project that will allow the addition of 24 dishes to the 64 dish MeerKAT radio telescope. Located in a remote area of the Northern Cape, MeerKAT was launched in 2018 and is a precursor facility to the next-generation radio telescope, the Square Kilometre Array (SKA).

According to Concor's contracts director Joe Nell, the scope of Concor's work will include a construction camp for about 250 people, 40 km of gravel access roads to the dish positions where the antenna platforms will be constructed, and the structural concrete foundations for the 24 telescope dishes. The camp will include facilities for wastewater and sewage treatment, settling ponds, water storage and security fencing.

Concor will also be building four guardhouses, which will be powered by solar energy. OptiPower will carry out the electrification of the works and the provision of fibre connectivity to the new installation with approximately 60 km of trenching, electrical power cables, fibre ducting and fibre cables required. The Concor-OptiPower venture (COP) will also design a further 109 satellite foundations, with the associated roads, power and fibre installation.

"A key constraint of this current project is the need to limit any radio frequency interference (RFI) in the vicinity of the MeerKAT telescope array," says Nell. "This is due to the highly sensitive nature of the radio telescope equipment, which is designed to detect extremely weak radio signals from astrophysical sources."

He highlights that RFI from manmade radio signals emanating from commonly used equipment like cellular phones, vehicle electronics, microwave ovens and many more can easily distort or corrupt weaker signals, and even damage the telescopes themselves.

"This means that we have set up our office in the town of Carnarvon, some 100 km from the site," he says. "We are in the design stage of the project, and will begin work on site in June this year."

Nearer the time of site establishment, a specialised RFI container will be established on site from which the team can communicate and operate certain electronic equipment. The container will be insulated to prevent any signal reaching the telescopes. Dealing with the RFI means that every vehicle and item of equipment required on site will need to be tested and certified, says Concor site agent Roy van Leeve.

"We have employed an RFI expert to test our equipment and submit the necessary data to the client," says van Leeve. "After careful analysis of this data, we will be granted a permit for that particular item of machinery or advised what steps need to be taken before machinery can be passed for use on site."

He notes that just about every model

of construction vehicle built within the last decade is likely to include telematics, which presents a potential RFI risk in this project. The construction camp itself also needs to be located a suitable distance from the MeerKAT site to avoid RFI, so it is planned to be about 15 km away.

For the roadwork, Concor will be operating in a geological environment of mainly sandstone and calcrete, overlying mudstone and shale, where 20 tonne hydraulic excavators will be put to work.

"It is vital that the roads be well designed and constructed, especially in terms of their vertical and horizontal alignment," he says. "This will ensure that the low-beds and other heavy trucks delivering construction material and large componentry can navigate the route safely."

For the radio telescopes' concrete foundations, Concor will be using two methods depending on conditions. Where bedrock founding conditions are deeper than three to four metres, eight piles will be cast for each foundation's seven metre diameter cap; most of the foundations will be done this way. In those cases where bedrock is shallower, a pad foundation will be cast with an 11 metre cap. The limited number of foundations has meant that Concor's common practice of establishing its own on-site batch plant is not feasible. Instead, the concrete will be sourced commercially – presenting another logistical challenge.

"We will require about 5,000 t of concrete aggregates, which will have to be delivered some distance in trucks with capacity of 34 t each," says Van Leeve. "Added to this, the trucks will need to undergo RFI testing well in advance, so that they have the necessary RFI permit to enter the site and discharge their load." The same restrictions apply, of course, to all suppliers that must deliver to site. Where the testing and permitting of vehicles is not possible or viable, he says that a certain amount of double-handling of equipment and materials is likely to be inevitable.

Broadly speaking, however, Concor's proven track record on constructing similar projects has positioned it well for the work at MeerKAT, Nell says. The infrastructure aspects are quite similar to the eight wind farms that the company has constructed to date. It is also in the process of completing another two of these wind farms.

"Contractually, we have been very successful in carrying out these projects efficiently and on time, in a spirit of collaboration that has overcome various challenges and earned us considerable repeat business from clients," he says. "Our experienced management team and staff ensures that planning is detailed, and implementation is professional."

Concor will also be making use of SMME suppliers from the local Kareeberg municipal area, which includes the towns of Carnarvon, Brandvlei, Williston, Loxton and Vanwyksvlei. wn

Enabling the Techtrepreneur™

"Job creation in a time of job uncertainty; by linking skills and capacity with the opportunity to meet the market need in a geographical proximity". André Hoffmann, CEO and founder of "MyTechie", explains.

MyTechie is essentially a Technician-as-a-Service (TaaS) solution. We match qualified technical services resources, such as electricians, plumbers, fibre-broadband technicians and a variety of skilled artisans, to be available in areas where service providers and consumers require accredited and competent technical services and skills. This service is all available via an easy-to-use digital services trading platform, with mobile and geo-location capability.

We are initially focused on a business-to-business model (B2B) by introducing large national project rollout programmes to the community based technical teams.

The platform will evolve in the coming months to include consumers who might need the local village technician to demystify some 'tech' in their homes or businesses - as the Internet of Things (IoT) becomes challenging in the world we now live in.

South Africa has a lot of latent talent and skill, unemployed and underemployed. All we require to unlock this is to leverage technology effectively, make it visible to the market it addresses, and preferably within proximity to be viable for both the buyer (customer) and the seller (technician).

MyTechie aims to close the gap between learning, application, and market demand for skills and capacity within the proximity of local

communities and thereby improve the earning capability and economic survivability of our people of all ages.

The proximity of the dispatchable technical resource to the market need at the edge means that our environment's impact is significantly reduced. Travel distances are much shorter, making MyTechie a very 'Green' service delivery option for companies. It also means that in a global pandemic situation like we are currently experiencing, you would have healthy pods of dispatchable capacity that remain isolated and reduce the risk of person-to-person disease transmission.

Systemically viable and highly scalable to meet your needs in your area, our 'village' technician takes ownership of the area and become a 'TechtrepreneursTM'. They will proudly support all the 'tech' certified to represent and thereby reduce the customer adoption friction across the broadband service delivery ecosystem.

We believe the best way to emancipate workers is to empower them to control their own future.

WHAT IS UNIQUE ABOUT MYTECHIE?

Finding work-based experience is a big challenge for graduates today. MyTechie provides a tiered roadmap, incentivised financially, from INTERNSHIP to QUALIFICATION to MASTER of the craft. 'Each one takes the hand of the one below them and uplifts them.'

MyTechie is not just a 'Yellow-pages' for services; we provide an ecosystem of support around the candidates that will include financial services, medical aid, retirement instruments, and much more. This will give the systemic support for SMMEs that they would not usually get out in the harsh world of competitive hustle in the gig economy.

At MyTechie, we will leverage the group's buying power and the internal wallet to reduce supply-side costs of consumables, tools, training, and other resources, thereby creating some disintermediation to the advantage of the Techtrepreneurs™.

Quality is in the DNA of the platform. We value and incentivise professional affiliations with relevant professional voluntary associations like the South African Institute of Electrical Engineers (SAIEE) and the Institute of Information Technology Professionals of South Africa (IITPSA), and others to leverage continued professional development, mentorship and professional ethics.

We also value the collaboration with the industry associations like the Digital Council Africa and others to bring some surety to the service delivery quality and STANDARDS, particularly with the fibre-based inside plant installations.

MyTechie provides improved revenue earning potential for its independent agents by what we call 'Opportunity Density.' – 'More arrows in their quiver.' Leveraging geo-data of market needs and matching this to the agent's skills gap, we then access appropriate micro-courses from affiliated training providers. This will derive additional economic value for them in the operational areas.

We embrace a systemically viable culture of stakeholder optimisation. We create a value chain balance, rather than the traditional MBA mantras of 'maximising shareholder value or 'customer focus,' each of which can result in an imbalance and internal or external pain points, and ultimately have been shown to drive unacceptable levels of inequality.

THE WAY WE WORK IS CHANGING!

Employment is no longer a reasonable expectation for our youth. We need to develop an entrepreneurship culture from the school level. We need to set our youth's expectations and train them to embrace a resilient lifestyle that is battle-hardened towards coping in austere economic conditions. These 'black-swan global pandemics that occasionally rattle the financial balance and are outside our control.

A job for life with benefits and the expectation of a comfortable retirement is a pipedream for most in the 21st century. Now it is more short-term, on-demand and flexible. Skill-based micro-project decisions are increasingly driven by data and algorithms and visible availability and proximity to the market.

Value Proposition to Service Providers:

- On-demand trained resources available 24 by 7.
- Geo-mapping of skills resources to demand and supply.
- Skills are mapped to Geo and time availability of the end-customer.
- Quality guarantee in private space.
- Self-regulating.
- Fourth industrial revolution compatible.
- Accurate and up to date skills record of all technical agents used.
- Accurate records of all inside or outside plant work undertaken.
- A direct up-sell of your products and services by a commercially enabled workforce.
- Go Green by reducing travel distances to reach your customers.

Tap into a competent team of brand trusted 'village' technicians supporting the technical industries in meeting the consumer needs within their communities. In doing so, they are supporting everything from fibre-to-the-home installations, renewable energy solutions, to the entire Internet of Things ecosystem, across its lifecycle from the private property boundary gate and in and around the smart home. Competent technicians, vetted, trained, certified and available in the communities you serve.

They are all equipped with their smart device, tools, and the MyTechie App. You will be able to select the technician or team of your choice and dispatch them in their zone to undertake inside-plant site surveys. Our Techies will install fibre drop cables with termination, customer premises equipment and commission it with the Network Operations Centre. Explain and match the customer needs to your products where required. Convert copper to fibre services or up-sell to higher-value products. Provide first line (Tier-1) network field support and so much more.

This resource pool is growing daily, driven by the reality of ongoing corporate retrenchments and structural economic changes. The skills are nevertheless coalescing in this MyTechie family to;

- Achieve economic sustainability for ourselves;

- To adapt ourselves to a demand-driven economy that does not depend on jobs for life; and
- To benefit from the growing buying power of the federation.

By far, most companies and individuals in the MyTechie federation are from previously disadvantaged backgrounds, with an encouraging number of females being confident to mix in traditionally male-dominated domains.

Given the MyTechie business model and ecosystem's systemically viable nature, all these entities are given a supportive and enabling environment to develop their technical and entrepreneurial capacity to the maximum of their potential.

THE FUTURE

Besides the direct consumer demand for the deployment of technology in our homes and businesses, the opportunity for technicians, electricians and other artisans to participate in corporate-driven national projects is growing daily as MyTechie is facilitating skills for service providers on several national projects in 2021:

- A Smart Energy rollout of a million IoT devices to around fifteen thousand businesses nationally over the next three years (using electricians).
- An innovative, locally developed solar Photo-Voltaic water heating system, national rollout using electricians with solar PV certification.
- Fibre-to-the-home cable connections in many of the smaller towns around South Africa.
- A national rollout of broadband fixed wireless customer premises equipment for a global service provider.

CALL TO ACTION:

- Artisans, electricians and technicians wanting to participate must email us their CV and supporting documents. If you have a small or medium company, send us your company profile and supporting documents to the same email address. We will get you matched up to market demand wherever you are. YOUR future – In YOUR hands – Today!
- Service providers and companies that what to tap into this on-demand resource pool for your projects and programs send an email to see how MyTechie can give you the EDGE (we live there).

CONCLUSION

We hope that you can see the benefits of this strategic blend of predominantly 'previously advantaged' skill and experience along with the development objectives of the young and upcoming black techtrepreneurs, collaborating in this systemically viable platform and ecosystem.

The usual contractor model quickly percolates the bulk of the revenue flow to the principal shareholders, leaving the guys at the bottom of the food chain with little more than the minimum wage. In the South African context, we have seen first-hand how political and other community based 'councillor' structures have set themselves up and benefitted from the top of the allocated fees. The extent of this corruption has trickled down crumbs for the hard-working technician working under challenging conditions in the hot sun are wholly unsustainable.

Not only that, but the technician on the ground is often not afforded the essential health and safety of Personal Protective Equipment by unscrupulous middlemen in their exploitative systems. The technician has done the training and knows how to splice the cable or line up the microwave system, configure the router, locate the fault, and keep the customer happy.

This model deliberately inverts the value chain's earning potential by distributing between 85% and 95% of the edge-focused service fees directly to the 'rubber-meets-the-road, where the skill and services are performed.

It allows the entrepreneurial and hard-working skilled artisan or technician to positively impact their economic well-being and achieve a reasonable 'middle-class' lifestyle. They can now afford to send their children to schools and set aside a little for the rainy days and retirement. To bring back the pride and dignity of 'decent work' for a decent reward, the upstream shareholders are still very adequately rewarded for their investment and business risks. wn

For more info, visit
www.mytechiesa.co.za

Practical steps to gain independence from the grid

As Eskom announces load shedding on an almost-weekly basis, which wreaks havoc with the economy, more and more businesses and households are investigating how to become less dependent on the national grid - at least during the power outages.

Besides the obvious ramifications for businesses across industries as diverse as manufacturing to retail, Covid-19 has sent large swathes of the working population home, and this means that every time there is a power outage these people lose their ability to do work.

REVOV, the leader in second life lithium-iron storage batteries for UPS systems and renewable energy sources, proactively promotes the philosophy of "freedom from dependence". "Freedom from dependence" says REVOV MD Lance Dickerson, "means that businesses are able to operate uninterrupted despite an unstable electricity grid and those working from home are able to complete their tasks."

Determining the most appropriate strategy to achieve freedom from dependence comes down to a combination of price (how much you are willing to pay for energy independence?), convenience (some systems are fully automated, others require constant monitoring), the average time of the planned or unplanned outage, the property size and location, among other factors. And lastly the impact on the environment
Dickerson has outlined four practical steps all businesses and households can take:

1. Decide what you need in terms of high priority and low priority loads - Run the high priority loads such as lights and plugs on your battery backup and only allow your low priority loads to run whilst the Eskom connection is live. For example, Dickerson says that "it is not practical to run geysers and stoves on a battery backup and these would typically be considered low priority". However, he says if these appliances are vital, they can be accounted for.
2. Determine the time you will be without power during Load-shedding - Once you've established the average and peak requirements and split them between high and low priority, you then need to decide how long you want to be able to power those differing priority loads on average. Load-shedding can be up to four and a half hours on average, and longer in extreme cases explains Dickerson. Now, some grids are allowing two-and-a-half hour blocks with no power, making battery back up even more viable to cover an outage as an average battery can provide between four to six hours. This period can be extended by switching off some of the high priority loads during an outage, and in addition limiting the number of lights on, and limiting the use of high power consuming appliances such as kettles, tumble dryers and microwaves.
3. Find a reputable UPS or solar installer - Look at the list of accredited installers on REVOVs website, and select an accredited installer that is nearby. If this installation is not done properly, this could result in your solution being as painful as the problem.
4. Look at your emergency energy requirements and determine baseline energy requirements

The simplest way to do this is to install a simple energy meter, which will log peak and average usage for a period of a week at least. Any reputable installer will have these available to install temporarily. Dickerson says that this will show how the system needs to be dimensioned to provide uninterrupted power during load shedding and average outages, and can be used to determine the system design to take the customer off grid partially or in totality.

"Independence from the grid means that, at the very least, businesses and individuals can continue their vital operations and are not at the mercy of load shedding or unplanned outages," says Dickerson. wn

Africa Research Journal

Research Journal of the South African Institute of Electrical Engineers
Incorporating the SAIEE Transactions

As of January 2019, the *SAIEE Africa Research Journal* is indexed by IEEE / IET Electronic Library (IEL) (popularly known as Xplore)

Manuscripts can be submitted by visiting the IEEE Xplore website: www.saiee.org.za/arj

Further training material on compiling manuscripts is provided online.

We call upon researchers to consider the *SAIEE Africa Research Journal* as a medium for publishing their novel scholarly research, and in this way, contribute to the body of published knowledge.

We are grateful to the leadership and support of the IEEE Foundation and IEEE Africa Council; through the partial sponsorship and support of these groups, the journal continues to be available as open access.

SAIEE
011 487 3003 | www.saiee.org.za

The Asset Management Revolution

Through the decades, society has relied on the electricity supply industry to serve people's core needs, drive innovation and push sustainable business and industry development. When it comes to managing key energy assets, critical, high-stakes decisions have to be made on a day to day, week on week basis, something which has become increasingly difficult as plant has aged, skills have become scarcer and demands higher.

To any South African entity owning rotating equipment that either generates precious kW.hrs or saves them - it's your duty in these times to get and keep that equipment running! SA INC relies on you! The irony of Eskom's latest System Status and Outlook briefing being on the "ides of March" (2021) should not be lost on us. SA INC and SA society needs every kW.hr we can squeeze out of all our rotating machines and associated plant across the land.

One of the industry challenges is that traditional asset management systems, housed in filing cabinets and spreadsheets, are not fulfilling the current needs of the Production, Maintenance and Engineering teams who manage their often irreplaceable assets. The information needed for quick, accurate decision-making is seldom readily available, resulting in delayed or incorrect decisions, sometimes with potentially catastrophic consequences.

We can no longer deny, a new approach is needed. The electricity supply industry in SA is progressing and evolving – and so should asset management technology and its approaches. That is why we at Sebenzana are proud and passionate about our Smart Asset Management Services that are all about bringing teams together and empowering them to make better decisions regarding the critical assets that serve their businesses and society at large.

Sebenzana has long existed as a growing team of specialist engineers supporting energy assets locally and internationally - including rotating equipment and associated plant. We strongly believe in teams and how teams (people) unlock value from physical assets – but through our work across SA, Australasia and Europe, we realised that even strong teams struggle without access to the right tools. Hence the development and incorporation of the Smart Asset Management Platform and its bespoke machine learning models to our expert services has opened up new value frontiers we couldn't have imagined when we started on the journey.

This unique Smart Asset Management Service consists of three key ingredients: energy asset expertise, the SAMP Platform and the involvement of an on-the-ground, site-based, Sebenzana SAMP-certified engineer.

SAMP PLATFORM

SAMP is simply short for Smart Asset Management Platform. It's a revolutionary technical solution and process that enables Production, Maintenance and Engineering teams to make better asset decisions together. The visual interfaces, dashboards and tools that guide teams to better decide on the scope and specification of Operations and Maintenance, Production and Engineering activities are based on the integrated analysis of two sets of data:

- The first set is from design, inspection, repair and replacement activities, as well as incident investigations. Such data is digitally

sebenzana

Our team of specialists and engineers has more than 50-years of combined generator-related experience, while our skilled turbo generator technicians conduct condition monitoring tests in accordance with international standards, providing preliminary feedback within 24-hours of leaving site.

SEBENZANA

ROTATING EQUIPMENT

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www.sebenzana.com

World-class, independent, multi-disciplinary engineering consultancy services

Generators, Turbines & Auxiliaries

- Machine failure investigation and root cause analysis
- Third-party inspection services
- Owner's engineer services on projects including specification review and development of repair work
- Risk assessment and life management of turbo generators
- Online and offline condition monitoring tests including EL CID, partial discharge, stray flux, stator and rotor insulation assessment tests and expert visual inspection
- Independent machine condition assessment services
- Development of work procedures and scopes of work
- Review of repair companies' proposed work scopes and quality documentation
- Engineering and technical support during outages and repairs
- Training on turbines and generators
- Operation and maintenance engineering on site

incorporated into the SAMP platform, replacing bulging, lever-arch files on shelves, spreadsheets and documents in key people's desk draws. The SAMP platform simplifies data capture at source, even for OEMs and third party repair organisations.

- The second data set is the asset's traditional online process data that is typically available digitally.
  Within the SAMP platform, these data sources are combined into a broad and deep data set that is then harnessed by proprietary algorithms, data scientists and international experts to provide insights into the asset's performance, integrity and risks.

Carefully crafted dashboards present Production, Maintenance and Engineering teams with a wealth of integrated information with which to answer asset performance questions such as:

- What parts of our plant are the highest risk at the moment, and how are these risks likely to change over the next two or three running cycles?
- Is the risk going to be high enough in the future that we should do something about mitigating it in the next maintenance intervention?
- What should we do now, and what will the effect of these actions be on the future performance risk?

The SAMP platform cascades the results of the advanced analyses and makes information visible to decision makers at different levels to help ensure that their decisions are well informed, evidence-based and rewarding. Best practise tools for specific equipment, like electrical test results and the all important management of vacuum conditions for condensing turbo-generators, are also seamlessly incorporated into SAMP and support the team's decision-making efforts.

As Production, Maintenance and Engineering teams use the SAMP platform to make asset decisions, more data is captured and the information gets further refined, leading to better insights and better decisions that, in turn, result in better asset performance. We call this improvement over time the SAMP Virtuous Operations and Maintenance Cycle. Due to increased collaboration and engagement, driven by interaction with the site-involved SAMP Engineer and the Platform itself, Operations, Maintenance and Engineering behaviours are positively impacted and this reflects in improvements in the assets' performance.

South Africa, regional players, if there is ever a time that the region needs you to "squeeze our sparks of light, from the darkness" (U2 lyric) we find ourselves in, it's now!

Business Leaders, Managers, Rotating Equipment Engineers, Maintainers, Operators, Producers, let's get generators spinning and making a contribution to our much needed economic recovery! Sebenzana is here to help. This is our passion and "calling" for these days. wn

PLEASE DO REACH OUT TO US FOR A CHAT:

CARL D is a Mechanical Engineer and Rotating Equipment Business Unit Lead, and available at carld@sebenzana.com

DAVID T is a Generator Specialist with over 30 years experience, available at davidt@sebenzana.com.

ANDREW C is Sebenzana's Managing Director and absolutely passionate about physical assets making a contribution to our region and society. He also serves as a Management Committee Member of the SA Independent Power Producers Association and is available via the Sebenzana office +2711-4478843.

At Sebenzana, we know critical assets have long lives and require bespoke operations and maintenance approaches to best serve your needs. Sebenzana's smart asset management service will bring a collaborative and evidence-based decision-making platform tool to your teams, allowing you to ensure your critical assets are well stewarded, now and in the future.

THE SAIEE ENTREPRENEURSHIP & INNOVATION CHAPTER

2020 LEADERSHIP

YOLANDA MABUTO
CHAIRPERSON

Founding Director: Divaine Growth Solutions & Globe International Partner
World Business Angel Investment Forum Member
BRICS Energy & Green Economy Director African Continent
WWCA African Ambassador | WEF

DR ERNEST BHERO
VICE-CHAIRPERSON

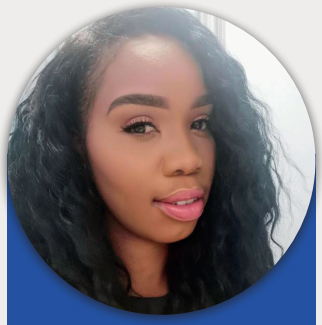
Professional Engineers (Electronics)
Advocate - High Court of South Africa

SIYABULELA MNYANI
TREASURER

Professional Technologist, Eskom
Professional Member, ECSA
MSAIEE, IPP Advisor, IEC Top Achiever

DR KINGSLEY OGUDO
SECRETARY

PHD in Electronics and Optoelectronic Systems
Professional Engineer Technologist
Professional Members: ECSA and MSAIEE
Senior Lecturer/Researcher: Electrical & Electronics Engineering,
University of Johannesburg



PALESA MORABE
MARKETING CO-ORDINATOR

Founding Director PALS Empowerment Solutions
Principal Associate: Future Leadership
SME & Skills Development Specialist

OUR VISION

Providing the best knowledge-driven innovation and entrepreneurial support for sustainable rapid economic growth for all, with due cognisance of previously disadvantaged groups and youth.

OUR MISSION

Entrepreneurial & Innovation Chapter (EIC) provides competitive advantage to its members and assurance to its stakeholders through the provision of timely knowledge-driven advice and exchange of information as well as wide-ranging and in-depth training. With a diverse pool of experienced mentors, and symbiotic partnerships, IEC will provide support at all levels of innovation, entrepreneurship, and successful running of businesses that will last for generations.

We call on any interested parties, who are members of the SAIEE, to join our chapter. Send a photo and your CV to entrepreneurchapter@saiee.org.za

SAIEE
ENTREPRENEURSHIP & INNOVATION CHAPTER

Fossil fuel bans jump fivefold in 2020.

CITIES CAN CHANGE THE GAME IN THE FIGHT AGAINST EMISSIONS AND AIR POLLUTION

The pandemic has thrown into stark relief the global battle of cities for cleaner air and a better future. The 2021 edition of REN21's Renewables in Cities Global Status Report, the only stock-taking of cities' energy transition efforts worldwide, shows that one billion people live in cities with a renewable energy target or policy, The number of cities that have enforced partial or complete bans on fossil fuels jumped fivefold in 2020.

For the second year, REN21 takes the temperature of how cities worldwide use renewable energy to battle emissions to prevent air pollution and climate change. More than half of the global population lives in cities, which account for three-quarters of global final energy consumption.

"With their impact at scale, cities are our best bet to plan, develop and build a renewable future. But all too often their potential for transformation remains massively underused," says REN21's Executive Director, Rana Adib. "It's a tough job to turn low-carbon ambitions into reality in built and densely packed environments. National governments must put money, capacity and above all legislative powers into the hands of local authorities."

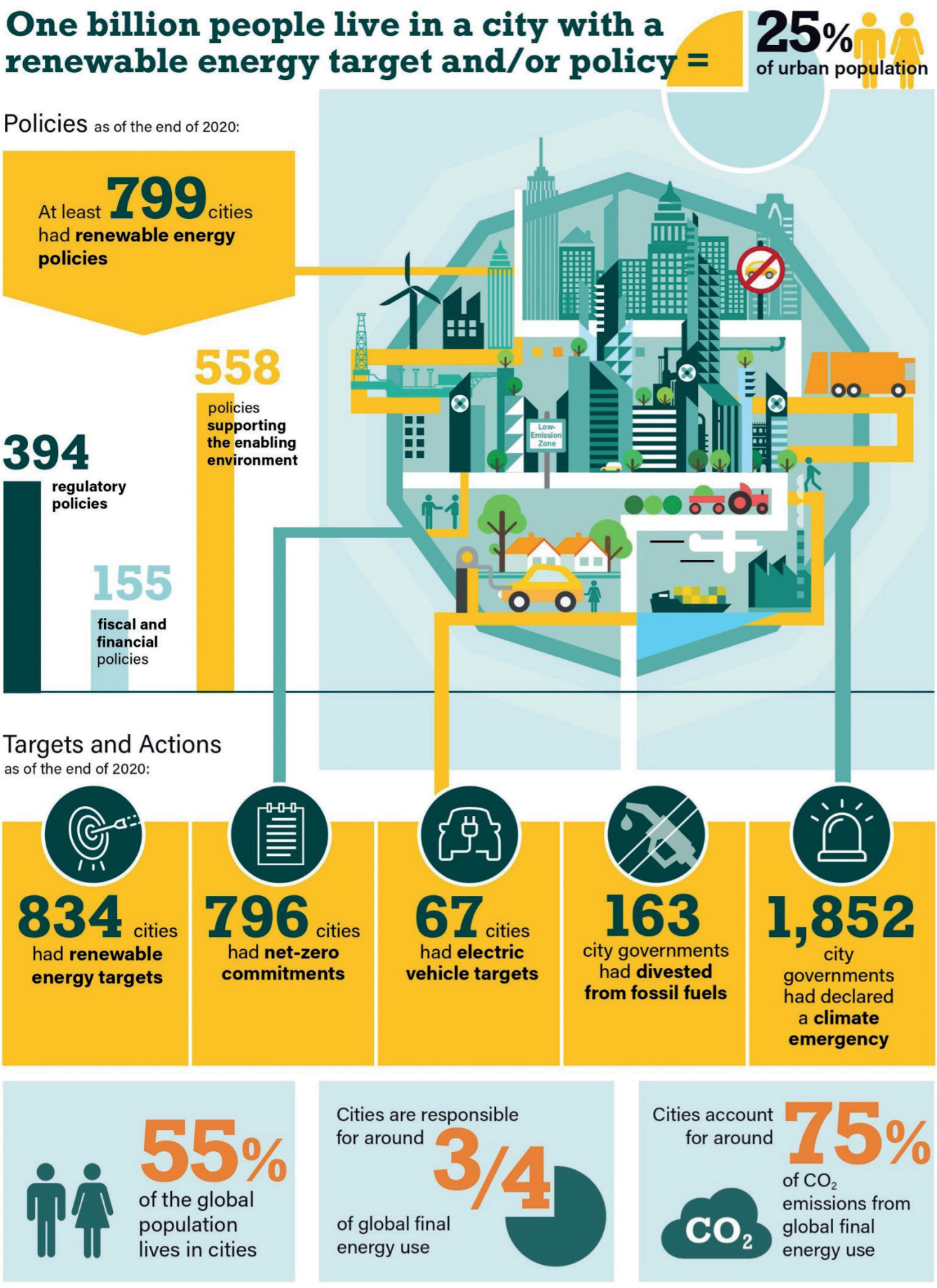
CITIES MUST TRANSITION TO RENEWABLES AND SET END DATES FOR FOSSIL FUELS IN ALL SECTORS

A critical factor for the success of cities' climate strategies is to rapidly replace fossil fuels with renewable energy in heating and cooling as well as in transport. These sectors are responsible for the biggest share of global emissions, and they are best addressed at the local level.

The report shows that often, purchasing renewable electricity for the city's own operations is one of the first steps local leaders take. But according to Adib, this is not enough. "Cities like Hamburg, San Francisco and Shanghai show, the more ambitious they are, the more they think of renewable energy everywhere. They impose strict building codes and renewable energy obligations. But most importantly, they set an end date to the use of gas, oil and coal."

By 2020, 43 cities had done so and enforced fossil fuel bans in heating and/or transport, five times as many as in 2019. In total, one billion people - about one quarter of the global urban population - live in cities with a renewable energy target or policy. "But as inspiring as these examples are," says Adib, "we are still a far cry from what is needed to curb climate change in time."

Figure 1. Key Facts and Trends in Cities, 2020



Source: See endnote 1 for this chapter.

A FLAVOUR OF CLEAN AIR AND CLEAR SKIES

Last year's lockdowns with the sudden disappearance of traffic, the complete alteration of lifestyles resulting in cleaner air and less noisy environments, have given citizens a flavour of how alternatives to packed roads and polluted skies could look.

City leaders are now building on this momentum, moving away from polluting fossil fuels and building clean and resilient energy systems in their place. "Growing citizen support gives Santiago a real mandate to take action against climate change. Our residents demand that the government take bold measures," explains Isabel Aguilera, Environmental Director for the city of Santiago (Chile).

THE RACE TOWARDS RENEWABLES IS AN OBSTACLE COURSE

The Renewables in Cities 2021 Global Status Report also shows that besides emission reductions, many other local benefits await those who take their energy future into their own hands: from the creation of local jobs and welfare to greater quality of life and healthier citizens. "The transition to a zero-carbon economy presents tremendous economic development opportunities for Orlando and the Central Florida region, some that we are already beginning to see stimulate our local economy, improve public health, reduce environmental impacts, and create meaningful high-wage jobs for our residents," says Mayor Buddy Dyer of the City of Orlando (Florida, USA).

Sometimes, like in recent examples from Japan and the Republic of Korea, city governments can even push national governments to be more ambitious. But, while the report features encouraging stories from all regions of the world, the large majority of cities have not yet figured out how to take ambitious action, or they lack the power and resources to do it.

"PROVIDE CITIES AROUND THE WORLD WITH SUPPORT"

Even those who seem ready and willing to move forward, run into obstacles. All too often, powerful fossil fuel interests put a stop to cities' decarbonisation plans. "It's a sad fact that wherever in the world cities seek to phase-out fossil fuels, the industry puts a lot of resources into fighting back. They take local authorities to court or, as seen recently in the US, convince state policymakers to make it legally impossible for cities to take such decisions at all," says Adib.

Martina Otto, heading the cities work at the United Nations Environmental Programme, concludes: "There is huge untapped potential. We can both increase the level of ambition and progress in meeting national climate commitments if national and regional governments around the world provide cities with support well beyond the creation of better financial conditions. Getting over territorial boundaries to empower cities means unleashing the power of our strongest allies."

ABOUT REN21 AND THE RENEWABLES IN CITIES GLOBAL STATUS REPORT

REN21 is the only global renewable energy community of actors from science, governments, NGOs and industry. We provide up-to-date and peer-reviewed facts, figures and analysis of global developments in technology, policies and markets. Our goal: enable decision-makers to make the shift to renewable energy happen – now.

The Renewables in Cities Global Status Report is an annual stock-take of the global transition to renewable energy at the city-level. The 2021 edition has been co-authored by over 330 experts and is endorsed by an Advisory Committee of 20 organizations including city networks. wn

Appointment of new CEO to National Research Foundation

The Board of the National Research Foundation (NRF) is pleased to announce the appointment of Prof Fulufhelo Nelwamondo as Chief Executive Officer (CEO) of the NRF from 01 April 2021, for a five-year term. The appointment was made in terms of Section 10 of the NRF Act, following consultation with the Minister of Higher Education, Science and Innovation.

Prof Nelwamondo is a seasoned executive with a proven track record in strategy, operational planning and successful implementation. He has worked within the National System of Innovation with multiple stakeholders in the public and private sectors and has led strategic mission-driven research portfolios that demonstrated huge financial returns and societal impact. He holds various leadership roles and responsibilities, nationally and internationally, including Chairman and Panel Member of several NRF committees such as the NRF Flagship Programme; the Centres of Excellence (CoE) programme; and the South African Research Chairs Initiative (SARChI).

Prof Nelwamondo has worked in areas of advanced modelling, information security, data science, and artificial intelligence, and is a Visiting Professor at the University of Johannesburg's Institute of Intelligent Systems. In 2017, he was awarded the Order of Mapungubwe in Silver, the highest civilian honour bestowed by the President of the Republic of South Africa, for his contribution to the field of science, particularly electrical engineering.

He holds a PhD in Electrical Engineering in Computational Intelligence from the University of the Witwatersrand. In 2008, he advanced his research endeavours as a Postdoctoral Fellow at the Graduate School of Arts and Sciences at Harvard University, and was the youngest South African to receive the prestigious Harvard-South Africa Fellowship. wn

Prof Fulufhelo Nelwamondo

Marthinusen & Coutts (M&C) and ACTOM Turbo Machines recently completed the refurbishment and return to service of the rotating machines forming the heart of SABS's world class National Electrical Test Facility's (NETFA) High Power Test Laboratory, just outside Johannesburg.

M&C and ACTOM Turbo Machines refurbish world-class SABS's NETFA High Power test laboratory

The High Power Test Laboratory can generate up to 40 kA and 14 kV high power surges for short-circuit and internal arc testing – among other tests. There are only a handful of similar facilities in existence globally, using highly specialised 85 MVA 3000 rpm BBC Oerlikon generators to produce the very high currents and voltages required.

The work on these units required great skill, experience, dedication, meticulousness and infrastructure which M&C and ACTOM Turbo are known for in the industry.

The refurbishment of the equipment for the laboratory, which had been out of action for more than 5 years, was performed between November 2019 and August 2020 – with much of this being carried out during the tough conditions of the Covid-19 Lockdown.

The refurbishment was for the lab's three main drivetrains, consisting of two 85 MVA 14 kV 3000 rpm generators driven by 1 MW wound rotor induction motors and one exciter drivetrain comprising an 800 kW 1000 rpm drive motor driving two DC generators supported by a 12.5 t flywheel.

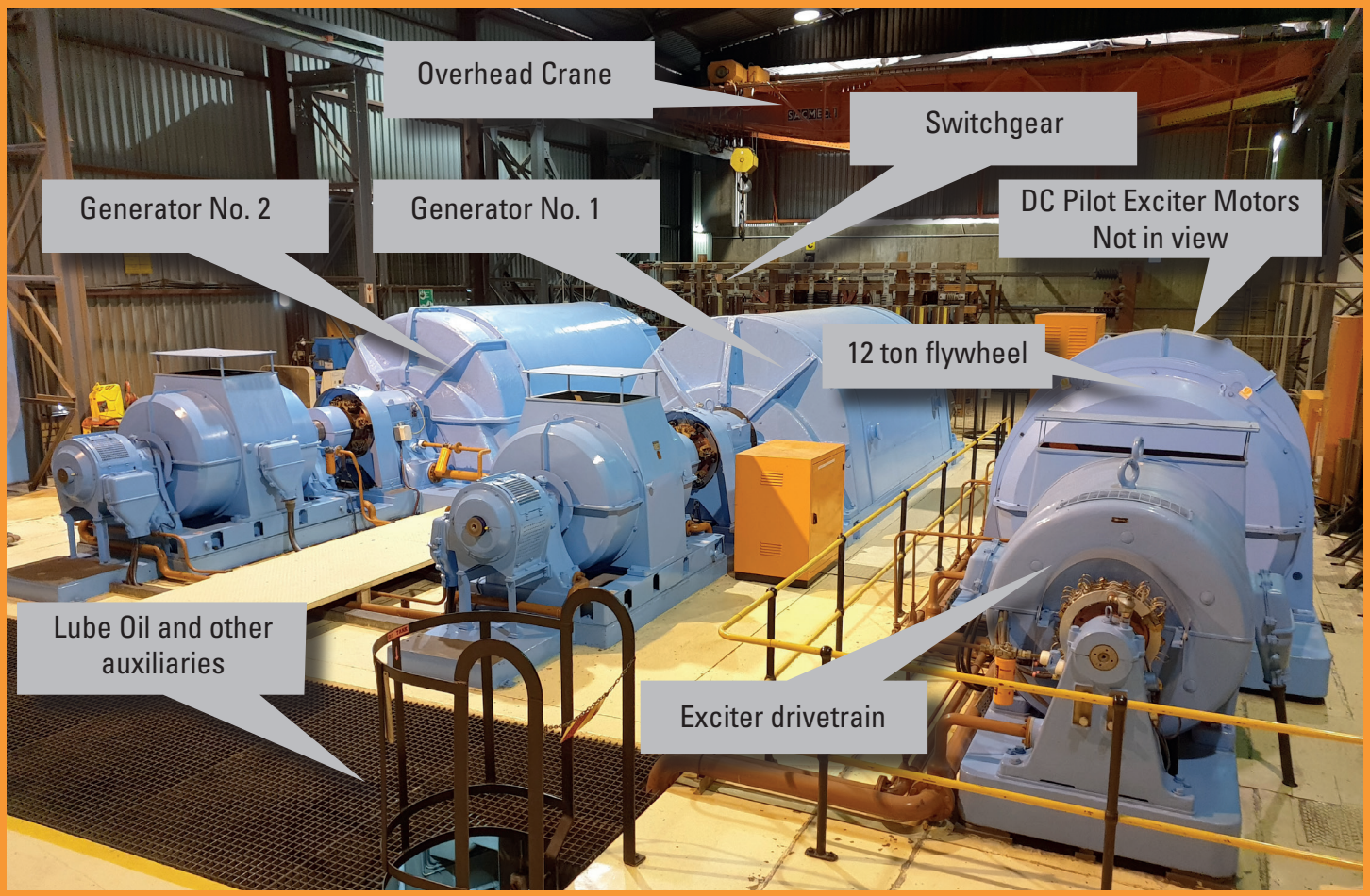
"The project is a good example of our division's electromechanical full solution offering and project management capability, giving the customer the peace of mind of having a single service provider ultimately responsible for their project," commented Mike Chamberlain, M&C's Commercial & Marketing Executive.

The full scope of work undertaken by M&C and ACTOM Turbo was:

- The removal, refurbishment and recommissioning of the two 85 MVA generators, drive motors and all the exciters.
- On-site refurbishment of the liquid resistance starters.
- Repair and servicing of the lubrication system.
- Repair and servicing of the ventilation system.
- Servicing the de-watering pump system.
- Refurbishment of switchgear components, bus bars and bushings.
- Cleaning and painting of the High Power Testing facility.
- Numerous additional aspects that arose during the recommissioning of the plant.

NETFA Consist of three laboratories i.e. Short Circuit, High Voltage and Materials / Installations with each of these laboratories being divided with a number of tests areas.

The High Power test laboratory is just one of three test facilities at the Short Circuit, the other two being a 10kA Temperature Rise Plant, 10kA Short-Circuit Plant, and a High Current 100kA test lab. The High Power test laboratory is also one of only three such facilities globally, and it is unique in being the



THE THREE DRIVE TRAINS

Two 85 MVA 14 kV 3000 r/min generators driven by 1 MW wound rotor induction motors.
One Exciter drivetrain: 800 kW drive motor (WRIM), driving two DC generators that are supported by a 15 ton flywheel that supply the generator field.

only such facility located at an altitude substantially above sea level.

The world-class NETFA facility is now fully operational again, ready for testing the following products:

- Power and distribution transformers
- Medium voltage switchgear and control gear
- High voltage fuses
- Prefabricated substations
- Medium voltage flameproof plug-socket assemblies
- Substation conductors and accessories
- High voltage switches
- Power cables
- Medium voltage terminal boxes
- Overhead line fault detection devices
- Current and voltage transformers
- Earthing and short-circuiting cables.

ACTOM Switchgear has already been making extensive use of the High Power testing lab since its return to service by M&C. Greg Whyte, Switchgear's Design and Development Manager, said the importance of this facility to industry, both locally and abroad, cannot be underestimated.

Lucas Monyai, Senior Manager of NETFA's Laboratory Services Division, and Seth Mnisi, Manager of the High Power testing laboratory, complimented M&C and ACTOM Turbo for completing the project in difficult circumstances and for going well beyond their original scope to address unusual problems that arose during the recommissioning process.

They also commented on the excellent working relationship that developed between NETFA, M&C and ACTOM Turbo. wn

WEG TAKES SOFT-STARTERS TO NEXT LEVEL WITH SSW900 RANGE

The new WEG SSW900 soft-starters are the ideal choice for complete motor control and protection. These units allow quick and simple access to application information and configuration settings in any installation throughout a wide range of industrial segments where a three-phase induction motor needs to be controlled.

The WEG SSW soft-starter installed in a panel.

With its well-structured menu interface, the WEG SSW900 line gives users a new level of interactivity, including Bluetooth connectivity. These soft-starters provide event logs with dates and times, as well as a setup and programming assistance. The built-in bypass extends the lifespan of the units, optimising space and reducing heat dissipation inside electric panels. This built-in bypass functionality also extends throughout the WEG soft starter product range, up to 1400 Amps.

By allowing the smooth acceleration and deceleration of motors by controlling the voltage, soft-starters greatly reduce mechanical stresses on couplings and transmission devices during the start-up of a motor. In pumping applications, the smart control prevents water hammer and pressure overshoots in hydraulic piping.

Available from Zest WEG and its network of branches and value-added resellers in current ranges from 10 A to 1,400 A – and for supply voltages from 220 V to 575 V AC – the WEG SSW900 soft-starters can operate at ambient temperatures of up to 55°C without current derating. They can substitute direct online starters or star-delta starters, bringing a range of benefits to the user's application. These include savings in electricity, as well as greater protection and increased durability of the electric motor.

Users also have access to diagnosis and fault history, and experience greater flexibility as the WEG SSW900 allows the installation of accessories in the application. Graphic monitoring and customisable main screens provide further convenience. The monitoring functionality is also extended by a USB connector available on all standard products. This provides access free of charge to product software available on www.weg.net. wn

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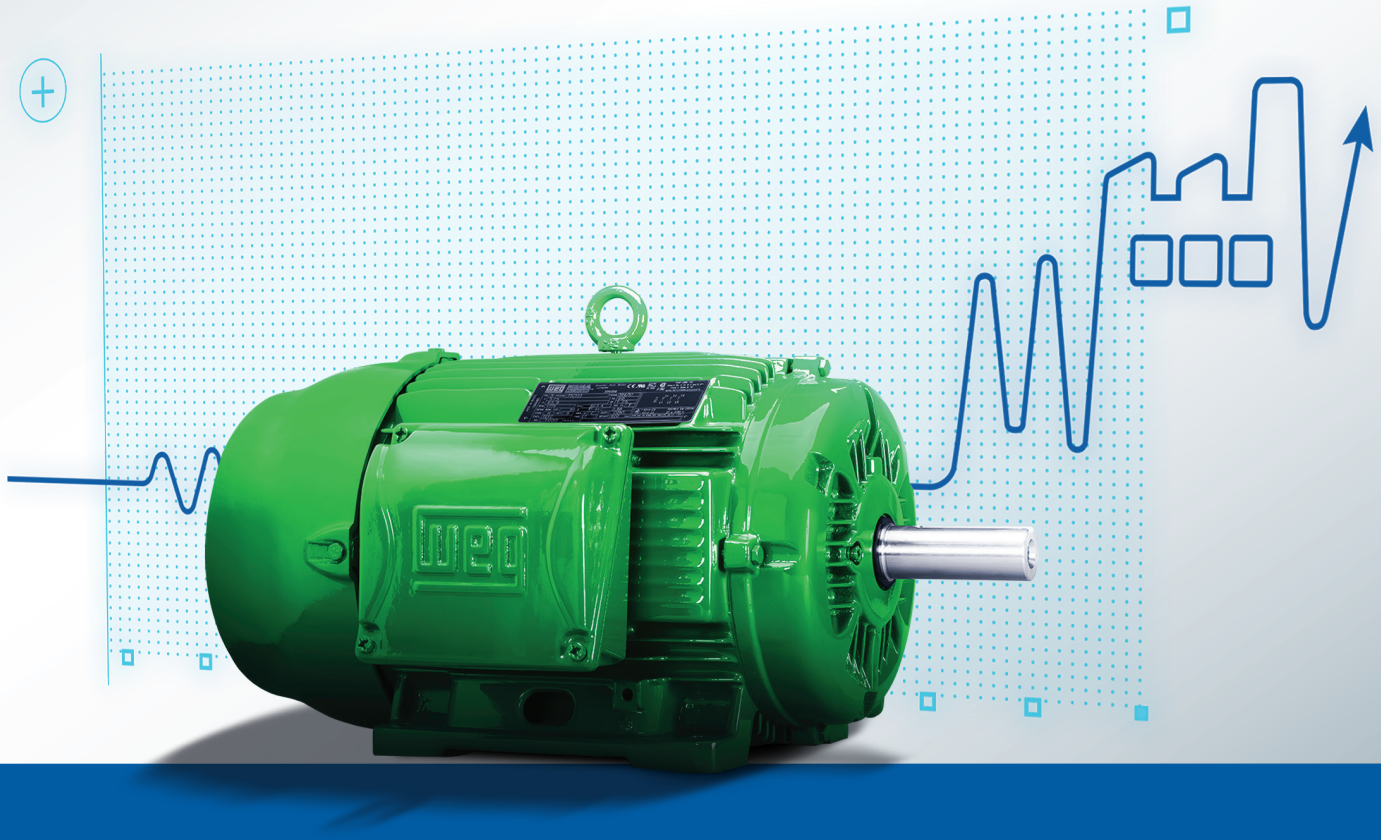

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Sustaining Life Span of Rotating Equipment in Plants

You are 17 times more likely to introduce defects during equipment start-up than during regular equipment operation. Additionally, over 90 per cent of rotating equipment has defects at start-up that result in premature equipment failures. What's causing these start-up defects?

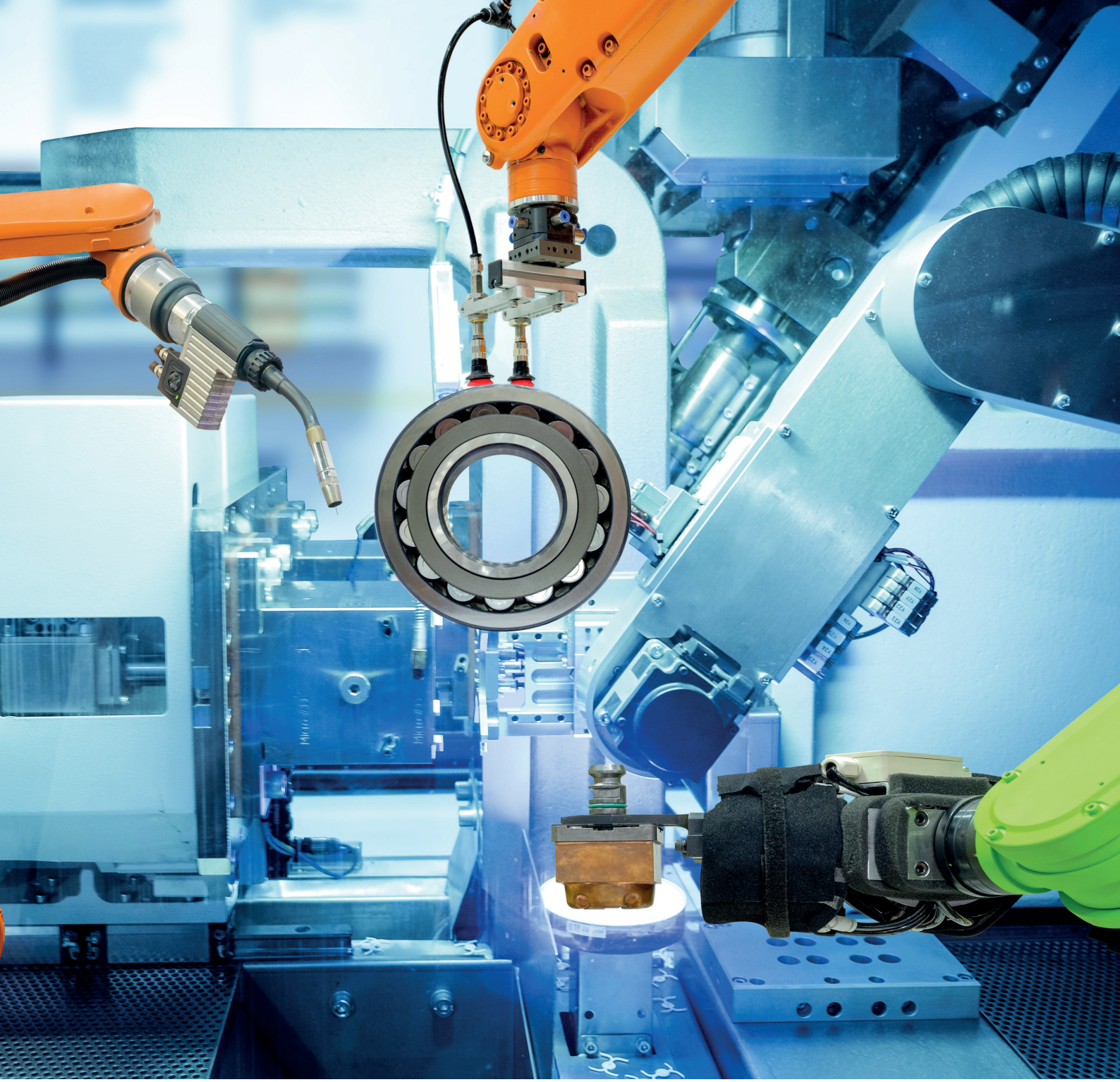
BY UWOAJEGA JOSEPH

Article courtesy of Reability Web

According to a study by a leading industrial equipment supplier, misalignment and unbalance are two of the most commonly overlooked conditions that lead to these unwanted statistical results.

Misalignment in equipment leads to increased vibration levels, bearing failures, coupling wear, seal failures, shaft fatigue, increased power consumption and other adverse effects. Unbalance in equipment can introduce structural-related issues, bearing defects and other problems.

Both conditions can create unwelcome safety concerns. Additionally, both conditions can be present on the same equipment and, working in concert, can, unfortunately, amplify the referenced failure conditions.



So, how do you prevent misalignment and unbalance conditions from making your equipment part of these negative statistics and placing your company at financial risk?

The answer is to apply condition monitoring technology and procedures, such as laser alignment, equipment balancing and vibration analysis, to your equipment.

These condition monitoring activities will lead to reduced equipment downtime, reduced equipment failures, improved safety, reduced financial risks, increased equipment uptime, lower operating costs and increased profits for stakeholders.

What reliability improvements can you make in your facility that do not require expensive or complicated actions? Start with the basics, such as:

- Align: shaft, coupling, etc.;
- Balance: rotating components, such as fan blades, impellers, rotors;
- Tighten: eliminate looseness and excessive vibration;
- Lubricate: correctly, meaning not too much or too little;
- Inspect;
- Apply condition monitoring;
- Understand where your efforts should be focused on.

Don't wait until the equipment has been installed and is operating. These essential functions must be included in your equipment's specification, design, purchase, and routine operation. Failure to address these vital aspects from the beginning through your equipment's operation will result in higher maintenance costs and reduced equipment reliability.

SUSTAINING BEARING LIFE

Like any mechanical device, bearings wear out over time. This is an unavoidable fact of life. Yet, there are ways of getting the maximum life out of the bearings in your rotating equipment.

To start with, there are five simple things you can do to maximise bearing life. These five steps are: keep your bearings clean, dry and cool, and keep your equipment balanced and aligned. Clean, dry and cool means addressing the lubrication issues of the equipment. For instance, circulating oil systems are used when the heat buildup at the bearing is more than a static oil system can radiate away. In this case, the system provides external cooling. However, just like in a car, circulating oil must be changed periodically. Oil deteriorates over time from heat, oxidation, catalytic reactions, and dirt or water contamination. It is a good idea to change the oil whenever it becomes dirty or cloudy.

Grit and dirt contamination act as abrasives and over time will remove the hard facing of the bearing. Once the hard facing is removed, the bearing will quickly deteriorate to failure. Therefore, it is essential to keep the dirt contamination out.

In wet environments, keeping bearings dry can sometimes be challenging. It is also vital since water will separate the lubricant. If you notice a milky look to the grease being purged from the bearings, it indicates contamination by water.

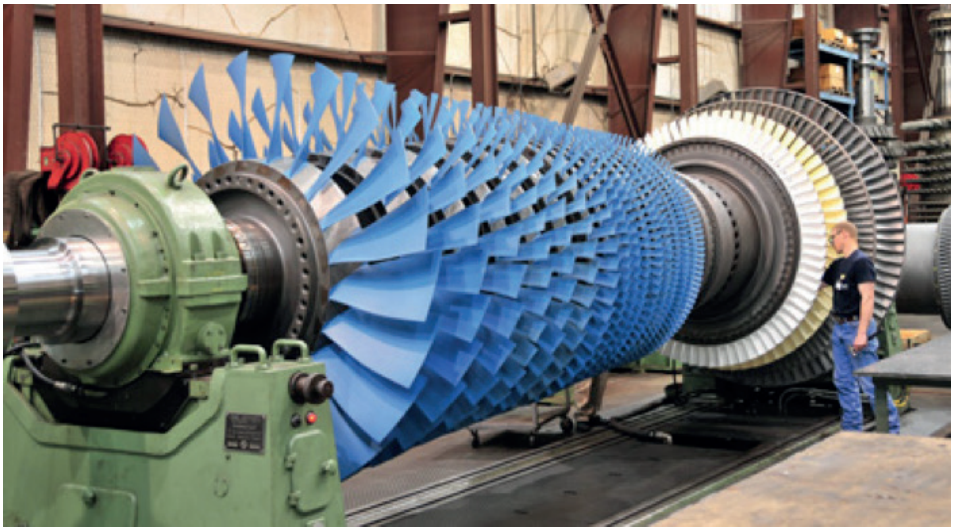


Figure 1: Protective coatings can help increase the efficiency and extend the service life of a gas turbine

Balanced and aligned refers to minimising the destructive energies present when imbalance and misalignment are allowed to continueKeeping these forces to a minimum significantly adds to extending bearing life. Many companies use vibration monitoring equipment to determine the severity of these forces or shut down the equipment if these energies get too large. As an example of vibration levels seen in the field, it is not uncommon to see vibration velocities of 0.10 in./sec or lower for initial operation, 0.30 in./sec for an alarm setting and 0.45 in./sec as the shutdown setting for a heavy-duty fan. However, as there are many applications, it is always best to check with your fan supplier on these matters.

ACHIEVING LONG-TERM RELIABILITY

Long-term reliability is a common goal for all plant operators. Achieving it requires a considered approach that takes into account a range of contributory factors and makes use of the most appropriate technology and manpower available to them.

Rotating equipment in direct contact with the process media and under constant attack presents a significant challenge. It is possible, however, to reduce degradation to a minimum by selecting the correct coating system.

Generally, turbines, compressors and pumps are all subject to various environmental conditions that contribute to corrosion, erosion, fouling and various temperature-related issues.

The first step is to understand the operating environment of the machinery. The sources of degradation can be classified, and specific coating systems can be used to increase efficiencies, lengthen the interval between scheduled maintenance, and reduce unscheduled maintenance events.

In the case of a gas turbine, the flow path of air and fuel presents

several different conditions that can harm the turbine's performance. The combination of heat, microscopic abrasives and a gradually increasing concentration of corrosive elements can cause significant damage to a once smooth airfoil surface. As the surface finish slowly degrades, the efficiency of both the compressor and the turbine is reduced.

COMPRESSOR SECTION

This process can be arrested in the compressor section of the gas turbine, and the surface is restored by applying suitable metallic coatings. A range of options is open to suit a gas turbine's specific duty, but all include a type of metal deposition where a rigid corrosion-resistant surface is created.

An aluminium base layer is typically used in gas turbine compressors for corrosion protection of ferritic/martensitic steel components in moist conditions. It provides galvanic protection, which means that minor scratches to the surface layer are less likely to cause corrosion. It is produced by spraying a slurry of aluminium and an inorganic binder, rendered insoluble by a medium-temperature baking process. This layer can be then covered by a harder layer that might include metals, such as chromium.

The harder layer is usually applied using a spray coating method, such as chemical vapour deposition (CVD), atmospheric plasma spraying (APS), low-pressure plasma spraying (LPPS), or high-velocity oxygen fuel (HVOF). Which one is applied will depend on the coating thickness required and the sensitivity of the part to heat, as some processes are hotter than others.

By applying corrosion inhibiting and surface finish enhancing coatings to the compressor section, it is possible to increase efficiency and extend the gas turbine's service life.

HOT SECTION

Modern gas turbine hot section components are made using nickel or cobalt-based superalloys and are designed to operate at high temperatures.

However, these alloy compositions are not as well suited to providing corrosion and oxidation protection. It needs to be supplemented with custom coatings that can deliver the hot corrosion and oxidation protection required for extended service lives.

The oxidation process causes a layer of metal-oxide to form on the surface, which, in general, protects the underlying material. Therefore, the oxidation process slows down as the thickness of the oxide layer increases. This process can be replicated with the intentional formation of oxides that provide a protective layer, preventing a further atmospheric attack.

Corrosion of a gas turbine component usually occurs in one of two ways. Hot corrosion may occur between 788°C and 899°C, and it attacks the entire surface of the component. Alternatively, corrosion at cooler temperatures is more localised and tends to create distinct layers of oxide and exposed metal. Further damage can be caused by erosion, which involves repetitive mechanical abrasion by particles in the air stream.
Stand-alone high-velocity oxygen fuel applied MCrAlY coatings are sufficient to combat corrosion/oxidation at lower firing temperature gas turbines. For newer technology, higher firing temperature gas turbines, the combination of a MCrAlY bond coat coupled with a ceramic thermal barrier coating, reduce the substrate's surface temperature, thus reducing the degenerative effects of oxidation and corrosion.

COMPRESSORS

Pumps and compressors account for more than 20 per cent of the world's electricity demand, and the energy costs to run them represent 95 per cent of the running costs. Therefore, it is essential to minimise these costs by improving performance and efficiency. These efforts also will have the beneficial effect of improving reliability and service life.

While turbines extract energy from a gas expansion process, turbofans and compressors are used to increase the energy of gases. As such, the main issues with these components are corrosion, erosion and fouling.

CONCLUSION

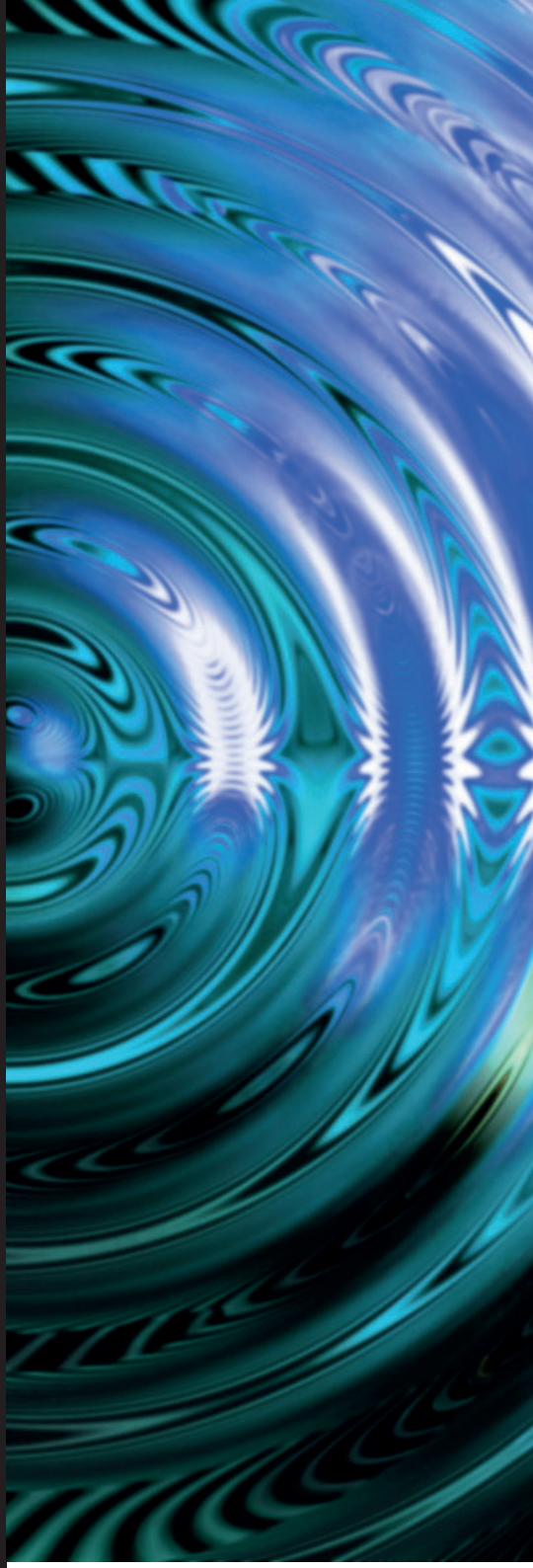
Proper equipment function and sustainability requires a properly aligned and balanced machine. Allowing a machine to operate in an unbalance situation can result in coupling damage, bearing damage, cracks, loose components and many other costly maintenance issues.

Bearings should be clean, dry and cool. Loose debris can dislodge and impact the balance quality of a machine/equipment. Debris buildup on the impellers/blades and other rotating parts can create unbalance conditions.

Before balancing the machine, it is imperative that the rotating surfaces (e.g., blades, etc.) are cleaned of any debris. Removing buildup will help ensure that the machine can be appropriately balanced and remains in a balanced condition. wn

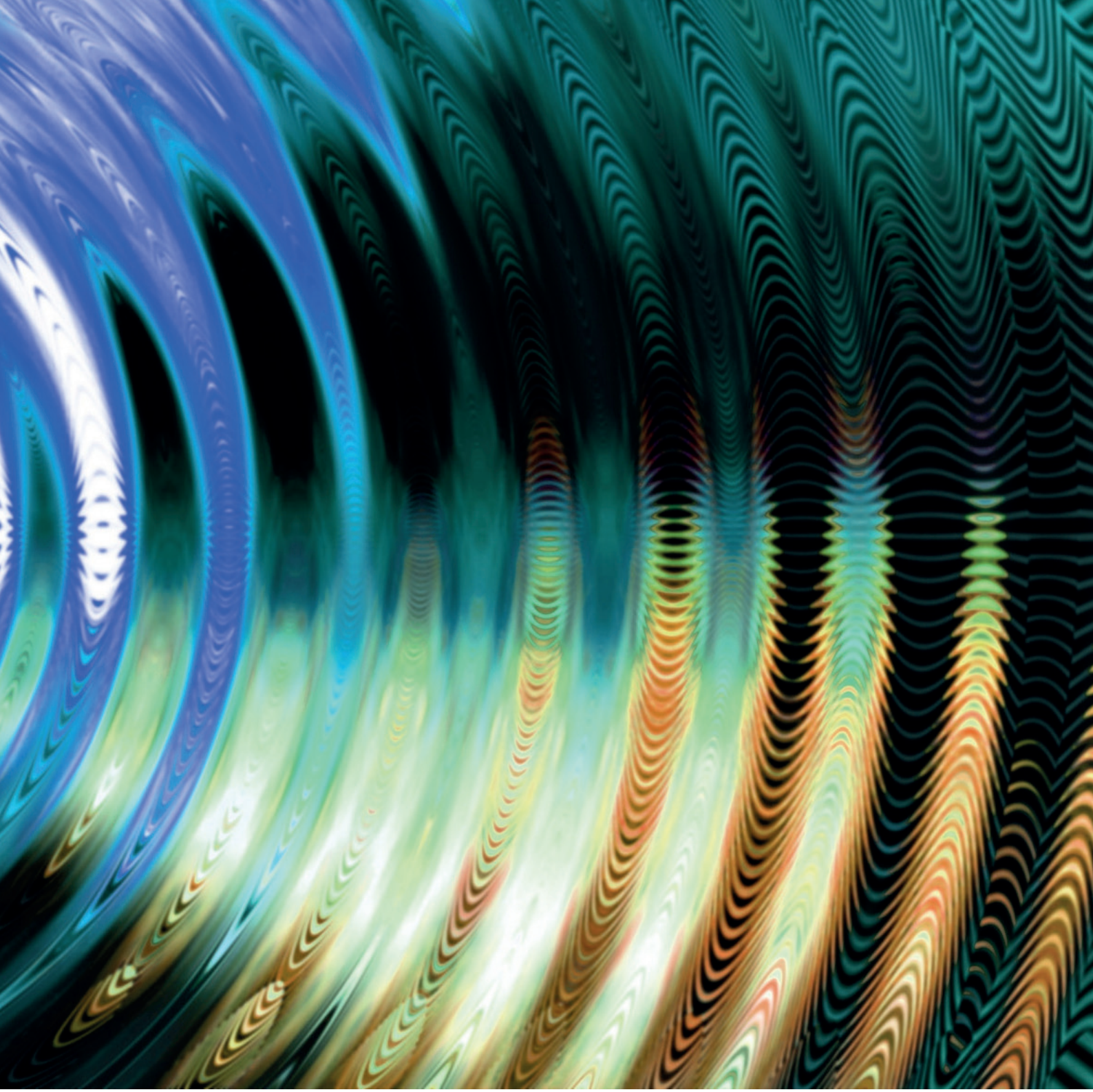
Magnetoresistive Sensors and Piezo-resistive Accelerometers for Vibration Measurements:

A Comparative Study



This experimental study focuses on the comparison between two different sensors for vibration signals: a magnetoresistive sensor and an accelerometer as a calibrated reference. The vibrations are collected from a variable speed inductor motor setup, coupled to a ball bearing load with adjustable misalignments. To evaluate the performance of the magnetoresistive sensor against the accelerometer, several vibration measurements are performed in three different axes: axial, horizontal and vertical. Vibration velocity measurements from both sensors were collected and analyzed based on spectral decomposition of the signals. The high cross-correlation coefficient between spectrum vibration signatures in all experimental measurements shows good agreement between the proposed magnetoresistive sensor and the reference accelerometer performances. The results demonstrate the potential of this type of innovative and non-contact approach to vibration data collection and a prospective use of magnetoresistive sensors for predictive maintenance models for inductive motors in Industry 4.0 applications.

BY ROGERIO DIONISIO, PEDRO TORRES, ARMANDO RAMALHO AND RICARDO FERREIRA



It is known that vibrations can degrade or cause many problems in industrial equipment and machinery [1]. The information gained from the vibration signals can be used to predict catastrophic failures, reduce forced outages, maximise utilisation of available assets, increase the life of machinery, and reduce maintenance costs related to machinery's health. First, it is essential to understand what vibration is. It can be understood as a movement or mechanical oscillation of an object's equilibrium position, be it industrial equipment or infrastructure, and can be periodic or random. Focusing on industrial machines, the existence of vibration can be an indication of the existence of a problem or deterioration of the equipment. If the causes are not identified and corrected, the undefined vibration itself can cause additional damage. The effects of vibration can be severe, causing noise, excessive energy consumption and, in the worst case, can damage the equipment so severely that it leaves it out of service. The leading causes of rotary machinery vibration are well defined, and it is known that they arise

due to imbalance, misalignment, wear or looseness in bearings and other components [2]. The degradation of many mechanical components' functioning can be correlated with a change in the vibration spectrum [3], which is why vibration analysis is one of the most popular predictive maintenance techniques.

In the context of predictive maintenance, one of the strengths of Industry 4.0 is that it is essential to continuously monitor machines to predict which parts are likely to fail and when. In this way, maintenance can be planned, and there is an opportunity to replace only parts that show signs of deterioration or damage. Machine vibration is one of the most common measurements in rotating equipment monitorisation.

Machine-mounted sensors are vital components in vibration measurements and analysis. A full spectrum vibration signature can be obtained with measurements in three axes (horizontal, vertical, and axial). The accelerometer is typically used for low-to-medium frequency measurements on different parts of the equipment. In this work, another type of sensor, the magnetoresistive sensor, was tested to measure vibrations in rotating machines to establish a comparison with an accelerometer and validate the use of this type of sensor in the analysis of vibrations.

Many scientific works have been produced regarding the analysis of vibrations in motors for predictive maintenance purposes. In [4], a case study is presented for vibration analysis of electrical motors, performed under different speed conditions using an accelerometer's measurements. In [5], a system of neural networks was implemented for predictive maintenance in electric motors to detect the type of failure based on the analysis of vibrations. In [6], monitoring of the induction motor condition is presented through vibration analysis techniques.

Vibrations are detected by measuring displacement, velocity, and acceleration, and the piezoelectric or capacitive accelerometer is the most used sensor for making these measurements. However, there are other types of sensors that have been developed and adapted for measuring vibrations. In [7], it has been shown that magnetic sensors are pretty sensitive to detect vibration by measuring the magnetic field strength and can be a low-cost alternative to accelerometers.

Magnetoresistive sensors are characterised by their high sensitivity and can be a fascinating solution. Besides vibration analysis, the magnetoresistive effect is commonly used in navigation systems [8], crankshaft position sensors [9] or magnetoresistive heads in disk drives [10], among other applications. In [11], the authors present the principles of its operation and the potential applications for industrial scenarios.

Another issue discussed by the scientific community is the use of non-contact instrumentation and sensors based on magnetoresistive effect offer this possibility, unlike the accelerometer that needs to be rigidly attached to analysed equipment. One of the works where magnetoresistive sensors are used for vibration analysis is presented in [12], in this case, focused on turbo-machines. Another fascinating work was developed in a master thesis [13], where the author studies the use of giant magnetoresistance sensors (GMR) in the detection of vibrations.

Accelerometers are widespread in the industry, but due to their high sensitivity and high level of integration, the magnetoresistive sensor can be a real alternative for measuring industrial equipment vibrations. Based on this, present work demonstrates that it may be possible to obtain a proper vibration spectrum based on different sensors. Depending on the application, one can choose the type of sensor for the most appropriate solution. Due to the magnetoresistive sensors' high sensitivity, a lot of noise can be acquired over a wide range of frequencies; therefore, the acquisition systems need to overcome this and through well-designed filters to select the desired spectrum range. This work was developed for vibration analysis in induction motors but can be easily tested on other types of machines presented on the shop floor.

The remainder of this paper delves into the description of the proposed comparative study with the contents organised as follows: Section 2 describes the magnetoresistive sensor and electronic circuit board. Section 3 presents the proposed experimental setup and methodology. Section 4 introduces the results and discusses the comparative study, focused on spectral analysis evaluation of both sensors' performance when applied in an induction motor enabled with a load with an adjustable vibration setup. Finally, in Section 5, conclusions, ongoing and future works are discussed.

MAGNETORESISTIVE SENSOR

INL—International Iberian Nanotechnology Laboratory developed the magnetoresistive sensor. It comprises a magnetic sensing

layer stack, a magnetic reference layer stack, and a tunnel barrier between the magnetic sensing and magnetic reference layer stacks. In the absence of an external magnetic field, the magnetoresistive sensor is configured. An exchange bias pinning the reference layer lies along a reference direction; an exchange bias pinning the sensing layer lies along a first orthogonal to the reference direction. The magnetic anisotropy of the sensing layer is parallel to the first direction. The combined action of the magnetic anisotropy and sensing layer exchange coupling creates a well-defined direction along which the free layer rests in the absence of an external field. Under the influence of a magnetic field along the reference direction, the sensing layer magnetisation rotates smoothly and uniformly. Thus, a high-quality linear response can be achieved with no shape anisotropy [14].

The stacks consist of 464 magnetic tunnel junction (MTJ) elements connected in a series to minimise the $1/f$ noise of the sensor [15]. The size of each MTJ sensor is 40 × 40 µm, while electronic pads are 200 × 400 µm and separated by 250 µm. The MTJ stack consists of (unit: nm) 5 Ta/15 Ru/5 Ta/15 Ru/5 Ta/5 Ru/20 IrMn/2 $CoFe_{30}$/0.85 Ru/2.6 $CoFe_{40}B20$/MgO 2 × 41 [25 kΩµm^2]/2 $CoFe_{40}B_{20}$/0.21 Ta/4 NiFe/0.20 Ru/6 IrMn/ 2 Ru/5 Ta/10 Ru [16]. As depicted in Figure 1, from data measured at INL premises, the sensor presents a short linear range (4 mT) that is adequate for applications that require high sensitivity levels, such as vibration in motors, metallic canister detection in high speed convey belts, among others. The remaining specifications of the MTJ sensor are:

- Bias voltage between 0 V and 54 V;
- Bias current: 156 µA;
- Output voltage: 223 V output voltage/1 V bias voltage/1 T magnetic field.

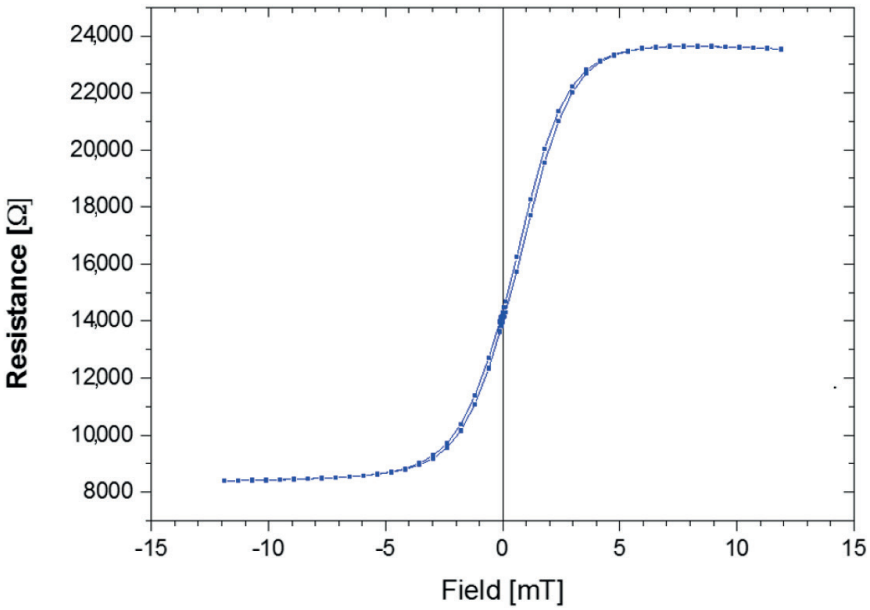


Figure 1. Measured resistance variation of the magnetic tunnel junction (MTJ) sensor with a magnetic field.

PRINTED CIRCUIT BOARD

For this investigation, four MTJ sensors were etched in a complete Wheat- stone bridge die-structure to compensate for thermal drift and other effects. When an external magnetic field is applied generally to the sensor's side, the magnetisation vector will rotate and change the angle Ø. This will cause the resistance value to change and produce a voltage output variation in the Wheatstone bridge. This change is directly related to the angle of the current flow and the magnetisation vector. Two bridge dies were mounted in a Printed Circuit Board (PCB) shown in Figure 2c (the bridge-dies are located on the opposite side). In each square from Figure 2b, there are two series of MTJs, one for each bridge, with the reference layer (RL) in the same direction:

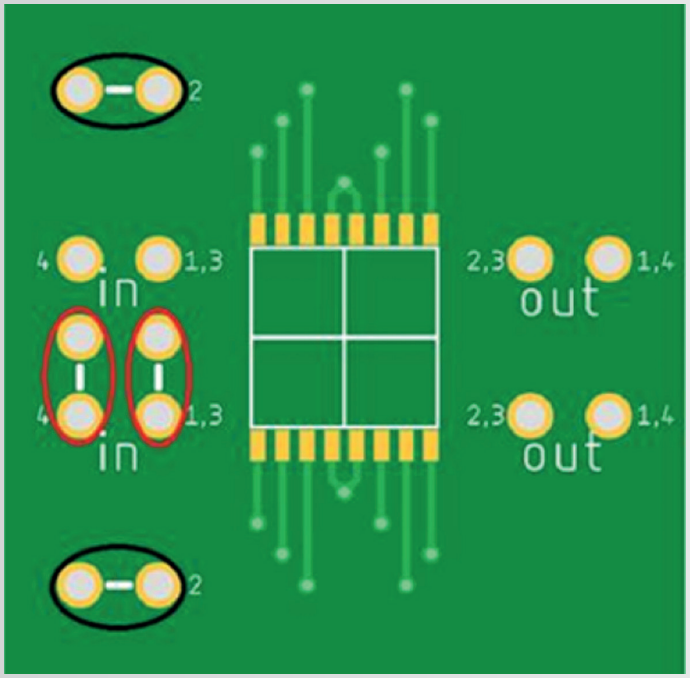
- Top left, the RL is up;
- Top right, the RL is down;
- Bottom left, the RL is left;
- Bottom right, the RL is right.

With this arrangement, the top elements are sensitive to the Y direction, while the lower elements are sensitive to the X direction. Thus, both bridges are sensitive to the X and Y directions of the magnetic field. The PCB was designed with several connection points, or jumpers, to facilitate individual characterisation of each MTJ sensor from the bridge arms. This is a valuable technique to understand the bridge offset.

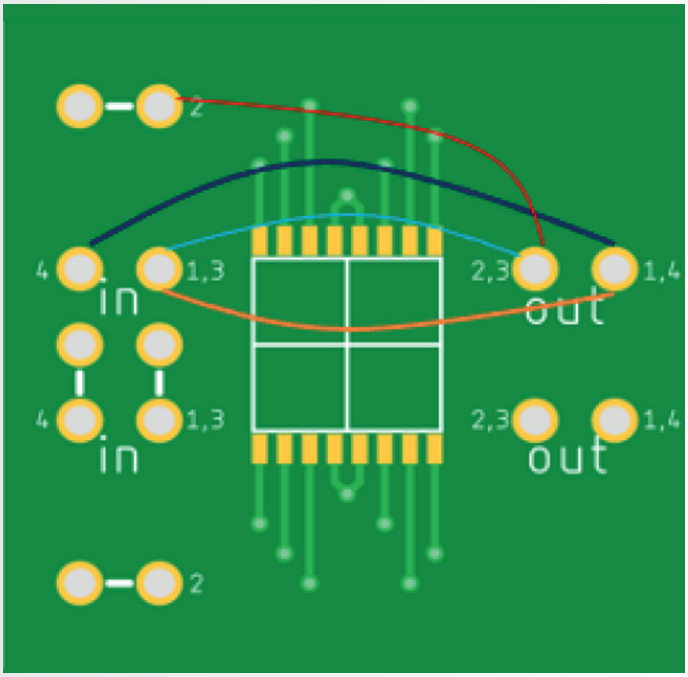
From Figure 2b, the pins of the top half are connected to one bridge and the bottom half to the other bridge. All jumpers must be removed to measure the isolated elements (MTJ resistance). As an example, if the measurement is done between pins:

- 1,3 and 1,4: Resistance 1 is measured;
- 2 and 2,3: Resistance 2 is measured;
- 1,3 and 2,3: Resistance 3 is measured;
- 4 and 1,4: Resistance 4 is measured.

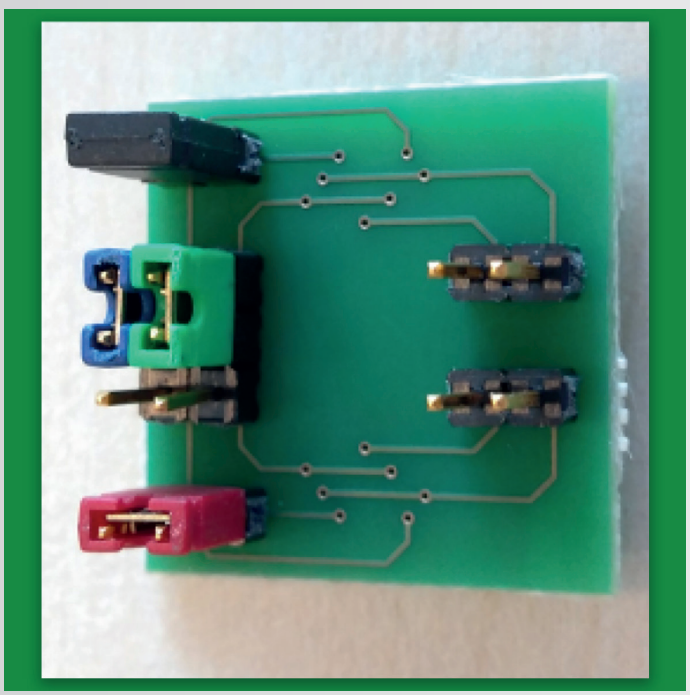
The same approach can be followed to the bottom part of the board to measure isolated element resistance from the other bridge.



(a) PCB footprint with jumper location.



(b) PCB testing connections for one bridge.



(c) Picture of the lower side with jumper inserted.

Figure 2. PCB of the magnetoresistive sensor.

From Figure 2a, when a jumper is placed in the leftmost upper jumper, the top bridge is formed. On the other hand, if a jumper is placed on the leftmost lower jumper, the bottom bridge is formed. To measure the bridges, the horizontal jumpers should be placed on top of the horizontal white stripes. If the vertical jumpers are disconnected, on top of the vertical white stripes, each bridge needs an input signal, and if they are connected, the input signal is shared. Each bridge's output signal is accessed between pins 2,3, and 1,4, where the word "out" is written under them.

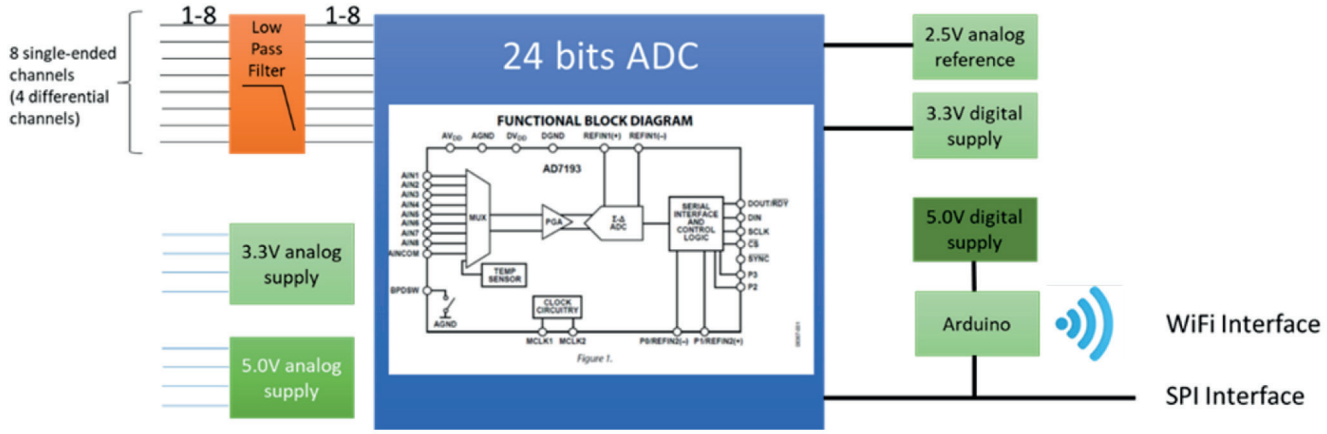


Figure 3. Block diagram of the magnetoresistive sensor circuit.

ACQUISITION CIRCUIT

The block diagram of the acquisition circuit is presented in Figure 3. The output voltage of the sensor bridge was input to an amplifier circuit based on AD8429 (Analog Devices, Inc., Munich, Germany) after a 128 gain amplification. Finally, a 24-bit analogue-to-digital converter AD7193 (Analog Devices, Inc., Munich, Germany) with a sampling rate of 4.847 kHz is used for data acquisition and further analysis. The final implementation in a PCB is prepared to work as an Arduino shield, responsible for data communication with a computer or other microcontrollers (Raspberry Pi or similar) via WiFi, SPI or USB interfaces.

The physical implementation of the circuit in a PCB board is depicted in Figure 4.

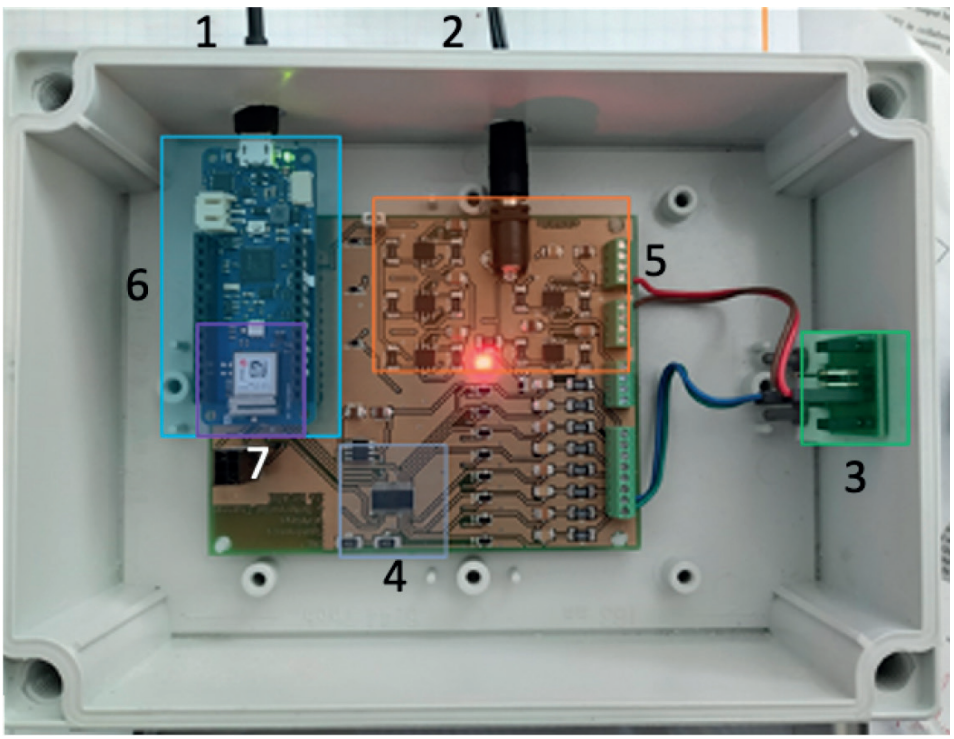


Figure 4. The physical implementation of the magnetoresistive sensor circuit.

Each section of the board is enumerated and described as follows:

1. Communication cable for programming the microprocessor and retrieving measurement data;
2. Power cable or batteries (between 7 V and 15 V);
3. MTJ sensor that measures the magnetic field;
4. Analog to digital converter with 24-bit resolution;
5. Power supply for the MTJ sensor, ADC and microcontroller (Arduino);
6. Microcontroller Arduino for collecting data, computing and web server;
7. WiFi and Bluetooth communication SoC to send data wirelessly.

EXPERIMENTAL SETUP

The experimental setup is composed of an induction motor with variable speed via a frequency converter. The motor shaft is directly coupled (rigid coupling) to an adjustable load. Different faults can be emulated, such as misalignments and eccentricities on the motor shaft faults in roller bearings. By manually adjusting the relative position of the load with the motor shaft axis, unbalance and different misalignments can be emulated: angular misalignment, parallel misalignment, or a combination of both. Table1 presents the

ROTOR BODY DEFECTS	MAXIMUM VALUE
Unbalance	0.06 kg M
Parallel misalignment 3 mm	
Angular misalignment	2.5°

Table1. Maximum defects allowable with the experimental setup.

maximum allowable defects with the experimental setup.

MOTOR DRIVE: A frequency converter from GUNT Hamburg.
TACHOMETER: An inductive sensor from FESTO, and associated display electronics, to measure the rotation speed of the motor (rpm).
ELECTRIC MOTOR: A motor from Industrie Elektronik (typ. LGHA 63) whose characteristics are:
Power input: P = 0.2 kW;
Motor speed: n_1 = 3000 rpm;
Voltages: U_a/U_f = 160/200 V;
Currents: I_a/I_f = 1.6/0.22 A;
S_f 1.0;
IP 44.

where U_a refers to the terminal armature voltage, U_f is the field excitation voltage, I_a is the terminal armature current, I_f is the field excitation current, S_f is the Service Factor, and I_P is the Ingress Protection index.

ACCELEROMETER SETUP

Besides the generic equipment described in the previous section, the specific equipment that is used in this experiment are:
Piezoelectric accelerometer: Itisaone-axis accelerometer—DYTRAN model 3134D, Madrid, Spain—which operates with a sensitivity of 500 mV/g.
ICP® signal conditioner: It is the model 482A21 Line Powered Signal Conditioner from PCB Piezotronics (Madrid, Spain). This unit provides constant current excitation to the built-in transducer amplifier and decouples the DC bias voltage signal.
ADC: It is a NI DAQ 6008 device from National Instruments (Lisbon, Portugal) for connection to a USB port. Its function is to digitise and serialise incoming analogue signals so that the computer can interpret them.
PC: Computer running LabView software to process, store and visualise data.

The accelerometer was installed on three different ball-bearing structure to measure vertical, horizontal and axial vibrations, as shown in Figure 5. The accelerometer was fixed using bee wax to ensure a good energy transfer and minimise spurious effects and damping.

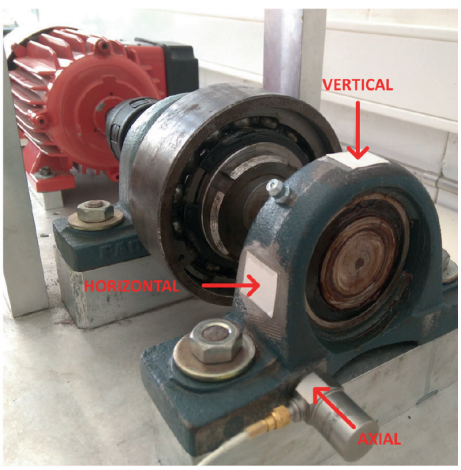


Figure 5. Motor load with 3 locations for fixing the accelerometer for vertical, horizontal and axial measurements.

Once all the previous connection is complete, a LabVIEW application was programmed to acquire data from NI DAQ 6008, as shown in Figure 6. For that case, the acquired signal must be configured as an analogue input (voltage). Since the accelerometer has a sensitivity of 500 mV/g and the NI DAQ device provides a voltage signal that needs to be converted in acceleration, we used the following conversion:

$$V_{input} \cdot \frac{1g}{0.5\,\mathrm{V}} \cdot \frac{9.8\,\mathrm{m/s^2}}{1g} = Acceleration(\mathrm{m/s^2})$$

Afterwards, the acceleration output is integrated to give a proportional velocity signal and filtered by a lowpass filter with a cutoff frequency of 5000 Hz, half of the NI DAQ 6008 device's sampling frequency. From the resulting FFT, the RMS velocity value is stored in a text file for subsequent analysis. Due to the sensitivity of the accelerometer, and according to Equation (1), the scale factor applied to the acquired signal must be 2 × 9.8 = 19.6.

Before conducting any measurements, the accelerometer was calibrated using a handheld shaker from PCB Piezotronics, Madrid, Spain—model 394C06 [17]. The shaker consists of an electromagnetic exciter driven by an oscillator at a frequency of 159.2 Hz. A small accelerometer provides servo feedback to maintain a constant vibration level of 1 g. This enables accelerometers with masses up to 210 g to be excited without influencing the reference level. The accelerometer in use weights 48 g, well below the limit imposed by the manufacturer. The accelerometer was screwed to the shaker's head, as shown in Figure 7a, and the resulting signal acquired. The resulting spectrum in Figure 7b shows a predominant spectral line with a peak at frequency 158.96 Hz, a 0.15% deviation compared to the shaker reference frequency (159.2 Hz).

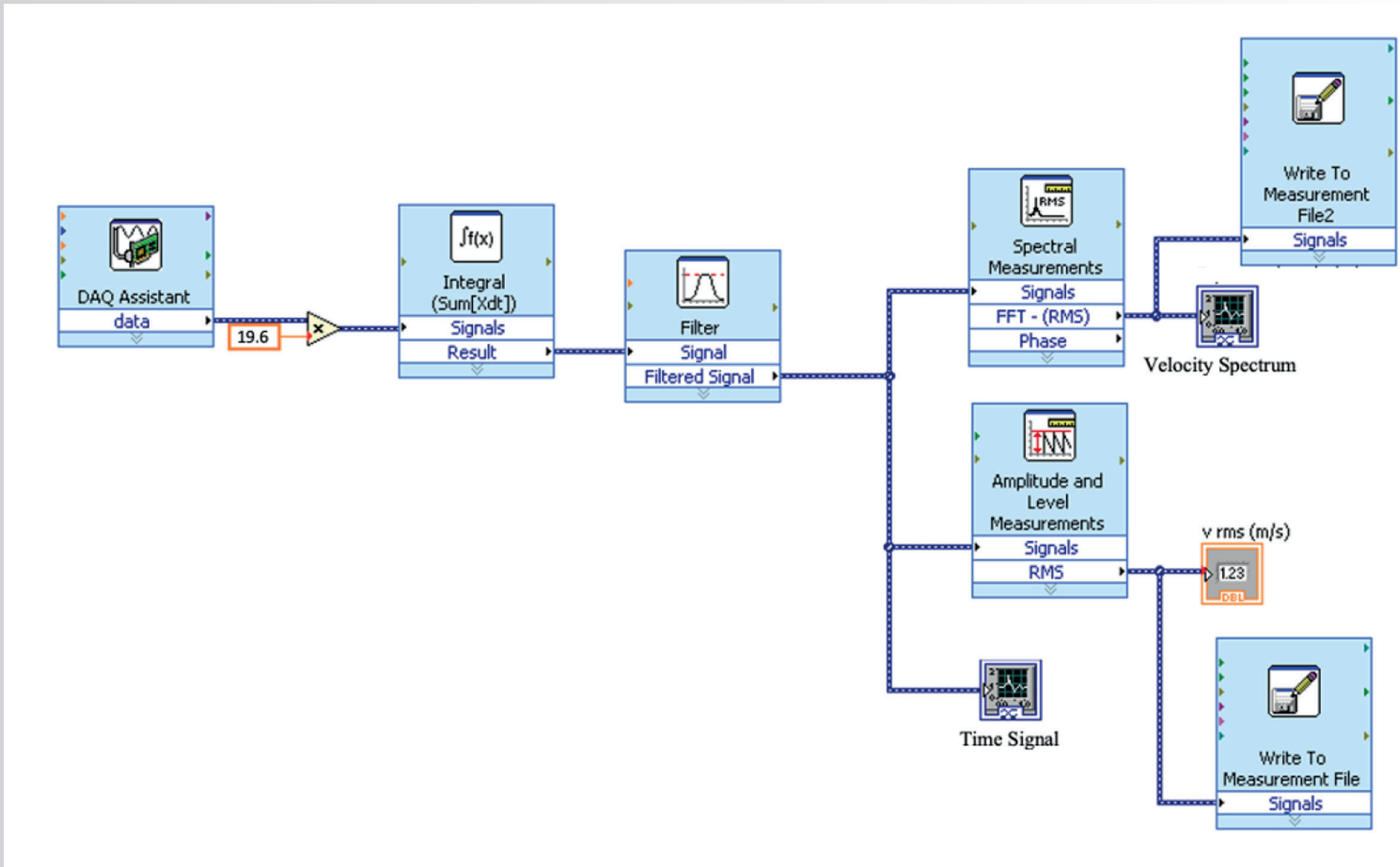
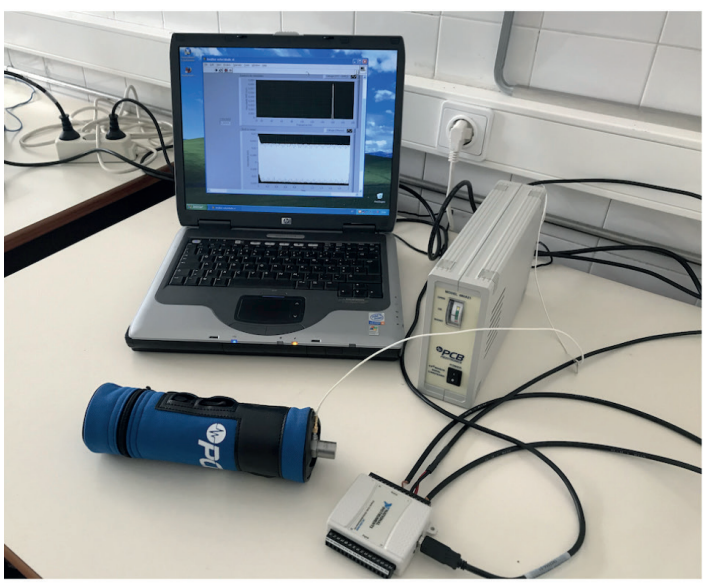
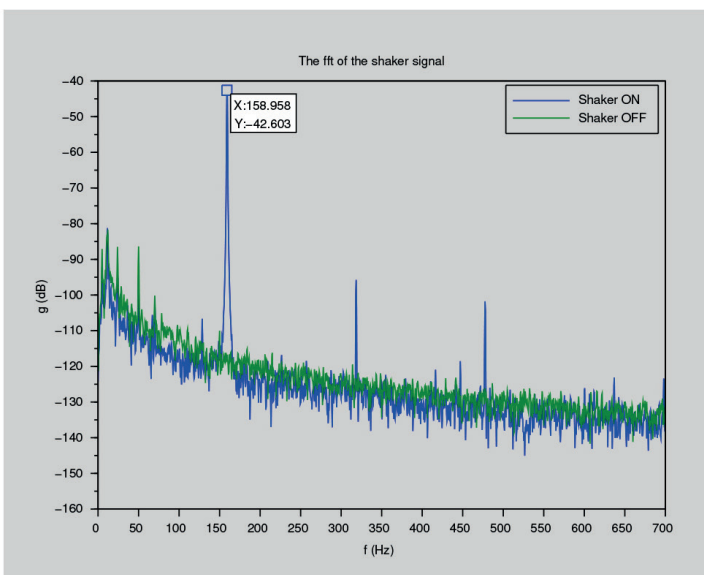


Figure 6. Extract of the software program, developed in LabView, for acquisition, processing, visualisation, and signal storage.



(a) Calibration setup.



(b) Spectrum measurements

Figure 7. Accelerometer calibration setup and spectral results.

MAGNETORESISTIVE SENSOR SETUP

For each measurement with the magnetoresistive sensor, a magnet was fixed to the motor load structure represented in Figure 5 in the exact locations that the accelerometer was fixed. The magnet works like an amplifier or transducer and locally generates a magnetic field correlated with vibrations in the motor's mechanical structure. The variations in the magnetic field are captured by the magnetoresistive sensor, electronically processed and spectrally analysed. Besides mechanical vibrations caused by mechanically induced unbalance or misalignments, other spectral components caused by the electromagnetic field generated from the motor's stator circuit can also be captured [18]. The magnetoresistive sensor was placed close to the magnet at approximately 30 cm for vibration measurements in horizontal (Figure 8a), vertical (Figure 8b) and axial (Figure 8c) axes. During each measurement, the signal was acquired and sent to a computer for storage and analysis. Besides the motor and variable current drive, the specific equipment that was used in this experiment are:

Magnetoresistive sensor circuit: Sensor and conditioning circuit with USB output (Figure 4).

PC: Computer running a serial port acquisition software (CoolTerm [19]) to capture and store raw data from the USB port.

VIBRATION MEASUREMENTS

Vibration measurements were acquired in axial, horizontal and vertical directions and three rotational speeds: 750, 1500 and 2250 rpm, as described in Table 2.

For all measurements, the motor load was adjusted with an unbalance of 0.007 kg m, a parallel misalignment of 0.8 mm and an angular misalignment equal to 0.23°. For each measurement campaign, the information gained from the vibration signals is stored in a computer and converted into a frequency domain by processing an FFT. The parameters for collecting vibration signals are given in Table 3.

	DIRECTION	VELOCITY (RPM)
Measurement 1	Axial	750
Measurement 2	Axial	1500
Measurement 3	Axial	2250
Measurement 4	Horizontal	750
Measurement 5	Horizontal	1500
Measurement 6	Horizontal	2250
Measurement 7	Vertical	750
Measurement 8	Vertical	1500
Measurement 9	Vertical	2250

Table 2. Measurements campaign.

	ACCELEROMETER	MAGNETORESISTIVE SENSOR
Number of averages	5	10
Sampling Frequency (kHz)	10	4,847
Window Type	Hanning	
Overalp (%)	75	

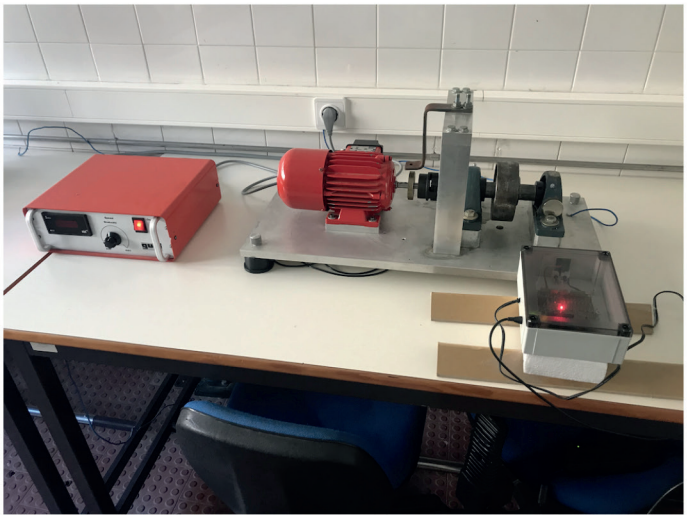
Table 3. Parameters for vibration measurement.

We have applied a windowing function (Hanning window) and time overlap to the time samples to avoid losing information due to attenuation at the window edges when processing the FFT. Both sensors use individual setups to acquire signals and convert them to a digital format, with different sampling frequencies. The signal generated from the accelerometer was downsampled to the same sampling frequency as the magnetoresistive sensor signal to accommodate cross-correlation calculations between signals in Section 4.

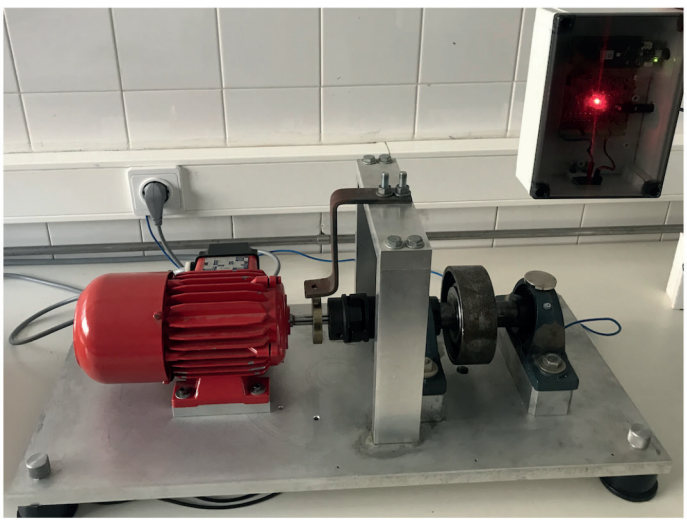
RESULTS AND DISCUSSION

Spectral analysis was applied to the vibration velocity of the motor load, using two sensors consecutively. The measurements followed the specifications from Table 2. For example, the spectrum measurements on the vertical axis are presented in Figure 9 for a frequency range between 10 Hz and 180 Hz. This range was selected due to high spectral lines density related to the low-frequency signatures, usually found in motor vibrations. The vibration velocity u of the signal's spectrum was also normalised (|u/max(u)|) to simplify visual inspection.

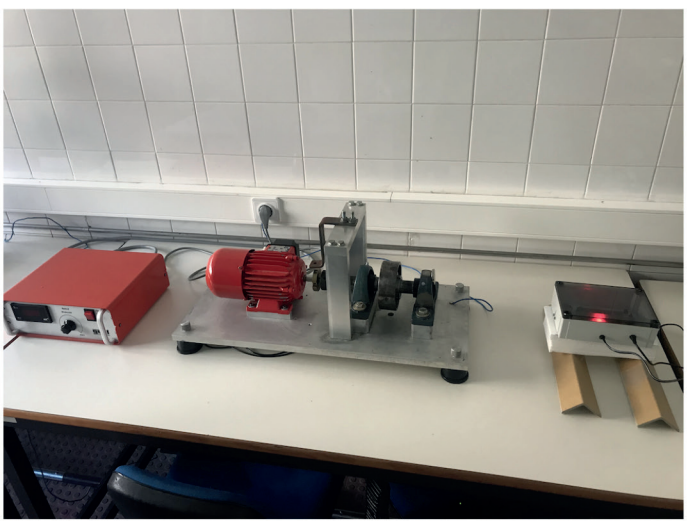
The measured signal is firmly structured with many low-range spectral components (consistent with what is expected for the mechanical movements of the various components



(a) Setup for the vibration measurements on the horizontal axis.



(b) Setup for the vibration measurements on the vertical axis.



(c) Setup for the vibration measurements on the axial axis.

Figure 8. Experimental setup with the magnetoresistive sensor measurement on three axes.

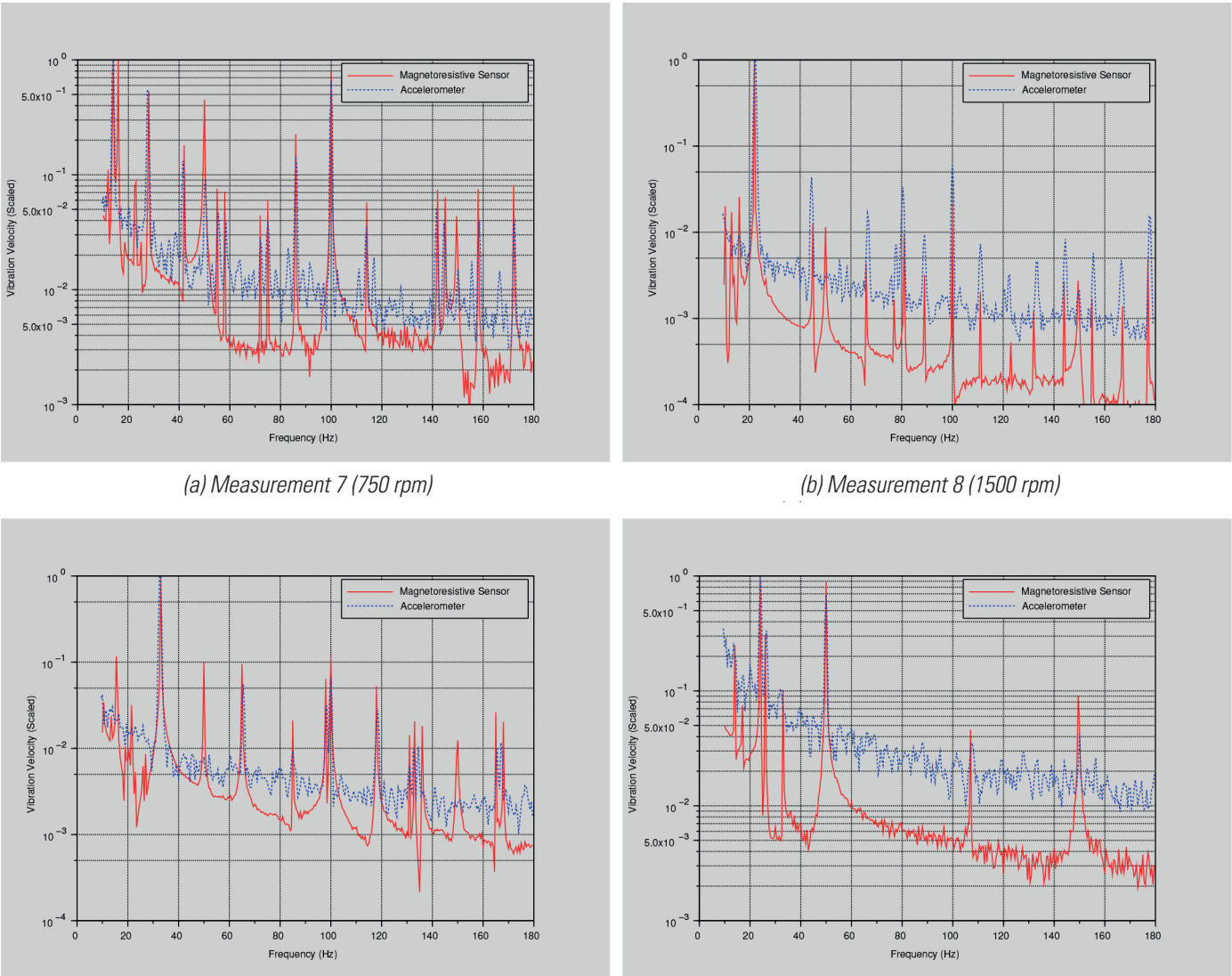
of the motor). The appearance of main components at 12.5 Hz, 25 Hz and 37.5 Hz can be noticed, for both sensors, at Figure 9a–c for 750 rpm, 1500 rpm and 2250 rpm, respectively, which is consistent with the rotation velocity of the motor ($v_{rps} = v_{rpm}/60$). Other spectral components, multiple of the rotational frequency, are also noticeable, particularly in Figure 9a. The same results are also present from the other two axes' measured signal (horizontal and axial).

As with the accelerometer, the signal captured by the magnetoresistive sensor is firmly structured at multiple spectral lines, containing information related to the mechanical movement of multiple moving parts, mechanically coupled to the structure and the magnet. Besides the spectral lines related to the movement and vibrations of mechanical parts, the results show that the magnetoresistive sensor is also susceptible to spectral components at the supply frequency, 50 Hz. This is visible in Figure 9a. Therefore, the magnetoresistive sensor can detect vibration movements and magnetic field variations. This corroborated the same sensor results when it was tested with industrial equipment on the shop floor to detect vibration signals [20]. It can be seen in the spectrum from Figure 9 that there are signal peaks at the frequency of 100 Hz. Therefore, in a spectrum analysis in electric motors, it is known that there are always signal peaks at the frequency of 100 Hz, resulting mainly from the magnetic interaction between the rotor and the stator. Regardless of the number of motor pole pairs, this phenomenon occurs. It is inherent in all induction motors. However, this work's focus is related to the comparison of measurements between two types of sensors. The presence of a magnet may affect magnetoresistive sensor measurements. Still, the sensor responds correctly to the vibration measurements, and this point gives us support to continue with additional experiments with magnetoresistive sensors for vibration measurements.

Considering the accelerometer as a reference, we select a metric that can measure the magnetoresistive sensor's performance. The Pearson product-moment correlation coefficient c_{xy} is computed as a measure of similarity between spectral signatures from both sensors,

$$c_{xy} = \frac{\sum_{i=0}^{N-1} x_i y_i}{\sqrt{\sum_{i=0}^{N-1} x_i^2 \sum_{i=0}^{N-1} y_i^2}}$$

where N is the number of spectral samples, x_i and y_i are the vibration amplitudes of the spectral components from



(a) Measurement 7 (750 rpm)

(b) Measurement 8 (1500 rpm)

(c) Measurement 9 (2 250 rpm)

(d) Measurement with motor holted (0 rpm).

Figure 9. Spectral analysis of velocity vibrations on the vertical axis at (a) 750, (b) 1500, (c) 2250 rpm and (d) motor halted. Full line: magnetoresistive sensor; dashed line: accelerometer.

the magnetoresistive sensor and the accelerometer, respectively. Figure 10 shows the results, where 0 means no correlation and a value close to 1 means a strong association between results. Considering 0.5 as the threshold for both signals is correlated, most of the measurement has passed the correlation test. The presence of noise, combined with the magnetoresistive sensor's high sensitivity to particular spectral components, can justify the fact that no measurement attained a cross-correlation close to 1.

Considering the results for each axes, the rotational speed does not seem to have a direct influence on the correlation results.

The excellent correlation results from the vertical axis, with values between 69% and 73%, may be explained by the type of support used to fix the magnetoresistive sensor, independent of the experiment table where the engine is located and unaffected by the vibrations caused from the motor rotation. The setup table's vibrations may have negatively influenced the measurements on the horizontal and axial axes since the magnetoresistive sensor was installed on the same setup table as the motor, as shown in Figure 8a,c.

Another vital aspect that influenced the results is noise. From the experimental results, we propose two options to mitigate the influence of noise in magnetoresistive sensor measurements and increase the cross-correlation values: one related

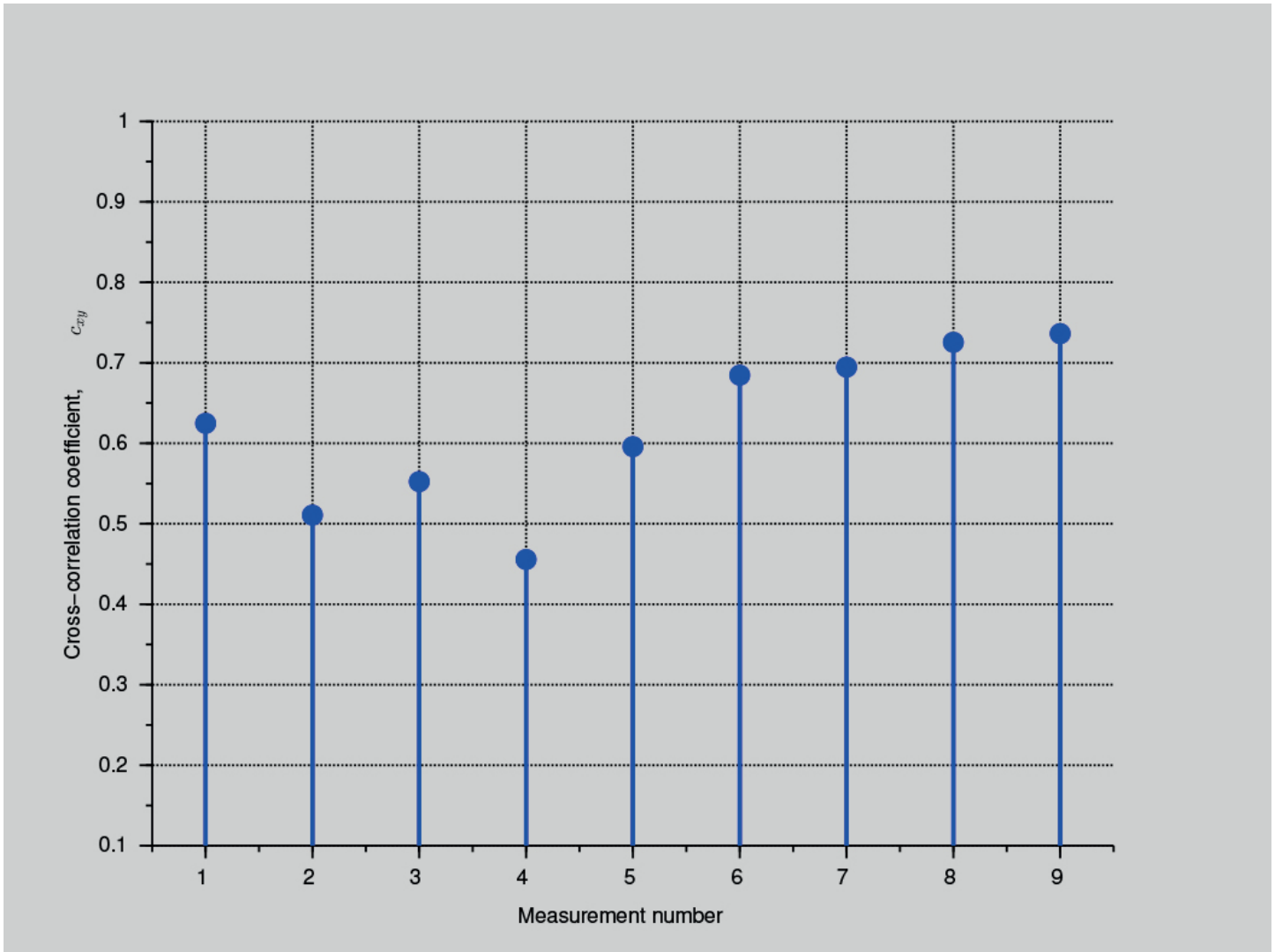


Figure 10. Cross-correlation from all measurements: 1–3 axial, 4–6 horizontal and 7–9 vertical axes.

to external influences and another to the magnetoresistive sensor device's internal parameters.

One approach is to mitigate external interferences, using electromagnetic shielding of the sensor outside the direction for which the measurement is made, and taking measurements as far as possible from sources of intense electromagnetic radiation, usually found in factory shop floors, such as high voltage cables or high power luminaires.

Another approach is to adjust specific parameters from the electronic circuit that captures the magnetoresistive sensor's signal. It can be adjusted and fined tuned to capture the spectral components and discard lower power spectral components generated from the motor vibrations. However, this option could discard helpful information regarding specific spectral components with relatively low power. Filtering the signal conveniently, removing the outer components from the spectral window under analysis (software or hardware) is, in our opinion, the preferred option. According to the standard ISO 20816-1: 2016 [21], most of the valuable information is spectrally ranged between 2 Hz and 1 kHz, such as spectral components caused by misalignment and unbalance.

COMPARISON WITH OTHER MEASUREMENT TECHNIQUES

Other techniques to measure vibrations in induction motors are currently available or subject to research. They can be classified as contact or non-contact vibration measurements and use different types of sensors.

Optical sensor with Fiber Bragg gratings (FBG) [22] are immune to electromagnetic noise but require a bulky setup and permanent contact with the motor. The

microelectromechanical system (MEMS) accelerometer, proposed in [23], can be reliably employed to detect simple to complex bearing faults but is sensitive to temperature and operates over a limited temperature range.

Other sensors are used for non-contact vibration measurement, such as the magnetoresistive sensor. Microwave sensors [24] are very accurate but require complex software, Phase-Locked Loop (PLL), to recover information from the reflected signal. Eddy current sensors [25] effectively detect static shaft displacements, unbalance response and misalignment, but are limited to measure vibrations from metallic objects at a very close distance.

Hall effect sensors [26] suffer from the non-linear characteristic curve, and the high sensibility to environmental impacts results in limited usability. Compared to other techniques, magnetoresistive sensors' key benefit is that they can be bulk manufactured on silicon wafers and mounted in commercial-integrated circuit packages. This allows magnetic sensors to be auto-assembled with other circuit and system components in a small footprint.

CONCLUSIONS

Accelerometers are widespread in the industry, but due to their high sensitivity and high level of integration, magnetoresistive sensors can be a natural alternative for measuring vibrations in industrial equipment, particularly in cases when a contactless approach is a requirement. However, care must be taken to improve the measurements' quality with magnetoresistive sensors by installing the sensor on a damped surface to prevent local vibrations that may adversely affect the measurement process.

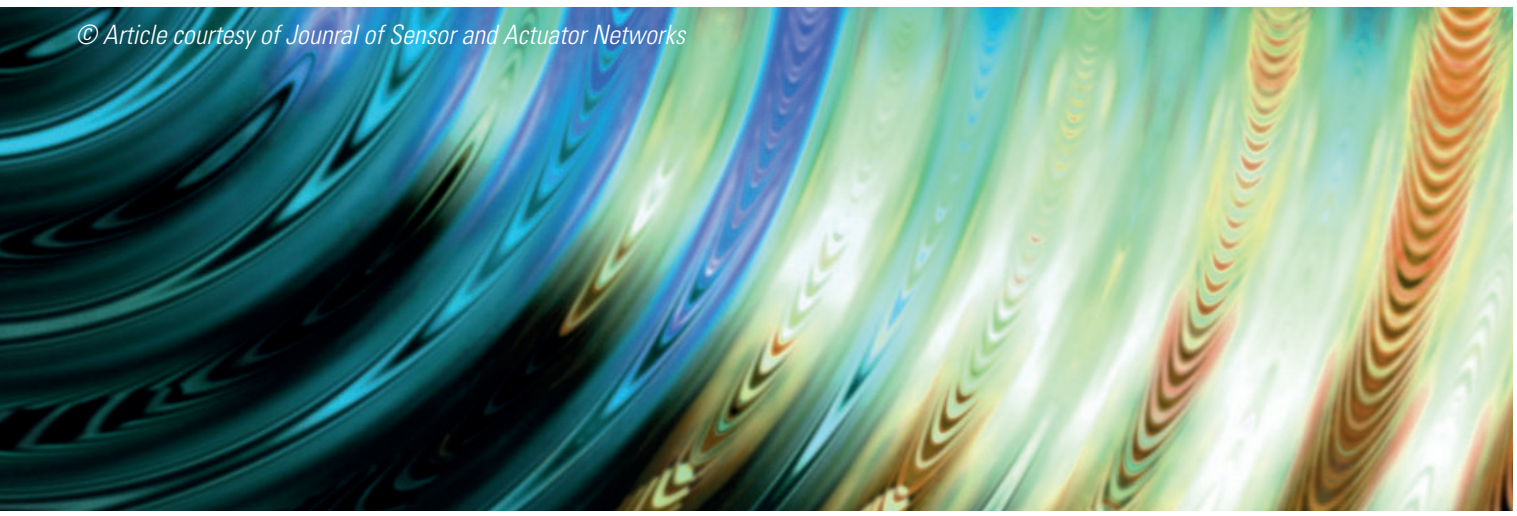
Due to the high sensitivity of the magnetoresistive sensors, noise can be acquired over a wide range of frequencies, so it is essential that the acquisition systems overcome this disadvantage and, through well-designed filters, select the desired spectrum range. Thus, the use of magnetoresistive sensors to detect vibrations in the presence of strong external disturbing magnetic fields is only advisable if appropriate care is taken in the treatment and analysis of the results.

This work demonstrates a specific combination of the various failures that the experimental setup can emulate. It may be possible to obtain a good match between the spectral signatures measured from the input of different types of sensors (accelerometers and magnetoresistive sensors).

Depending on the application, one can choose the type of sensor for the most appropriate solution. Additional measurements are necessary to compare both sensor performances when defective operations, caused by a single defect, are emulated. Future work will include a detailed specification of each defective operation's experimental setup (unbalance, parallel and angular misalignments).

This work was developed for vibration analysis in induction motors but can be easily tested on other machines presented on the factory shop floor. The potential of this type of innovative approach to data collection for predictive maintenance models in systems will be implemented and tested, as future work, to monitor the vibrations of refurbished industrial label loom machines as one milestone of the process to convert old but still operational, industrial machines into Cyber-Physical Systems in the scope of the Industry 4.0 paradigm. wn

REFERENCES



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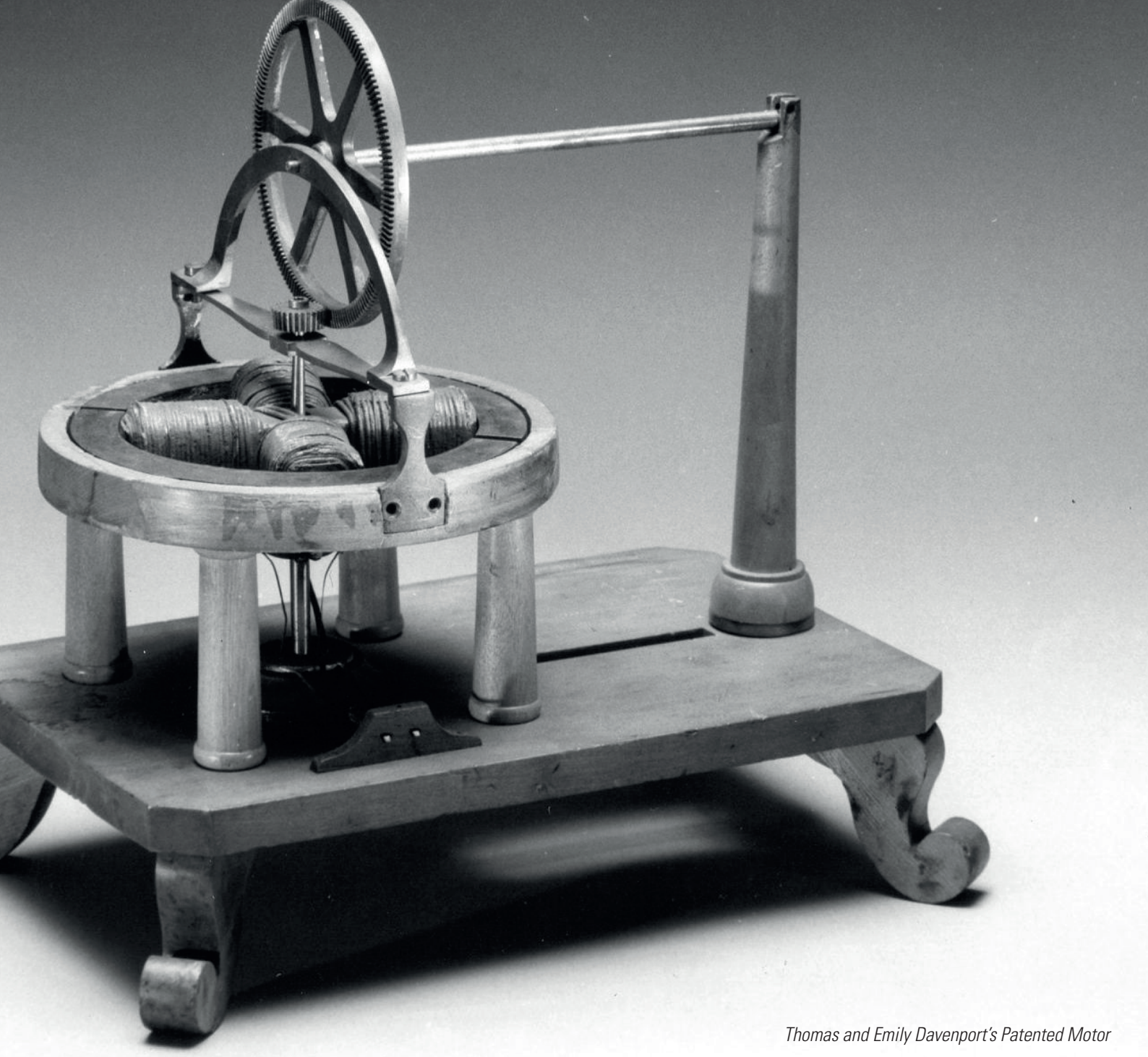
The History of Electric Motors

Few electrical engineers know when the initial concept for electric motors started, about 280 years ago. There was very brilliant scientist extremely interested in electricity.
Early incarnations of the electric motor first appeared in the 1740s through the Scottish Benedictine monk and scientist Andrew Gordon. His invention enabled him to get the rotation, regrettably at that stage, it could not produce helpful work but motion.

BY HENRY DU PREEZ | FSAIEE
SAIEE ROTATING MACHINE SECTION COMMITTEE MEMBER

Since the birth of technology, the pace of innovation has continued to accelerate. New inventions and technologies make our lives easier, but what's fascinating is that technology often leads to innovative ideas and discoveries, making it easier to design and build even newer technology. This ever-accelerating cycle of innovation continues to reshape and redesign the world we live in.

The story of electric motor technology has been no exemption, following this innovation trend for the past 200 years. Looking back at the invention of the first electric motor in 1832, it is hard to imagine the impact electric motors have already made on our lives and other technologies, and even harder to imagine the next 200 years of innovation. By retelling the electric motor's history, we will witness the accelerating cycle of innovation in live-



Thomas and Emily Davenport's Patented Motor

action and better understand what is in store for the future.

Based on his work, Michael Faraday and Joseph Henry continued to develop early electric motors experimenting with electromagnetic fields and discovering how to convert electrical energy into mechanical energy.

Hans Christian Ørsted experimented with electricity in 1820, when he observed that a compass deflected when he held an electrified rod next to it. He had just discovered electromagnetism, and although undoubtedly, he had no grasp of his discovery's impact, he just set the ball in motion for the innovation of electric motor technology.

Hans Christian Ørsted announced the flow of electric current through a wire produced a magnetic field around the wire. Andre-Marie Ampere followed on to show that that the magnetic force was a circular one, producing in effect a cylinder of magnetism around the wire.

In 1821 Faraday took this further and, with a simple apparatus, proved that it could transform electrical energy into mechanical energy - the first electric motor.

The motor features a stiff wire that hangs down into a glass vessel with a bar magnet secured at the bottom. The glass vessel would then be part filled with mercury. Faraday connected his apparatus to a battery, which sent electricity through the wire, creating a magnetic field around it. This field interacted with the field around the magnet and caused the wire to rotate clockwise.

Faraday's apparatus.
(Can be view in the Faraday Museum).

The electric motor was first developed in the 1830s, 30 years after the first battery. Interestingly the motor was developed before the first dynamo or generator.

In 1834 The first electric motor was made.

Thomas Davenport of Vermont invented the first official battery-powered electric motor. This was the first electric motor that could produce enough power to perform a task, and this motor was used to power a small printing press.

HISTORY AND INVENTORS

1834 - Thomas Davenport of Vermont developed the first 'real' electric motor ('real' meaning powerful enough to do a task). However, Joseph Henry and Michael Faraday created early motion devices using electromagnetic fields. The early "motors" created spinning disks or levers that rocked back and forth. These devices could not do any work for humankind but were essential for leading the way to better motors in the future.

The first Davenport motor.

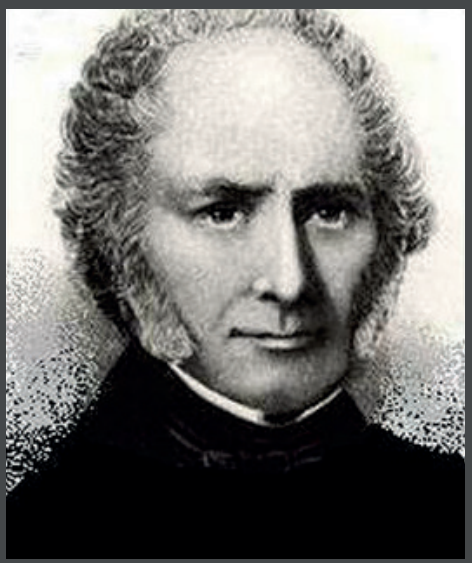
Davenport's various motors were able to run a model trolley on a circular track and other tasks. The trolley later turned out to be the first significant electric power application (it was not the light bulb). Rudimentary full-sized electric trolleys were finally built 30 years after Davenport's death in the 1850s.

A few years later, in the United States, Thomas Davenport and his wife Emily Davenport were granted the first DC electric motor patent in 1837. Their design was a partial adaptation from Sturgeon's first motor. Unfortunately, despite years of experimentation, Davenport's motor design was still plagued by Sturgeon's original design's same power and efficiency issues.

THE ELECTRIC MOTOR'S WORLD IMPACT BEFORE LIGHT BULBS

Trolleys and the connected power systems were very expensive to build but transported millions of people to work in the 1880s. Until the power grid's growth in the 1890s, most people (middle and low classes), even in cities, did not have the electric light in the home.

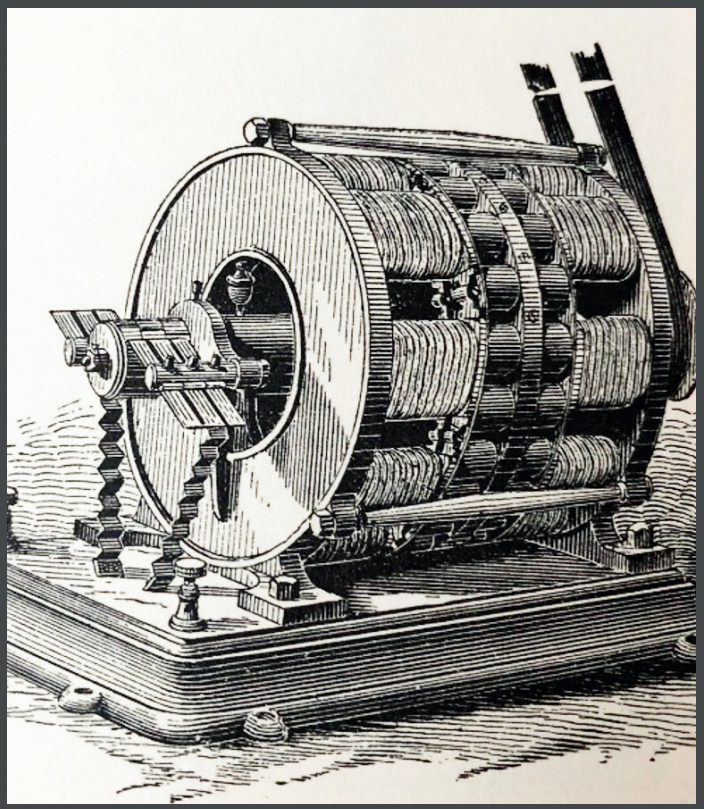
It was not until 1873 that the electric motor finally achieved commercial success. Since the 1830s, thousands of pioneering engineers have improved motors and created many variations.



1886 – William Sturgeon

THE INVENTION OF THE DC MOTOR

William Sturgeon invented the first DC motor that could provide enough power to drive machinery. Still, it was not until 1886 that the first practical DC motor that could run at a constant speed under variable weight was produced.
Frank Julian Sprague was its inventor, and it was this motor that provided the catalyst for the broader adoption of electric motors in industrial applications.



James F. Wood and his spark-free dynamo.

In the late 1880s – Motors are used for commercial use.

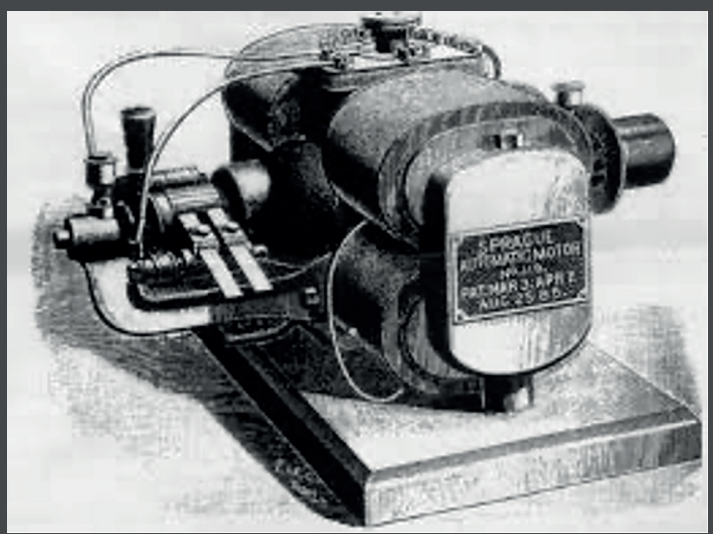
Despite Davenport's great discovery many years previously, electric motors were not widely used commercially for another 50 years.

Scientists and engineers continued developing various types of electric motors to make them suitable for use in commercial settings. Before long, electric motors began being used throughout industry, in factories and the home.

THE FIRST PRACTICAL DC MOTOR

Following the early demonstrations of electric motor capability, electric motor technology's interest exploded, inspiring hundreds of new inventions and discoveries. Still, the first generation of electric motors was glorified paperweights. They were impractical, having voltage loss across windings, an unstable supply current, and common sparking. For the next 50 years, engineers and physicists worked to solve these problems by optimising and redesigning the electric motor's fundamental components.

Several improvements were made to the rotor and armature design between 1835-1886 to develop the first 'practical' motor, with notable contributions made by the Italian physicist Antonio Pacinotti and Belgian electrical engineer Zénobe Gramme. However, only American inventor Frank Julian Sprague is credited with inventing the first 'practical' motor in 1886.



Frank Julian Sprague's 'Practical' Motor

Sprague's electric motor eliminated sparking, voltage loss across windings. It could deliver power at a constant speed - making it the first 'practical' DC electric motor, enabling the broader application of electric motors. Sprague's motor designs were practically reliable and robust, but these designs' efficiencies left much to be desired. Sprague would use his motors to develop the first electric trolley system the following year in Richmond, Virginia, in 1887.

THE FIRST GENERATORS AND ELECTRIFICATION

Zénobe Gramme developed his Gramme machine in 1871. His machine could convert mechanical energy into a continuous current of electrical energy. While presenting his invention at the 1873 World's Fair in Vienna, Gramme accidentally discovered the reversibility of electric motors when he connected two DC devices 2 km from each other, functioning as the motor and the other the generator.

The discovery of DC electric motor reversibility proved that electric motors could be used as generators, converting mechanical work into electrical energy and returning unused energy to the source, which helped develop early power grids.

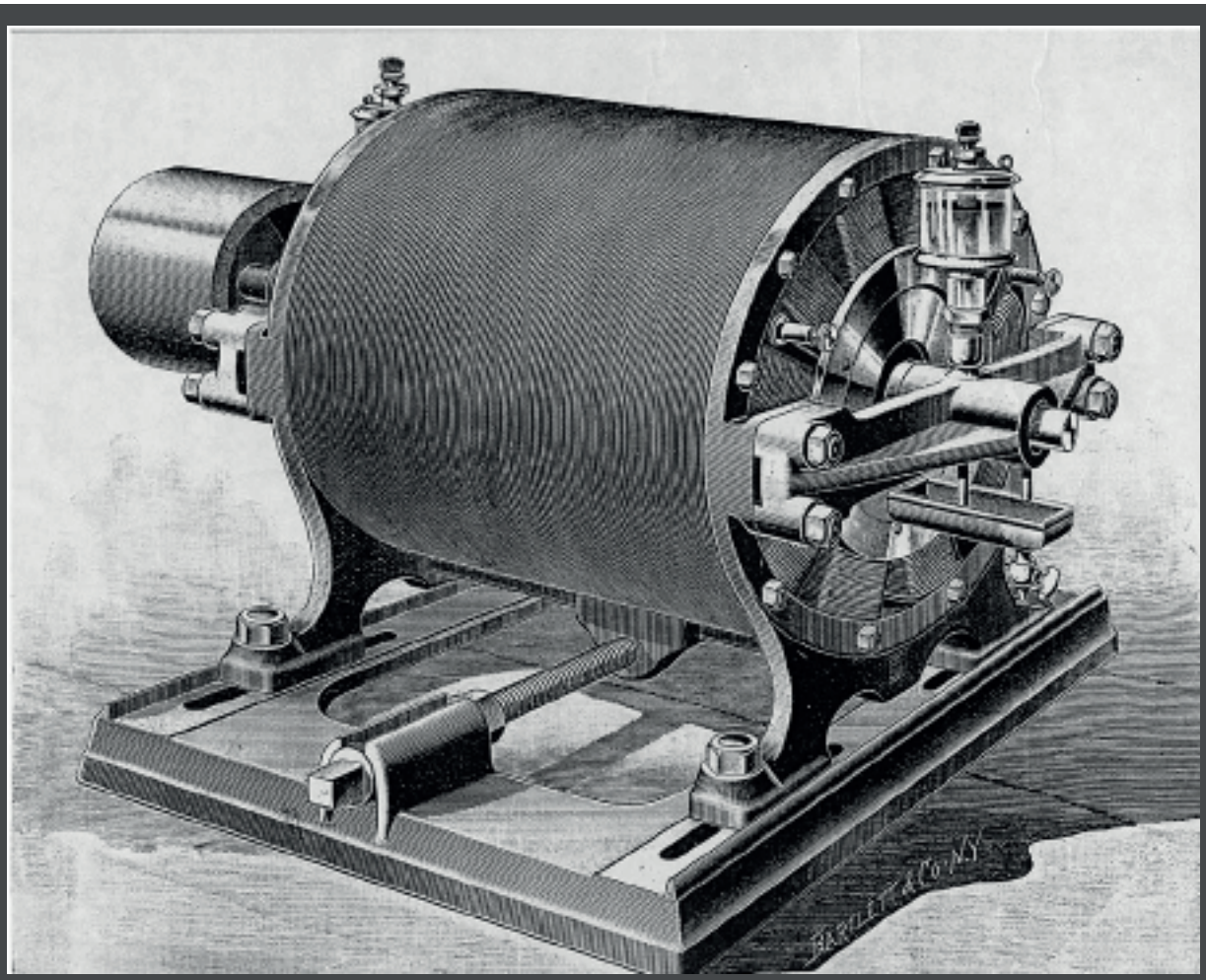
In 1887, Nikola Tesla invented an AC induction motor that he successfully patented a year later. It was not suitable for road vehicles, but Westinghouse engineers later adapted it. In 1892 the first practical induction motor was designed, followed by a rotating bar winding rotor.

1891 – The development of three-phase motors. General Electric started developing three-phase induction motors. To utilise the bar-winding rotor design, GE and Westinghouse signed a cross-licensing agreement in 1896.

USE OF MOTORS TODAY

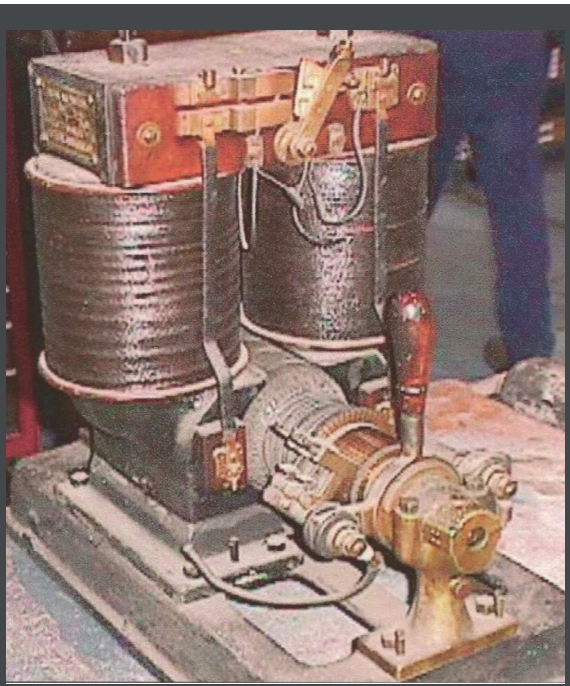
In the 21st century, AC and DC electric motors are now widely used in industries worldwide. They are an integral part of many applications motors have led the field in designing and manufacturing effective drive solutions for a wide range of challenging applications. The world would undoubtedly be a vastly different place without the electric motor! wn

DC Motor - Progress in the design of electric motor development.



1888 – The AC induction motor is patented.

Generator built in 1893 and was in service until 1935



DC machine and the brush gear position had to be advanced or retarded by hand to suit the load conditions.

The progress in electric motors has been very rapid.

A 5 HP induction motor manufacture in 1910 weighed around 150 kg, whereas the equivalent motor today would weigh around 40 kgs.

Halbach Magnets and Reluctance Motors

Halbach magnetised PM brushless machines are novel in that their magnetisation is self-shielding. They offer many attractive features, such as sinusoidal airgap field distribution and back-emf waveform, negligible cogging torque, potentially high airgap flux density and no need of rotor back-iron. Hence, they have recently attracted many research and development interests and extensive exploitation for their applications.

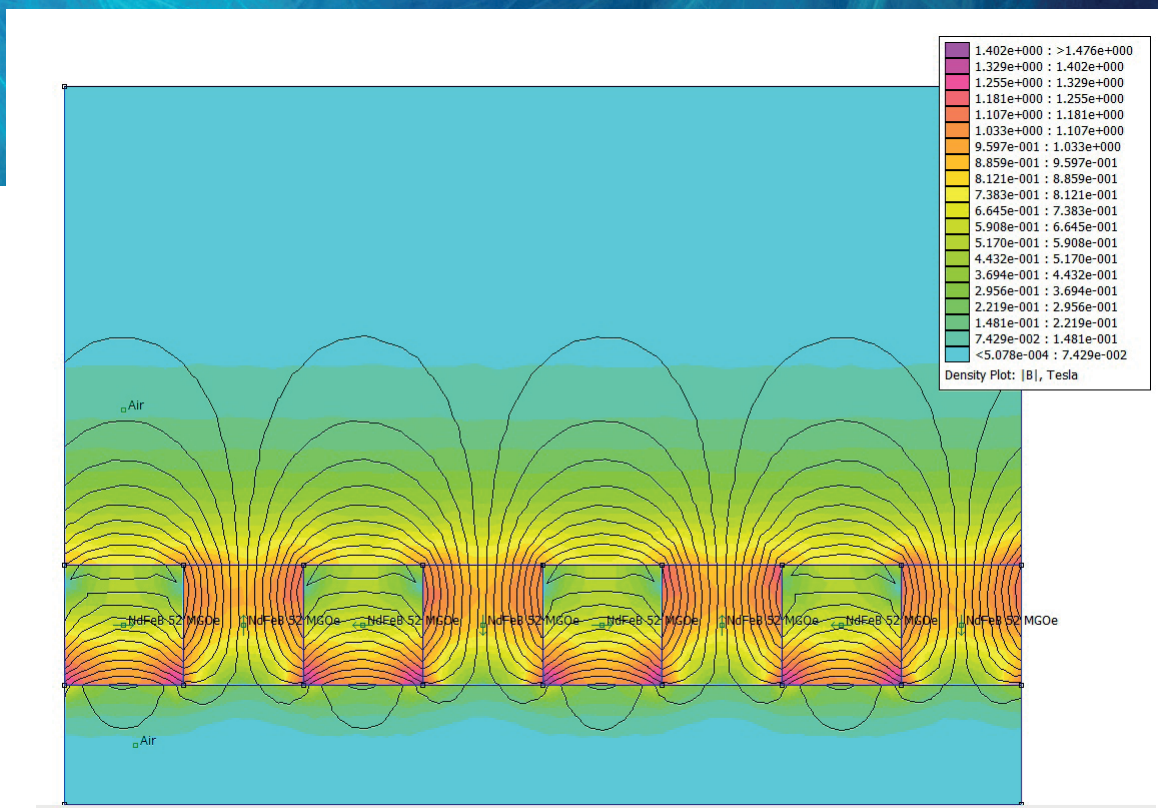
BY DUDLEY BASSON

HALBACH MAGNET ARRAYS

A Halbach Magnet is a special arrangement of permanent magnets, which are arranged in a rotating pattern of magnetisation orientation, to achieve an augmented magnetic field on the one side and a greatly reduced magnetic field on the other. This principle was first invented by J Winey in 1970 and by J Mallinson in 1973 in which he saw the potential for improvements in magnetic tape technology. During the 1980s, Klaus Halbach, while at the Lawrence Berkeley National Laboratory, independently invented the Halbach array to focus particle accelerator beams.

In addition to linear, or planar, configurations, Halbach arrays can also be configured in circular, or cylindrical arrangements, with the magnetic field concentrated at either the outer diameter or the inner diameter. An electric motor can be constructed using a cylindrical Halbach array, with the magnetic field directed inside the cylinder and a rotor with windings inserted into the field. The Halbach array can either be stationary, with the windings rotating, or the Halbach array can serve as the rotating element, with the windings stationary. In the latter configuration – sometimes referred to as an "inside out" design, the stator windings would be electrically commutated, and the motor could be operated as a brushless DC (BLDC motor) or as a brushless AC (BLAC) motor (also referred to as a permanent magnet synchronous motor or PMSM). Click here to see how to build a 3D printed Halbach brushless DC motor.

In this little beauty the fixed 'rotor' is slotted with windings to produce a rotating magnetic field and the rotating 'stator' is fitted with Halbach array magnets and have no back-iron. This motor is powered by 3-phased pulsed DC power which can be provided by the power electronics of a variable



Halbach Array

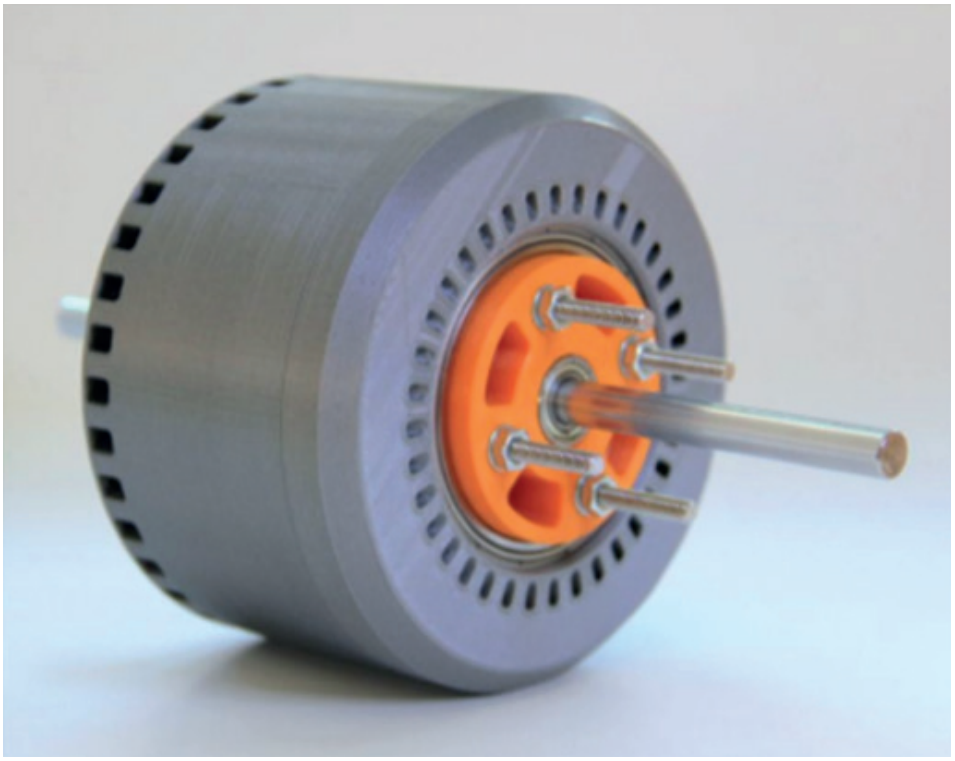
speed drive. The pulsed DC power should preferably be sinusoidal to avoid unwanted harmonics. We have here a situation where the distinction between 3-phase AC power and 3-phase pulsed DC power becomes blurred.

The effect of rotating the magnet orientations in a Halbach array to create a strong field on one side and a virtually zero field on the other is sometimes referred to as "one-sided flux."

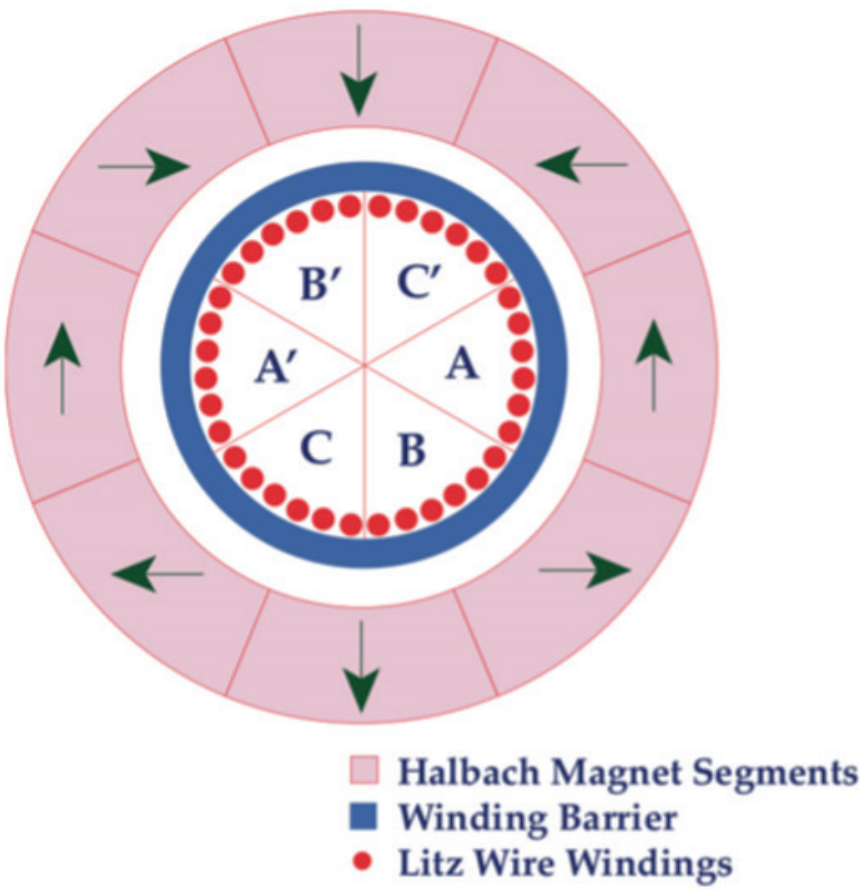
Permanent Magnet Synchronous Generators (PMSGs) are increasingly considered for large, direct-drive MW level wind energy conversion systems. High-efficiency, high-power density, low maintenance, and high reliability are some cited benefits of PMSGs making them attractive for onshore and offshore wind systems. However, as the PMSG's power level increases so will its weight and size. This research attempted to reduce the size and weight of PMSGs by using Halbach magnetic arrays instead of conventional magnets.

At present the largest wind turbine in use is the 14 MW Haliade-X offshore turbine. An analytical model of a MW Halbach array PMSG has been developed. This Halbach PMSG was optimized using a five-input particle swarm optimization algorithm. The resultant optimized Halbach PMSG is more compact and lightweight when compared to the conventional PMSGs of similar power ratings. Performance of the optimized design was verified with finite element analysis.

Although not yet mainstream, electric motors based on the Halbach array offer measurable benefits over conventional designs, including high power density and high efficiency. One



600W 3D printed Halbach brushless DC Motor



A Halbach cylinder can be used in an electric motor, as in this example, with the magnetic field concentrated at the inner diameter and the Halbach array rotating around the windings. Image credit: Lawrence Livermore National Laboratory

of the enablers of these benefits is that a Halbach array motor does not require laminations or back iron, so the motor is essentially ironless. This significantly reduces eddy current losses and hysteresis losses – often referred to as "iron losses" or "core losses."

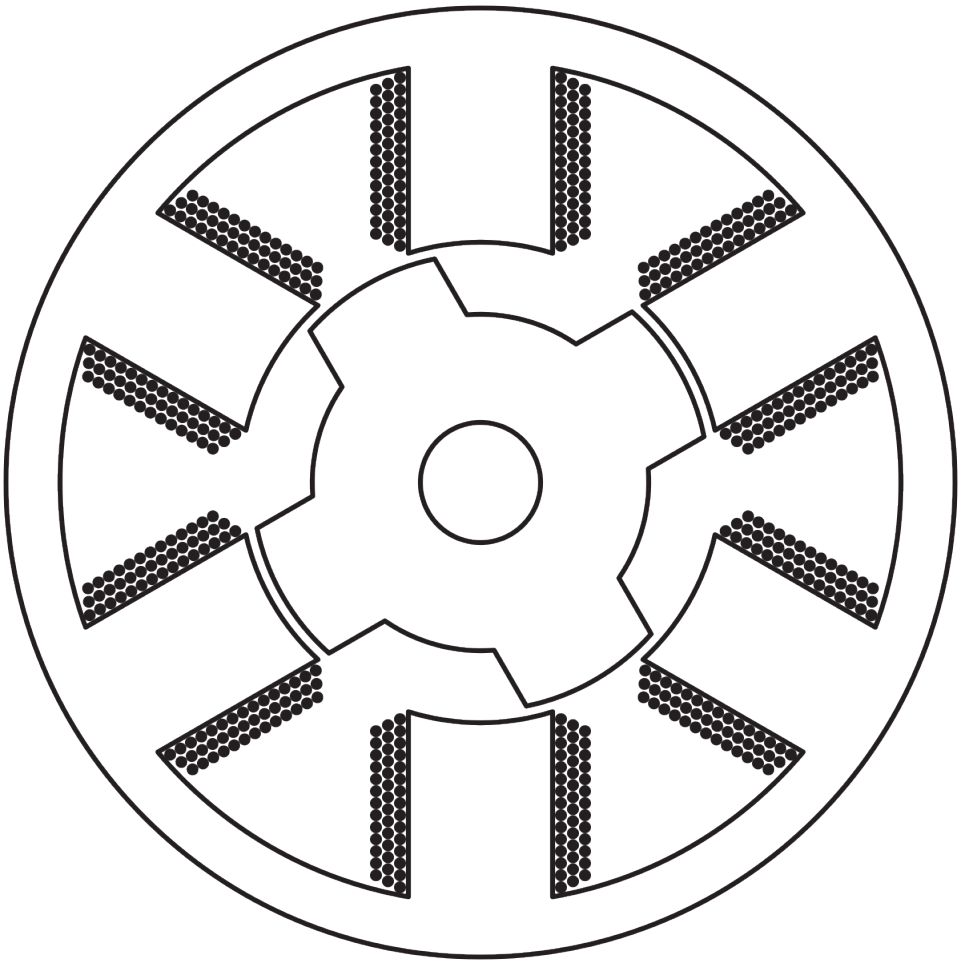
Eddy currents, and therefore eddy current losses, do however remain in the windings, due to the relative motion between the windings and the magnetic field. These can be reduced by using a type of wire, referred to as "Litz wire." The elimination of back iron or laminations also reduces weight and inertia, allowing the motor to start and stop faster and to reach higher top speeds (10,000 rpm or greater) for highly dynamic applications.

(Litz wire consists of individually insulated strands that are braided or woven together in a manner that minimizes losses).

The primary downside to neodymium Halbach array motors is cost – specifically, the cost of manufacturing the Halbach array. Because the magnets are arranged with each one repelling its neighbour, the processes of assembling the magnets and ensuring that the fixing method is adequate, is relatively labour intensive.

Neodymium magnets are the most widely used type of rare earth magnets. It is a permanent magnet made from an alloy of neodymium, iron, and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure.

Neodymium magnets have a remanence of up to 1,4 T and a high coercivity. A field strength of up to 2 T can be achieved using a Halbach cylindrical array. Developed independently in 1984 by General Motors and Sumitomo Special Metals,



Cross-section of switched reluctance machine with 6 stator and 4 rotor poles. Notice the concentrated windings on the stator poles.

neodymium magnets are the strongest type of permanent magnet available commercially. Because of different manufacturing processes, they are divided into two subcategories, namely sintered NdFeB magnets and bonded NdFeB magnets. They have replaced other types of magnets in many applications in modern products that require strong permanent magnets, such as electric motors in cordless tools, hard disk drives and magnetic fasteners and now most prominently in vehicle motors.

Ultra high field strength electromagnets are made using supercooled niobium-titanium Litz wire superconductors, most notably in the Large Hadron Collider at CERN. Niobium-titanium magnets have a critical field strength of 14,5 T and a critical temperature of 9,2 K. Research is underway for obtaining even greater field strengths using niobium-tin Nb3 Sn superconductors. Niobium-tin magnets have a critical field strength of 30 T and a critical temperature of 18 K, but the material presents mechanical problems.

RELUCTANCE MOTORS

The term 'reluctance' may seem to suggest unwillingness, but this is hardly applicable to reluctance motors which have developed to rival the performance of the induction motors used on electric vehicles.

A reluctance motor has a stator with

wound salient poles which attract the salient iron poles of the rotor which do not have windings. For a self-starting motor, the rotor will have a different number of poles to those of the stator. Typically, the motor would have six stator poles and four rotor poles. Subtypes include: synchronous, variable, switched and variable stepping. Reluctance motors can deliver high power at low cost, making them attractive for many applications.

Reluctance motors have been known for more than a century, first invented by Nikola Tesla, but their use was limited by the complexity of designing and controlling them. Advances in theory, computer design tools, and low-cost embedded systems for control overcame these obstacles. Microcontrollers use real-time computing control algorithms to tailor drive waveforms according to rotor position and current/voltage feedback. Before the development of large-scale integrated circuits, the control electronics were prohibitively costly.

Interestingly, Tesla Motors have introduced the IPM-SynRM (Internal Permanent Magnet Synchronous Reluctance Motor) for use on the model 3 electric automobiles, to supersede the induction motors (also invented by Nikola Tesla). This has brought considerable efficiency and performance advantages. Toyota have also introduced similar changes.

Tesla's specific innovation is the segmented permanent magnets (four parts instead of the more typical single solid magnet). According to Learn Engineering, it helps to reduce the eddy currents and lowers the risk of magnets overheating. Halbach arrays are not used in vehicle motors. Permanent magnets are embedded in the rotors of vehicle reluctance motors in a configuration that improves performance at high speed.

For details of the new Tesla vehicle motors watch this fascinating video (12 mins.).

Watch this video showing the Toyota Prius electric motors (4 mins.).

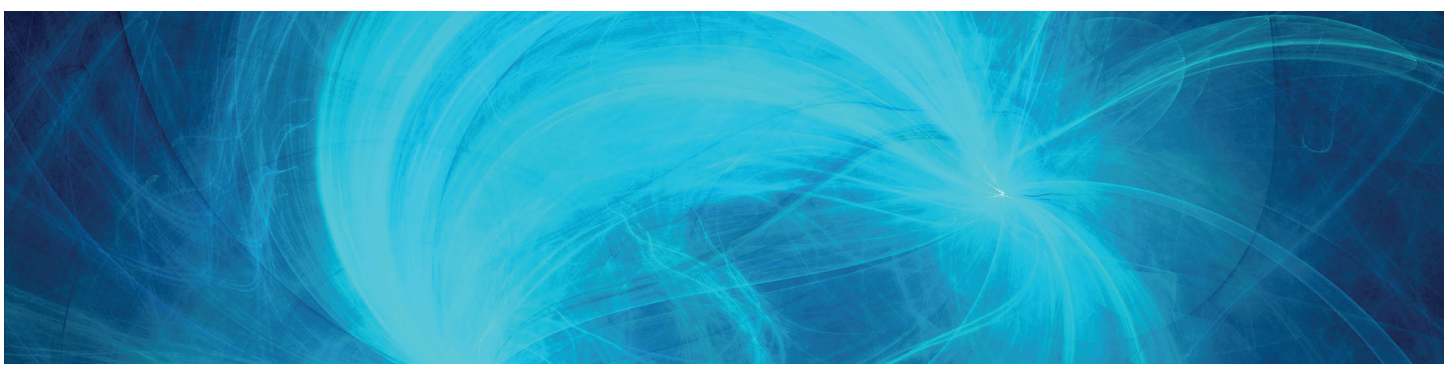
Watch this video for details of the Honda Hybrid E-Drive (25 mins.).

Watch the astonishing automation in the Audi e-tron electric motor production (15 mins.).

When a stator pole of a reluctance motor is equidistant from the two adjacent rotor poles, the rotor pole is said to be in the "fully unaligned position". This is the position of maximum magnetic reluctance for the rotor pole. In the "aligned position", two (or more) rotor poles are fully aligned with two (or more) stator poles, (which means the rotor poles completely face the stator poles), which is a position of minimum reluctance.

When a stator pole is energised, the rotor torque is in the direction that reduces reluctance. Thus, the nearest rotor pole is pulled from the unaligned position into alignment with the stator field (a position of less reluctance). This is the same effect used by a solenoid, or when picking up ferromagnetic metal with a magnet. To sustain rotation, the stator field must rotate in advance of the rotor poles, thus constantly "pulling" the rotor along. Some motor variants run on 3-phase AC power. If the stator and rotor have equal numbers of poles, the motor will run at synchronous speed. Most modern designs are of the switched reluctance type, because electronic commutation gives significant control advantages for motor starting, speed control and smooth operation (low torque ripple). As the rotor of a reluctance motor has no electrical activity or sparking commutator, these are the motors of choice in situations where there is a risk of the presence of combustible or explosive gases. Induction motors are not entirely free of sparking – there is a slight possibility that harmonic currents could cause sparking from an inadequately earthed shaft. Harmonic currents have been known to cause premature bearing failure by pitting the bearing races.

In the SI unit system, reluctance is expressed in inverse henrys H-1. The term 'reluctance' was coined by Heaviside. wn



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DATE	TITLE
01/04	Webinar: The Future of Hydrogen Economy in South Africa I 17h00
06-08/04	Planning Strategic Feasibility Studies
07/04	Webinar: Waste To Energy - An African Perspective I 11am
07-09/04	An Introduction to Artificial Intelligence for Professionals
12-14/04	Project Management for Engineers
13-15/04	Substation Design & Equipment Selection
15-16/04	Earthing & Lightning Protection
15-16/04	Technical Report Writing
19/04	Webinar: SAIEE Lightning Chapter Launch I 17h30 - Day 1
20/04	Webinar: SAIEE Lightning Chapter Launch I 17h30 - Day 2
20/04	Webinar: KZN Centre Breakfast Networking I 09h45
20-21/04	Writing Good Technical Specifications
20-21/04	IoT Standards & Applications
21/04	Webinar: Artificial Intelligence in Engineering I 17h00
21-22/04	Power Distribution
21-23/04	Power System Protection
22/04	Webinar: The impact of lockdowns on load demand in South Africa I 18h00
28-30/04	Fundamentals of Financial Evaluation of Projects
29/04	Run Your Project as A Business
29-30/4	Fibre Optics

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