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AUTOMATION

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

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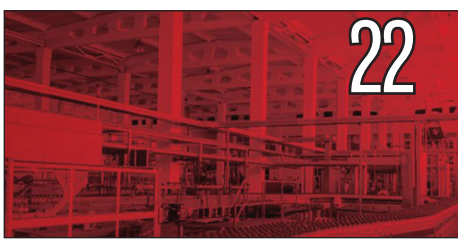

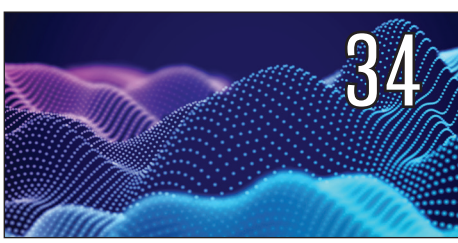

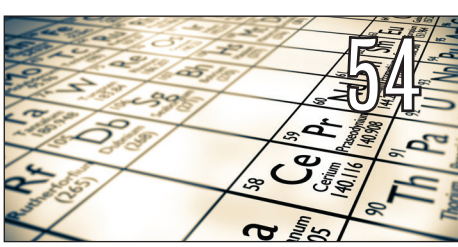

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Dear Valued **watt**now Reader

I bring you the 100th issue of **watt**now under my management, and this issue features Automation.

Our first feature article, "Conditioning monitoring with intelligent drives in Industry 4.0", on page 22, discusses how Industry 4.0 refers to the combination of physical assets and advanced digital technologies that communicate, analyse, and act upon the information. This enables organisations and consumers to be flexible and make more intelligent, responsive data-driven decisions.

Developing sovereign capabilities or ecosystem in Autonomous Vehicles (AV) would unlock SA's defence-related growth potential and create new sustainable pathways for companies and industry. Read this article, "A Potential Autonomous Vehicles Strategy for South Africa", on page 24.

Information Technology and Operations Technology discusses that Information Technology (IT) is defined as hardware, software, and communications technologies that focus on data storage, recovery, transmission, manipulation, and protection. Find it on page 34.

Dudley Basson did not disappoint in writing an article on Rare-Earth Elements. The first rare-earth element identified was discovered in the island village Ytterby, Sweden, by Finnish chemist Johan Gadolin in 1794. This was the single richest source of new element discoveries ever found. Read this article on page 54.

The November issue features Transportation, and the deadline for any articles is 20 October 2021. Please send your submissions to minx@saiee.org.za.

Herewith your October issue, enjoy the read!

Minx

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SAIEE Corporate Partner, Rosatom hosted a Waste To Energy Networking Event

The SAIEE Head Office hosted our 2021 Corporate Partner, Rosatom SA, in a Waste To Energy Cocktail party on the 16th of September. As far as Kenya and Uganda, the guest attended this networking event and rubbed shoulders with decision-makers in the industry.

Rosatom SA CEO Ryan Collyer welcomed all the delegates and explained Rosatom's stance on Waste to Energy. In his presentation, "Social and Environmental Impact of Controlled Waste Management", he explained that Africa is facing an insurmountable waste problem that affects its population and the environment. Sub-Saharan Africa generated 174 million tonnes of municipal solid waste (MSW) in 2016; this is expected to triple to 516 million tonnes by 2050. The growth in waste generation in Africa is expected to be so significant that Africa will overshadow any decrease in waste generation in other regions globally.

He went on to discuss the current energy situation in Africa. "Africa is in line to become the next tiger of the globe. However, it is facing a major power crisis that is holding it back," he said.

Six hundred million people in sub-Saharan Africa do not have access to Electricity. Electricity reaches only about half of its people, while clean cooking only one-third; roughly 600 million people lack Electricity and 890 million cooks with traditional fuels (IEA, 2018). Thirteen countries in SSA have less than 25% access, compared to only one in developing Asia, according to the World Bank in 2018. "This dramatic lack of energy access stifles economic growth and sustainable development," he said.

Collyer went on to discuss how Waste to Energy is a Solution for Africa.

- Incineration can reduce more than 90% of the initial volume of waste and considerably reduce the final mass of waste buried.
- The energy produced from waste could potentially replace power plants that use fossil fuels and cope with the low capacity to generate Electricity.
- A power plant fueled by municipal waste emits between 35% and 60% fewer pollutants than a fossil fuel power plant, after considering the equivalent of methane emissions that would have been released in a landfill.
- Reducing the waste makes finding optimal landfill sites located away from urban areas and water reservoirs easier.
- Implementing waste-to-energy technology could play an essential role in providing the 20 million jobs needed to absorb the flow of youth into the labour market each year.
- It also lowers the investment cost necessary for environmental protection measures, such as installing mineral or plastic coatings to waterproof landfill soils.

Collyer concludes in the actions needed to make this a winning recipe. He stated that we need to establish a waste management policy more suited to waste incineration. We need to develop a more efficient waste management sector, and finally, optimise Waste Collection."

To learn more on Rosatom's Waste to Energy Solutions, click here. wn

From left: Pascal Motsoasele (SAIEE Junior VP), Liya Botha (Marketing Manager, Rosatom SA), Prof Jan de Kock (SAIEE Senior VP), Irina Simonova (Business Development, Rosatom SA), Ryan Collyer (CEO, Rosatom SA) and Thobile Mkhonta (Hitachi Zosen INOVA).

The Alfeco Group School Development Drive refurbishes Dan Primary School

From left: CEO of Alfeco Group Sachin Ahuja, Dan Primary School Principal Helen Mathebula, Dept of Basic Education Circuit Manager Doreen Manzini, Va-Nkuna Royal Council of Dan Village Nkakasana, Amelia Muhlava and Deputy Minister of Police Honorable Mathale.

As the Basic Department of Education has struggled with limited budgets in public schools across the country, many schools in rural South Africa remain subjected to old inferior infrastructure that requires advanced maintenance.

The Alfeco Group in partnership with the office of the Deputy Minister of Police Honourable Cassel Mathale donated refurbishment material and furniture worth over R100 000,00 to Dan Primary School located in Dan Village, on 23 August 2021.

The school has been operating for about 81 years and most of its furniture was broken.

According to Kgotsofalang Mashilo, Corporate Affairs Liaison at the Alfeco Group, refurbishing a school is about providing a better future for learners by giving them a conducive learning environment.

"While the education of young people remains a vital activity to the growth of our country, the environment in which they receive this education should be equally prioritised to allow for better learning outcomes and thus a better future.

The onus is on companies and individuals with the means to extend their socio- economic portfolios to decrease the mounting pressure on the department and collaborate in creating better learning facilities for our young," says Mashilo.

In appreciation of the donation learner representatives of the school, Va-Nkuna Royal Council of Dan Village, Department of Basic Education officials of the district, ward councillors and other community stakeholders attended the event, under strict Covid-19 measures, to witness the official handover to Dan Primary School.

Dan Primary School principal, Helen Mathebula says they appreciate the donation from the Alfeco Group, in partnership with Honourable Mathale. "Such generosity is primary for the benefit of our learners and the community," says Mathebula.

Deputy Minister of Police, Hon. Mathale who is originally from Dan Village added that it is important to contribute towards improving the learning environment for the learners and teachers.

"I appreciate the contribution to improve the condition of our schools. Alfeco Group's progressive outlook and attitude towards people development is commended," concludes Mathale. wn

Collaboration between Booyco & Ramjack optimises Technology value for Mines

As part of bringing its cutting-edge collision prevention system (CPS) or proximity detection system (PDS) technology to the world, South Africa-based Booyco Electronics is now in a strategic collaboration with technology systems integrator Ramjack Technology Solutions.

"Technology is changing the way that key technical services are provided to mines," says Anton Lourens, CEO of Booyco Electronics. "The world is becoming a smaller place, and the value that service providers deliver to mining customers is no longer determined by a corporation's size."

Technological specialisation now demands expertise, skill sets and hardware that extend far beyond what single multinational companies can provide, says Lourens. This invariably leads to silos of expertise developing on mines that require bridging.

Booyco Electronics will therefore be working with Ramjack Technology Solutions to help mines to integrate their CPS and PDS solutions with other technologies effectively, in the interests of greater safety and productivity.

"With South Africa's mine safety legislation being very advanced in terms of requiring Level 9 compliance for collision avoidance, our partnership can offer considerable overall value to mines across the world," he says.

According to Mike Jackson, president and CEO of Ramjack Technology Solutions, Booyco Electronics fills an important space as a best-of-breed technology provider in a critical component of mine safety.

Booyco PDS solutions incorporate leading edge technology.

"Our role as a systems integrator is to help mines get more value from their chosen production and safety technologies," says Jackson. The company does this in two main ways, he says; horizontal integration bridges the gaps between the technology 'silos' on mines, while vertical integration takes the process right from instruments up to platform level.

He highlights that the inter-operability of leading technologies such as Booyco Electronics' collision avoidance systems is the optimal way to achieve the 'mine of future'. This allows mines to take up the best technologies available and ensure that they work together on their on-site platform.

"Technology providers like Booyco and Ramjack have the advantage of learning from the experience of many mines – not just one," he says. "This gives our customers significant added value, as they can benefit from the learnings that have taken place elsewhere, without bearing the cost of developing that experience on their own."

The two companies have already collaborated informally on a significant deep-level gold mining project in South Africa, and are excited by the prospects that this work has opened up. Lourens notes that mines globally are moving toward the Level 9 requirements outlined by the Earth Moving Equipment Safety Round Table (EMERST), even though relatively few have made it compulsory through national legislation. wn

The Booyco PDS or Collision Prevention System (CPS) has leveraged technology to achieve new levels in safety.

Real-world torque measurements enable electric car competition to go virtual

Student engineers are using a newly launched torque sensor for predicting the energy efficiency of a competition-grade electric car. Young technologists from the University of Sheffield alleviated their disappointment at the Covid-cancellation of Shell Eco Challenge Rally by instead developing a computer simulation tool for predicting electric cars' energy efficiency.

The university has a long association with the Shell Eco Challenge, in which student teams from around Europe compete to see whose car electric will cover the greatest distance on a single charge. So, when Covid shut down the event, rather than abandon their efforts Team Sheffield shifted their focus and set about a related project.

"We have been developing our own computer simulation tools for predicting our electric vehicle's (EV's) energy efficiency," says student Lucy Edwards. "This has let us calculate our vehicle's competition score for the 40 minute/15km competition run."
To put the competition into context, Shell Eco EVs achieve upwards of 800 km/kWh, whereas the EVs on the road today may achieve only 15 km/kWh (at the same 25 kph).

The competition EV are of course ultra lightweight, very aerodynamic single seaters and the drivers chosen by weight, whereas their road-going counterparts are better adapted for say a family day out. However, the competition demonstrates the potential of electric propulsion and, over the years, has undoubtedly helped development of the technology.

Sheffield's involvement is extra-curricular but provides a great opportunity for the students to apply what they have learnt in lectures in a practical context.

To build the simulation tool, the students used their knowledge of engineering theory to create a mathematical representation of all the energy losses present in the car. A key piece of data was the motor efficiency curves, which were derives using a dual-purpose powertrain test rig and motor dynamometer. This was developed in-house and based around a

TorqSense SGR521, the latest product from from Sensor Technology Ltd, Banbury based specialists focused on developing torque and load measuring technologies.

In fact, Sensor Technology is a regular supporter of Shell Eco Challengers; over the years it has supported several teams from mainland Europe and now one from the UK. "The student teams basically need to run lots of tests on their drive motors and map out the results," explains Mark Ingham of the company. "As such they are really no different from motor test engineers the world over.

"We are far and away the most active supplier of torque measuring technology and expertise to the Eco Challenge. It is very gratifying to know we give young engineers at the start of their careers a solid grounding in such an important subject, which they will be calling on for decades to come."Like their professional counterparts, the young engineers tend to want to develop a test rig that is accurate and easy to use. Usually, they also have space and time constraints, so want a compact design which is quick and easy to set up for each test.

"Our new SGR510/520 range fulfils all these requirements," says Mark. "It's only been on the market for a couple of months but is already proving itself to be a favourite in EV test labs around the world – and that is a rapidly growing market at the moment."

For the Shell Eco Challenge, teams across Europe have to design and build their own electric cars and motor controllers in-house.

Typically, powertrains are based on either a brushless DC, or PMSM motor - and complex control algorithms are needed for precision control. This requires custom electronics, typically based on MOSFETs and other carefully chosen low power loss components.

In fact, the rules of the Challenge are such that the controller is included in the motor testing that is done on each teams' entry.

In effect, the capabilities of each piece of hardware are quantified so that the teams can see how they compare with each other.

Lucy sums up the team's year: "With the tools and hardware we have developed we have posted competitive competition scores.

Of course, we are all hoping that soon Covid restrictions allow us to meet our competitors face to face and compete car against car. That will be real world engineering at its best." wn

Traction Transformers from Zest WEG for Rail Network

As an established supplier to South Africa's rail sector, Zest WEG will be supplying specialised traction transformers for new substations serving rail lines in Gauteng and the Western Cape.

Testing one of the WEG traction transformers during manufacturing

According to Dillon Govender, sector specialist – public sector business development at Zest WEG, work on the eight transformers ordered is currently underway, for delivery by the end of October 2021.

The company is supplying six 6MVA units that will step down from 88kV to 1220V, and two more 6MVA units stepping down from 44kV to 1220V. All the transformers will feature a dual output, as well as tertiary windings for small power applications like lighting in the area.

"This is part of an important fast track project, and the order follows a number of successful deliveries of these complex transformers by Zest WEG over the years," says Govender. "The units are designed to customer specifications and manufactured in line with global standards."

Through its workshop facilities in Gauteng, Zest WEG has become well known as a 100% local manufacturer of power, distribution and traction transformers for customers within South Africa, and has supplied well beyond the borders.

"We have established considerable local capacity in transformer manufacture, reflected in the growing confidence of customers in our design and production capabilities," he says.

"We are also able to leverage the value of being part of the WEG Group by drawing on the skills of experts from our Brazilian facilities."

This allows Zest WEG to constantly upgrade local skills through training and skill sharing by specialist engineers and technicians, whenever necessary.

This corporate relationship has also allowed the company to broaden its local offerings, at the same time as creating jobs and upskilling local employees.

"Zest WEG's depth of expertise means that we can also conduct design work locally, to meet the specific requirements of customers," he says.

"Our strong local footprint includes offering the necessary service support to customers, ensuring that we can provide the necessary backup for all our equipment." wn

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Unlocking SA youth's potential through Robotics education

When Statistics South Africa (Stats SA) released the 2021 first quarter's Quarterly Labour Force Survey (QLFS), it reconfirmed that the upward trend of youth (age 15 to 24 years) unemployment from the 2008 "low" of 44,8% has continued. A summary of the 2021 Q1 QLFS is depicted in Figure 1.

BY I SHAMENDRAN PILLAY

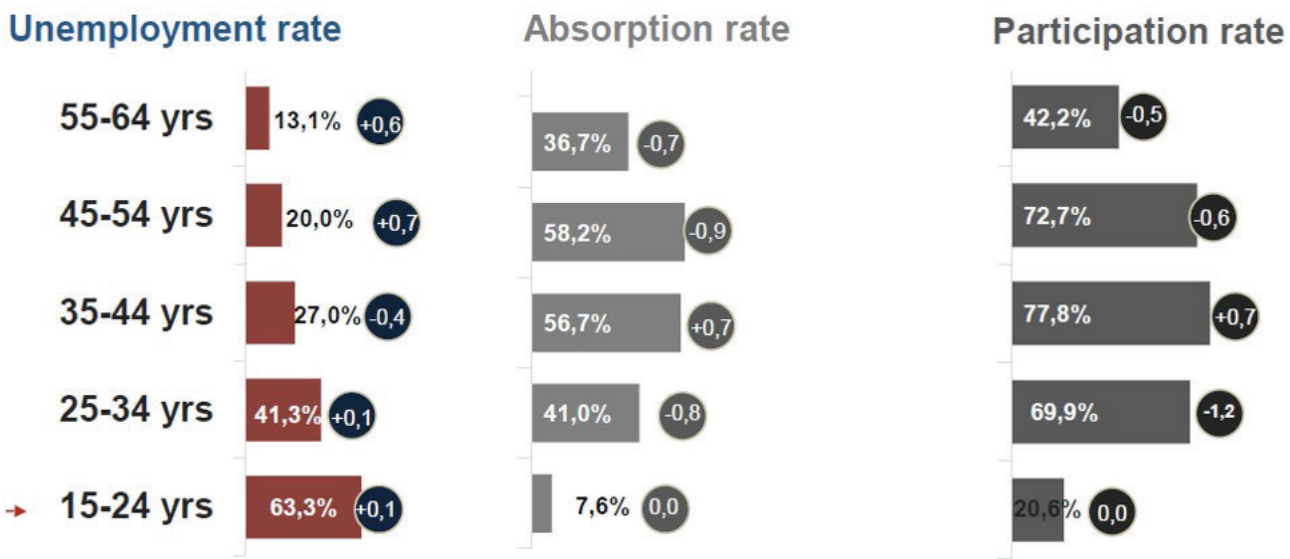


Figure 1 (Source Stats SA)

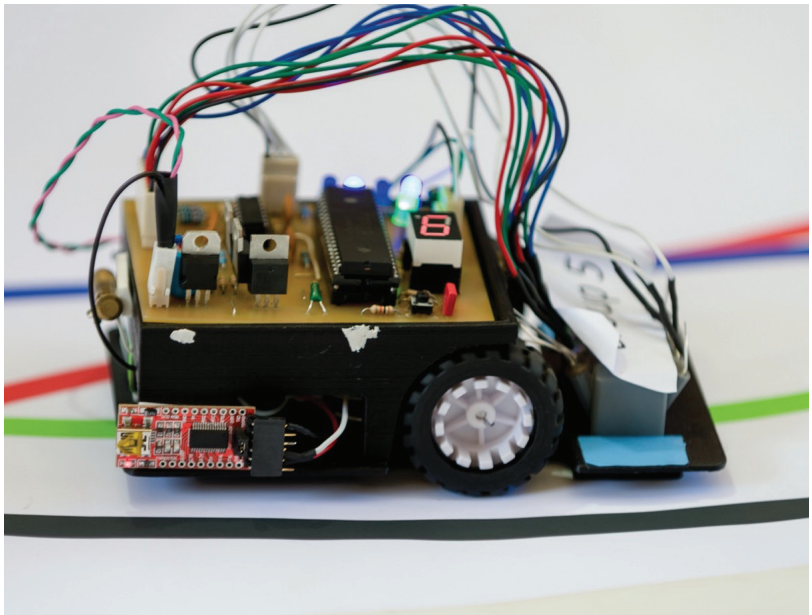
The Covid-19 economic impact impacted this number; however, the fundamental reasons for this trend lies elsewhere.

The recent events in South Africa also highlighted the importance of reversing this trend.

Now that there is a firm focus to move South Africa into the Fourth Industrial Revolution (4IR) to benefit from innovation-based prosperity, it is crucial to equip the youth with the required skills and tools. This will have the added benefit of increasing the rate of participation of the youth in the economy.

Unfortunately, a significant percentage of South African youth lack the basic skills required to access the benefits of 4IR. Urgent intervention is needed to address this lack of skills. The good news is that people and organisations in South Africa have a vision and passion for resolving this inequality.

A Picture from the 2021 UP Robot Race (Pictures taken by EYEscape)



A 2021 UP Robot Race Robot navigating the course (Picture by EYEscape)

One such individual began the Robot Science non-profit organisation. Mr Ettershank has decades of Robotics education experience and has been applying his passion for assisting the youth of South Africa for more than 20 years. Africa's largest privately-owned defence conglomerate currently employs Mr Ettershank to focus on this passion.

The University of Pretoria (UP) also began a Robot School in 2021 to enable their students to serve the community by allowing learners to learn robotics. The Robotics school is available to learners from Grade 7.

UP ROBOT SCHOOL

Such large organisations and SAs top-rated School of Electrical and Electronic engineering (according to 2020/2021 World University QS rankings) have embarked on this journey because there are definitive long-term benefits to this approach.

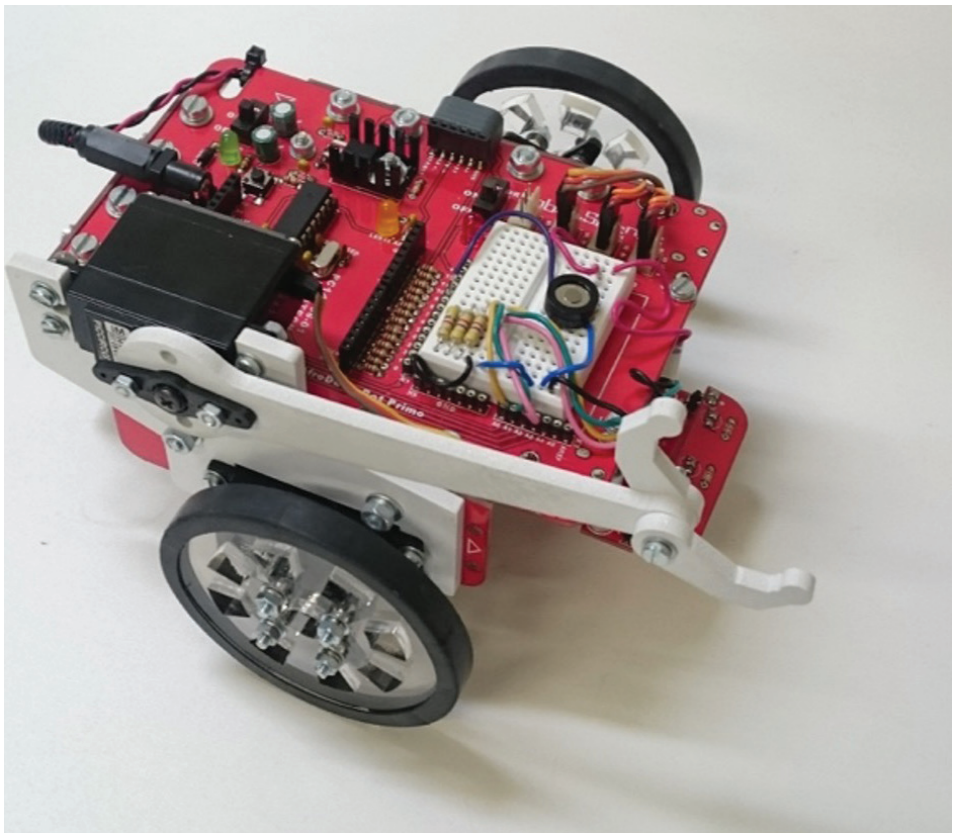
Both the above-listed initiatives focus on the design, production and programming phases of the robotics process. This process enables learners to gain more than just the essential technical robotics skills; it allows them to develop critical thinking, project management, and basic computer literacy in fun STEM-based activities.

The famous annual Third-year Robot Race-inspired the UP Robot School.

"If you make everything too easy, then you are effectively robbing young people of the true value of educational robotics. Our youth need to be emotionally and intellectually engaged in tasks that will build their sense of accomplishment; the only way to do that is by tackling difficult tasks." (Source: M. Ettershank)

"Learners experience the pleasure mixed with amazement when they download a program to a robot they've built, and it obeys their instructions. "I'm sure there's a big rush of endorphins because they've had to work for their gratification," says Ettershank. "Maybe one day I will read some scientific studies about whether overcoming challenges releases more endorphins than simply

THE SAIEE AFRIKA BOT competition



The current educational robot used by Ettershank

succeeding without even understanding why."

Funding from the South African Institute of Electrical Engineers [SAIEE] was used to buy parts, so underprivileged youth from Diepsloot, Alexander High School and inner-city areas like Hillbrow could build their robots and participate in 2016.

THE SAIEE AFRIKA BOT COMPETITION

The arrival of the Coronavirus in March 2020 posed an enormous challenge in terms of public gatherings, which has delayed the roll-out of these programmes. Still, Ettershank is optimistic that when the pandemic has passed, there will be a place for a new robotics competition for SA youth.

Ettershank currently offers regular free online robotics training sessions on Wednesday afternoons from 16h00-16h40 and Saturday mornings from 10h00-10h40 for youth who want to take advantage of a well-developed robotics program.

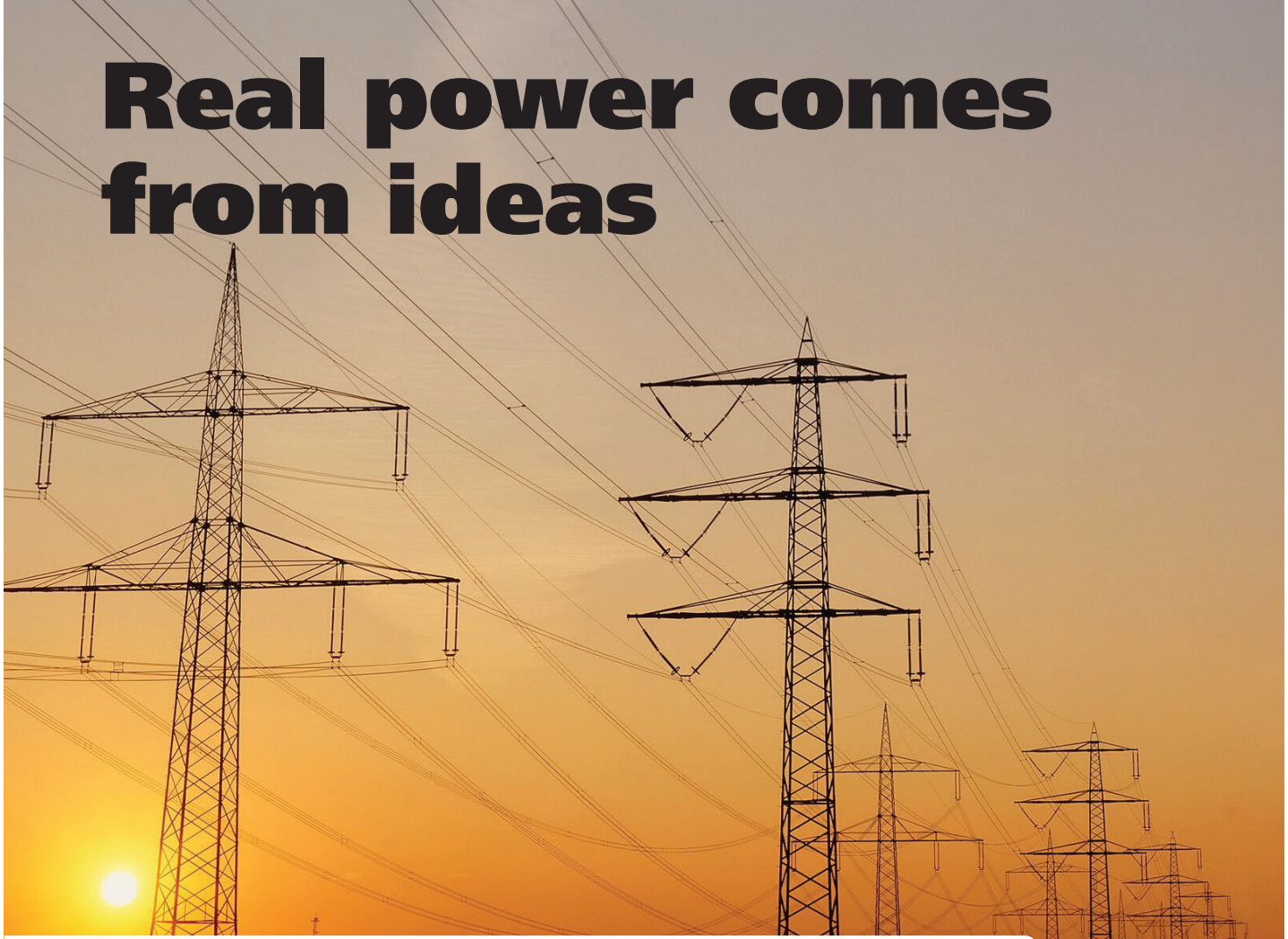
"I have thought long and hard about how to create a sustainable programme that doesn't exclude youth from underprivileged communities," says Ettershank, "so I am currently working on a proposal that will enable students to make and sell equipment to raise funds to participate."

Ettershank believes that he has been able to make a positive difference. "At the end of last year, despite the COVID-19 pandemic, a student who built one of my robots six years ago as a teenager graduated as an electrical engineer with ten distinctions," says Ettershank. "He was raised by a single mom who would not have been able to afford the robot kit that was paid for by the SAIEE.

When he graduated with flying colours, he was granted an interview with one of our subsidiaries where he's currently employed on artificial intelligence [AI] software projects."

With initiatives like these described in this article, it seems that there is a positive future for SA's youth and SA's participation in the 4IR. One can only hope that more corporates and individuals alike take up the gauntlet to either replicate or assist these initiatives so that these positive initiatives can gain a wider reach and unlock some of the potentials of SA's Youth. wn

Real power comes from ideas



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The Group is committed to all aspects of Sustainability and has put strategic targets in place to ensure sustainability goals are achieved. These sustainability targets include, amongst others the reduction in greenhouse gas emissions of 20% by 2030 and reduction in energy intensity of 7.5% by 2030. The Group is also committed to innovation and digital transformation with big data advanced analytics and predictive modelling to optimise business and production processes even further.

A project, recently implemented that moves the Group closer to achieving these two sustainability targets, is the deployment of Autonomous Guided Vehicles (AGVs). The AGV's are electric driven driverless vehicles.

There are six levels of automation indicating the degree to which the driveless vehicle is independent of the driver.

At level 0, the car has no control over its operation and the human driver does all of the driving.

At level 1, the vehicle's ADAS (advanced driver assistance system) has the ability to support the driver with either steering or accelerating and braking.

At level 2, the ADAS can oversee steering and accelerating and braking in some conditions, however the human driver is required to pay attention at all times to the driving surroundings and also perform all other driving tasks.

At level 3, the ADS (advanced driving system) perform all functions in some conditions, but the human driver must take over control when requested to do so by the ADS. In the other conditions, the human driver is required to perform the driving tasks.

At level 4, the vehicle's ADS are able to perform all driving tasks independently in most conditions and human attention is rarely required.

Finally, level 5 involves full control of the ADS in all conditions, and no driving assistance is required from a human driver.

Two level 5 autonomous vehicles have been successfully deployed at the Acerinox Europa stainless steel manufacturing facility in Spain and will in due course be deployed to other factories within the Group. The vehicles are electric vehicles capable of transporting 30 ton coils around the factory along pre-determined routes on existing roads, crossing intersections used by conventional vehicles. The AGV's replaces both a 30 ton forklift that consumed 109 liters of diesel per day, and the required five drivers to operate the forklift on a 24/7 basis.

The AGV's work 24/7, 365 days of the year in all weather conditions due to an automatic battery exchange at the charging station where no human intervention is required. The only human involvement is the loading and unloading of the coils. The AGV's transport up to 90 coils per day at speeds up to 1metre per second and travel a distance of 108 km per year. The resulting reduction in carbon emissions is 98 tons per year.

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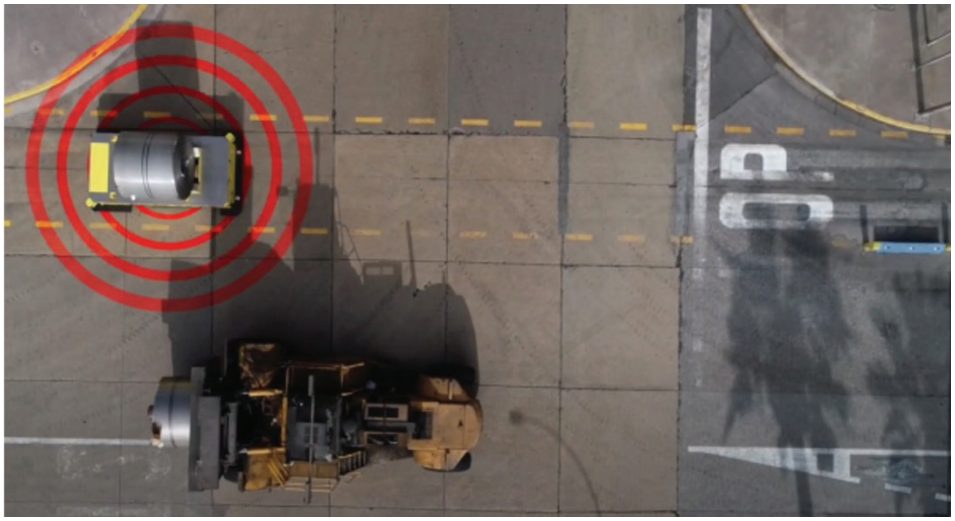
The AGVs have a SLAM (simultaneous localization and mapping) system, based on a map of their route that they continually update as they move and multiple laser guidance sensors that create a digital representation of the driving environment for navigation and activation of safety warning and automatic avoidance and braking systems.

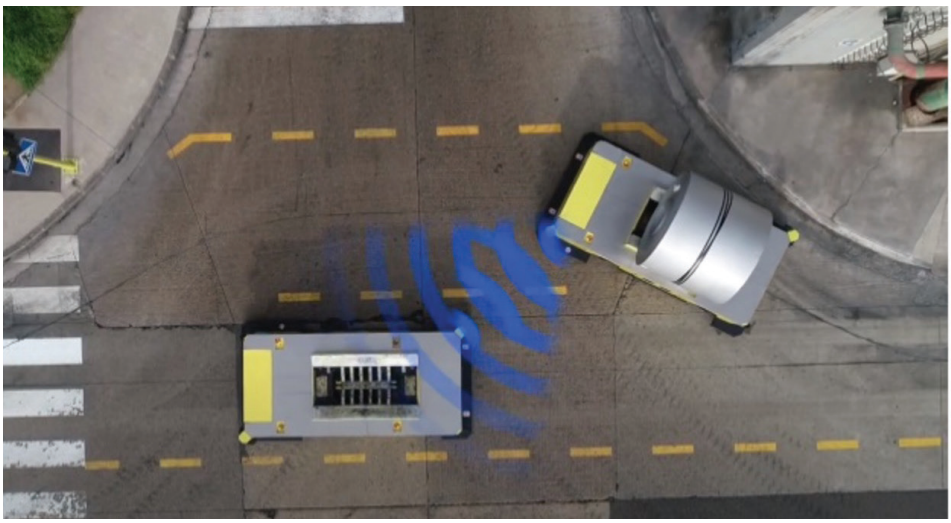
The two AGV's communicate with each other and with the traffic management devices, building access doors and manufacturing process management system of the factory.

The additional advantages of the automated process are the elimination of administrative procedures, non-value-added tasks and the real-time updating of material movements and stocks.

In 2020, Acerinox Europa won two awards for the 'Autonomous Logistics' project: the 5th 'Impulse for Connected Industry' award and the ABB Ability Digital Award. The Impulse for Connected Industry award was awarded by the Industry 4.0 Observatory. The award recognizes the work of Javier Carro, head of the Digital Transformation department of Acerinox Europa for his role in developing and implementing the project. wn



Safety sensors continuously scan for obstacles. If detected the vehicle automatically stops.



A simulation of the AGV sensors guidance systems communicating with each other.

The two AGV's in Acerinox Europa crossing at an intersection one with a 30 ton stainless steel coil payload.

COLUMBUS STAINLESS [Pty] Ltd

SAIEE Coffee table book

Second Edition

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 is now available at R350 (incl. VAT) from the Institute.

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

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.

AVAILABLE NOW!

SAIEE

Conditioning monitoring with intelligent drives in Industry 4.0

Industry 4.0 has emerged due to the intelligent networking of computers, people and devices, fuelled by data and machine learning, using all possibilities of digitalisation across the entire value chain.

This significant technological change has led to a whole new way of working in a digital world. It embraces the internet of things (IoT), artificial intelligence (AI), robots, drones, autonomous vehicles, 3D printing, cloud computing, and nanotechnology, to name a few.

TRENDS IN INDUSTRY 4.0 AUTOMATION SYSTEMS

In automation systems, the impact of Industry 4.0 on motor systems is a migration from the 'automation pyramid' to 'networked systems'. This means that the various elements of the system, such as motors, drives, sensors and controls, are interconnected and connected to a cloud data centre, where data is stored, processed and analysed, and decisions are made.

In an automation network, the amount of data is prominent. As sensors mainly produce data, the number of sensors in modern automation systems is increasing. Sensors are required to collect data from motors and motor-driven machines such as fans, pumps and conveyors, and then connected to the data network by various means to use the data.

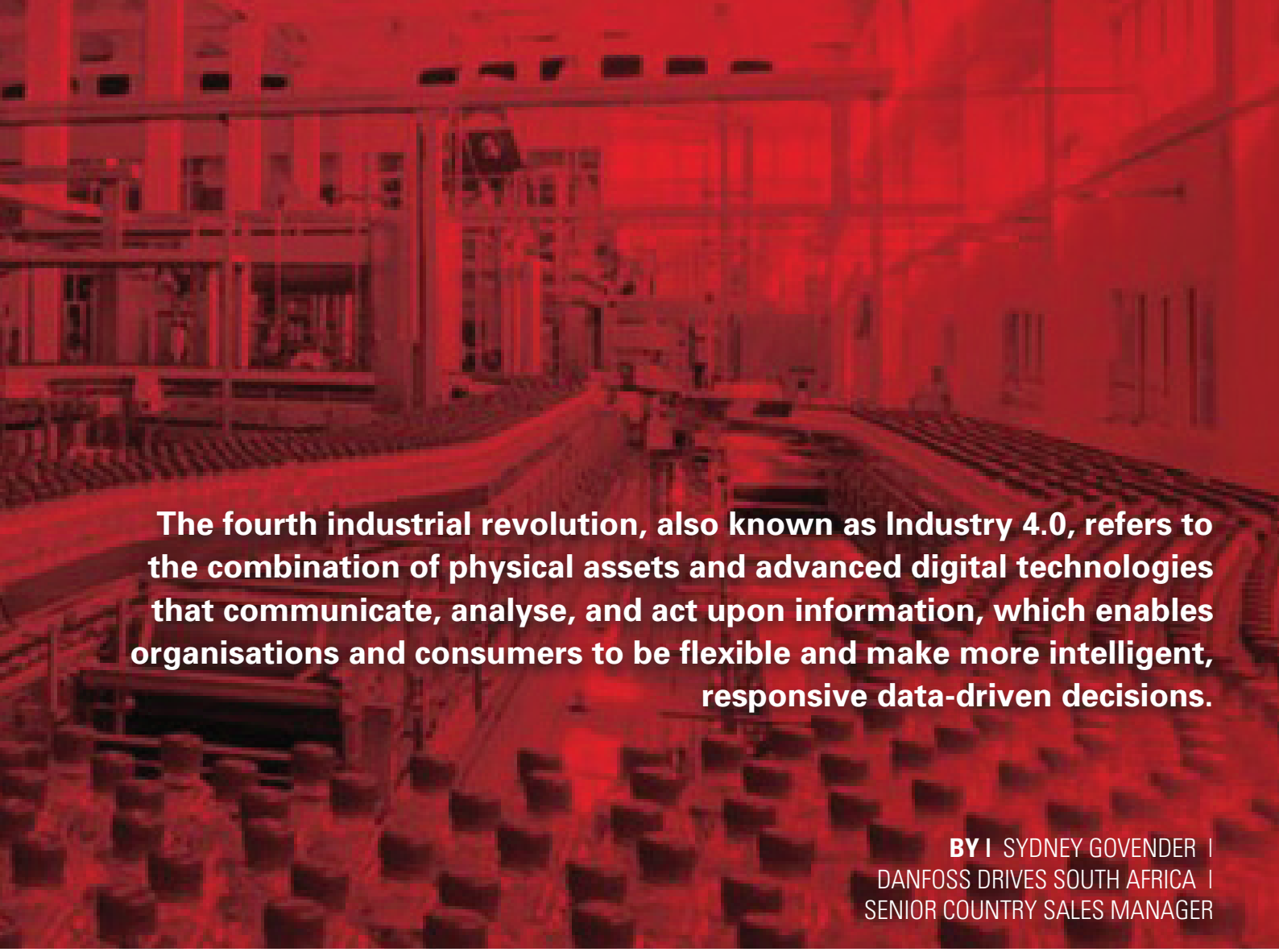
Modern variable-speed drives open new opportunities in the Industry 4.0 automation network. Traditionally, drives have been considered power processors for controlling motor speed.

Today, drives are also part of the information chain, using the advantage of built-in processing power, storage capacity, and communication interface within the drive itself.

WHAT IS AN INTELLIGENT DRIVE?

In the Industry 4.0 network, the drive plays an important role and is characterised by some enabling features:

- Secure connectivity: The drive can connect to other elements in a secure manner. Other elements



The fourth industrial revolution, also known as Industry 4.0, refers to the combination of physical assets and advanced digital technologies that communicate, analyse, and act upon information, which enables organisations and consumers to be flexible and make more intelligent, responsive data-driven decisions.

BY I SYDNEY GOVENDER I
DANFOSS DRIVES SOUTH AFRICA I
SENIOR COUNTRY SALES MANAGER

in the network may include drives, PLCs, sensors, and a cloud data centre.

- The drive acts as a sensor: The drive uses motor current and voltage signature analysis to sense the motor and application performance.
- The drive acts as a sensor hub: The drive acquires data from external sensors related to the drive's process.
- The drive acts as a controller: The drive can replace the PLC wherever application constraints allow.
- Bring your device concept: This uses wireless connectivity to smart devices such as a smartphone or tablet.

Information from the drive can be identified as follows:

- Instantaneous signals: Signals which are directly measured by the drive using built-in sensors. Data such as motor current, voltage, drive temperature, and derivative is power as a multiplication of current and voltage or motor torque. Moreover, the drive can be used as a hub for connecting external sensors that provide instantaneous signals.
- Processed signals: Signals which are derived from the instantaneous signal, which can include statistical distribution (maximum, minimum, mean and standard deviation values), frequency domain analysis or mission profile indicators.
- Analytics signals: Signals which provide indications of the condition of the drive, motor and application. The signals are used to trigger maintenance or lead to system design improvements.

Motor current signature analysis techniques enable the drive to monitor the condition of the motor and application. The technique allows the system to potentially eliminate physical sensors or extract early fault signatures that could not be detected.

For example, the technique makes it possible to detect winding faults in advance or mechanical load eccentricity.

continues on page 28

A Potential Autonomous Vehicles Strategy for South Africa

In the midst of a fluctuating South African (SA) defence budget and reduced local spending, research establishments and the industry are expected to keep up with the level of innovation or produce technology with foreign countries, where defence budget allocations are far superior or starting to exceed their own. Developing sovereign capabilities or ecosystem in Autonomous Vehicles (AV) would unlock SA's defence-related growth potential and create new sustainable pathways for companies and industry.

BY | KUSHAL UPRETY AND SHAMENDRAN PILLAY

An accelerated industry-wide program with faster time to market autonomous vehicle technology could significantly impact the economy as the previous Rooivalk or multilateral Advance Guided System projects. A flourishing AV ecosystem in SA has the prospect of developing new markets and being adopted throughout the African continent. Applying a dual-use (civilian/military) strategy to leverage existing industry capabilities effectively can bring cutting edge capabilities of defence technology to a wide range of use-cases in the form of highly automated solutions for the various sectors. However, transferring existing capabilities and technology

for commercial applications requires a profound understanding of the context of the application and industry awareness. Simply sharing blueprints or examples of the technology is not sufficient. Stakeholders must be in sync with incentives to adapt and develop technologies to tackle new problems.

By emphasising technological integration and focusing on the service industry, Kachila (Pty) Ltd has developed a Technology Roadmap and Business Strategy for AV capabilities that would align with the timelines with foreign frontrunners and create new uncontested markets globally. We look at the following timelines or current benchmark (Sources: Statista, Tesla, GlobalData UK Ltd)[1].
See figure 1.

With fragmented research in AI, Machine Learning and AV in select few institutions or research establishments and without extensive industry involvement, governmental participation or any significant projects, SA will have to produce the L5 Technology ecosystem for Over the Air (OTA) deployment by 2024 to be competitive in the foreign market. This ecosystem would be divided into the components depicted in Figure 2.

The lack of **Regulations** has restricted foreign direct investment at a large scale. A properly developed South Africa regulations for AV would attract lucrative opportunities and have the prospect of being adopted throughout the African continent, as it is a leader in the SADC region. SA's road deaths, which average 14 000 every year, are the highest globally (Source: Automobile Association South Africa). The regulations would also generate revenue, jobs and contract opportunities with the Department of Transport, Traffic or Law Enforcement, Legal Automotive and Insurance sectors to make roads safer in the future.

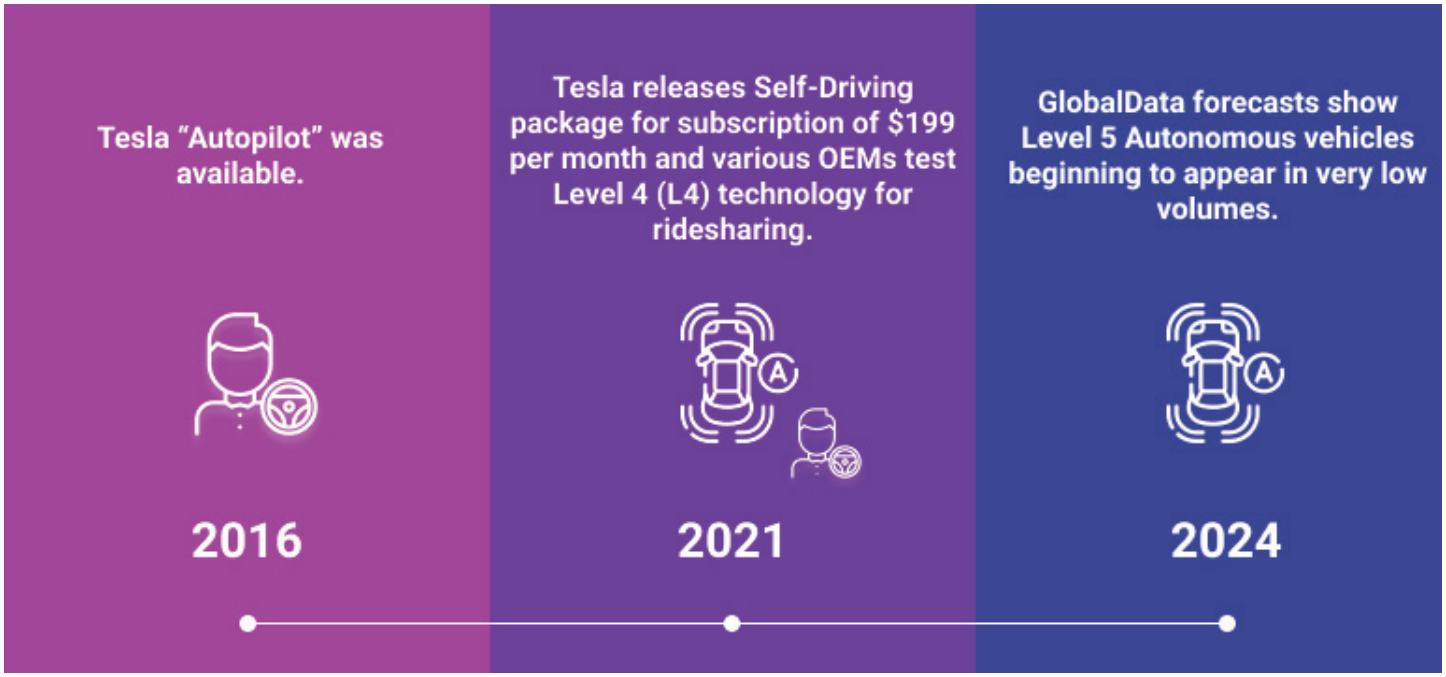


Figure 1

1 - The Society of Automotive Engineers (SAE) defines Level 4 automation as vehicles that can operate in self-driving mode within limited areas and speed, as per regulations; Level 5 automation as vehicles that perform the driving task in all conditions and do not require human interaction.

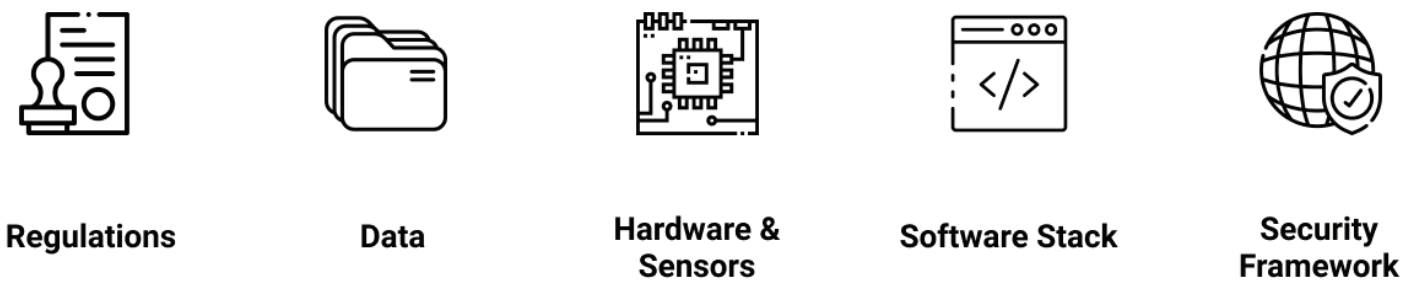


Figure 2

Adequate regulations and ecosystem framework would produce a large-scale investment in the Supply Chain to offer some of the most sophisticated hardware or lead local companies to create solutions that are not currently available across the African Region. Leading manufacturers now have no vested interest in offering AV products and automotive sensors in the African regions due to the lack of adequate liability and legal framework to put autonomous cars on the road.

This lack directly impacts the **data** required for unique settings. As autonomous functions are highly reliant on data, the lack of autonomous cars on African roads will lack data on African terrains, traffic patterns, or weather.

The lack of regulations also severely restricts foreign partnerships or programs that share previously collected data on automated driving (highway & urban), active safety, parking and additional cockpit components.

A curated AI-based **Software Stack** that intakes data from any sensors used to output meaningful predictions and points of interest can be used in AV and develop new markets for AI functionalities. The new AI functionalities can be deployed on any platform as a module to perform broad service-related tasks in multi-domain operations (defence, automotive,

commercial, security, space, to name a few domains).

The ecosystem would stimulate market and capabilities development in AI **Security Framework** such as cybersecurity, intrusion detection, electronic countermeasure considerations against hardware and software used for AI functions and networks of AVs.

This would be crucial for AV production and operation. An essential capability for future defence needs to be applied to other autonomous platforms, connected networks, command & controls, or coastal monitoring systems.

SA-CANADA CROSS NATION HYBRID COLLABORATION

In North America or, specifically, Canada, companies benefit from already established regulations, generous incentives and pilot programs to stimulate the development of AI and AV capabilities. Companies also have immediate access to a network of expertise and support initiatives across the continent. SMEs can develop, test or validate new technologies, tap into business opportunities and obtain support for commercialisation and export opportunities.

This favourable AV ecosystem has created rapid interest in industrial participation and helped grow numerous startups in the sector. Despite the large market in the AV and Automotive sector, the competition is relatively high between startups.

This competitive environment makes a hybrid collaboration between startups in the AV and well-established OEMs in the Aerospace and Defence sectors highly beneficial.

Such a potential collaboration brings prospects of commercialisation and Industrialisation of the current AV technology stack. It makes it relevant to various use-cases in defence, military, space, security and commercial sectors. This would enable companies in North America to be involved in new markets and experience doing business in other highly specialised sectors, which provide them with an edge over the competition in the automotive industry.

Significant export and market opportunities for companies in North America would also be available for the companies in the African continent through SA defence or industrial partners.

Collaboration would provide platforms (Aerial, UAVs, Land or Naval Systems) and data to support innovators (startups, industry and other partners) to test and develop other technology critical to future defence needs. The defence market is already interested in including AI and Autonomous functions in broader situational awareness, search and rescue, vessel tracking, and tactical tasks.

Preliminary research points to significant potential product development cost reductions when the Autonomous functions produced as a result of the commercial-defence collaboration are then applied to Military products, training and operation.

This could apply to integrating autonomous functions into Armoured Vehicles, for use in extreme environmental conditions, autonomous payload delivery or recovery systems, autonomous rescue, IED countermeasures, vehicles with UAV tethering capabilities and Land or Naval Vehicles to be used for surveillance as a part of situational awareness or broader situational and vessel tracking ecosystem. A modularised AI and AV technology that can be scaled or adapted would be one of the most valuable assets in the future.

On the other hand, a hybrid cross-nation approach allows for various technological and non-technological advantages for the SA industry when collaborating with foreign partners. Through niche contracting methods like Strategic Partnerships, Alliance Agreement or Licensing, SA firms can leverage partners' ownership and firm-specific advantages. This allows gaining experience doing business in new settings and developing new capabilities to be accelerated and give partners a competitive advantage in the market while keeping the investments relatively low.

SA companies could accelerate innovations by injecting themselves into autonomous pilot programs in foreign countries, develop and validate them by utilising their regulations and frameworks while simultaneously laying a foundation for regulations and frameworks in the home country that are compliant and competitive globally. This would also cater to cybersecurity and data breaches conformity. A universal standard would mean better market exposure to sell products usable globally.

This could create a Business Hub for SA companies to use these favourable business conditions to develop capabilities, platforms, and products that can be transferred to SA or access markets closed due to political restrictions. Foreign countries like Canada also have vehicle license exchange programs, share traffic rules and regulations, and conform to autonomous standards globally. AV

FEATURE - continued from page 23

The concept of the drive as a sensor hub involves connecting external sensors to the drive, thus saving the need for a gateway to connect the physical sensor to the data network. Vibration sensors, pressure sensors, and temperature sensors are examples of sensors connected to the drive.

The advantages of the concept include being able to correlate sensor data with different types of data present in the drive.

WHY IS CONDITION-BASED MAINTENANCE NEEDED?

The condition of a piece of equipment typically degrades over time. The introduction of Industry 4.0 and the availability of sensor data means that condition-based and predictive maintenance is now possible. The idea of condition-based maintenance is to detect the potential failure before an actual failure occurs.

Such maintenance strategies use actual sensor data to determine the condition of the equipment in service (condition-based maintenance) or to predict future failures (predictive maintenance).

Condition-based maintenance acquires data from the equipment itself and uses it to monitor the health of the equipment in service. For this purpose, critical parameters are selected as indicators to identify developing faults. In this case, planning maintenance actions provides many advantages such as:

- Downtime reduction;
- Elimination of unexpected production stops;
- Maintenance optimisation; and
- Reduction in spare part stock inventory

Condition monitoring follows a three-step procedure:

- Establish a baseline.
- Define thresholds.
- Perform monitoring.

CONCLUSION

Today, drives are more than simple power processors – they are vital elements in modern automation systems, with the ability to act as sensors and sensor hubs, process, store, and analyse data, along with connectivity capabilities.

Drives are often already present in automation installations and therefore present an excellent opportunity to upgrade to Industry 4.0. This enables new ways of performing maintenance, such as condition-based maintenance. The functions are already available in some drives, and early adopters have started using the drive as a sensor. wn

FEATURE - continued from page 27

vehicles tested in Canada can be used in other parts of the world due to these benefits.

Collaboration with the Canadian AV industry also reduces project risk, allowing the SA partners to be affiliated with the Canadian ecosystem (research institutes, industries, facilities, government). This affiliation creates a pathway for SA industries to develop products that fit local requirements.

Some SA companies have already had extensive engagement with current role-players in the AI space in North America; the integration plans, models, roadmap, timelines, and deliverables derived from this also has vested interest from the financial sector. A cross-nation collaboration with partial stakeholders like government establishments, defence sector, institutions, and startups venturing into developing new technology for future needs is seen as portfolios for investors, hedge funds and public participation by pre-IPO involvement. This could create non-traditional investment products, where investors could benefit from futures sales and get to own percentages of IPs and licensing rights, which would have more significant benefits than products tracked in today's market.

AV technology collaboration could be used to develop a new bilateral trade agreement between South Africa and Canada. This will enable companies to benefit from future MRO contract opportunities in both countries mutually and develop new clusters of markets and foreign export opportunities.

It would promote hybrid contracting methods to foster cross-nation collaboration in other future projects, mitigate project risk while maximising the return of investment by the companies and ensure the successful transfer of technology between the defence and commercial sectors. 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.

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Biomedical Engineering at its Best

What is engineering? In 1844 the Oxford dictionary first described engineering as, "The branch of science and technology concerned with the design, building, and use of engines, machines and structures."

In recent history this has extended of many more modern branches of engineering, and one in particular that has revolutionized the lives of humans; namely biomedical engineering. First scientifically referred to in 1960, biomedical engineering improves the livelihood and health of humans, often treating deformities and indications that were thought to be untreatable not so long ago.

Health professionals today confront many problems that require practical solutions based on the fundamental aspects of device and system analysis and design. Due to this, the biomedical industry is currently one of the fastest growing and innovative industries in the world. Southern Medical is a proudly South African company that finds itself at the heart of this growth and innovation.

We are dedicated to the development and manufacture of high quality orthopaedic and neurosurgical implantable devices for spinal, foot, maxillofacial and neuro-surgeries. This means we provide the necessary devices for surgeons to treat an array of common health problems, from chronic back and neck pain, to correcting flat foot, broken wrists and overbites.

Not only do we supply the devices themselves; but also, the instruments and equipment needed to implant them. These require just as much engineering as the devices themselves to ensure procedures are performed quickly, accurately and easily. Examples of such instruments are; placement instruments, drivers, reamers, trial implants and distractors. All of these need to be stored neatly on an instrument tray. Yes, we design and manufacture those too.

The team behind this engineering is, well, the engineers. The Southern Medical management, technical, quality and processing departments have a collective eleven engineers, six of whom are female. We believe our team is a good representation of the engineering capabilities in South Africa. Together we hold a range of Bachelor's, Honour's and Master's degrees and professional registrations in mechanical and biomedical engineering. These are from the University of Pretoria, University of Cape Town, University of Johannesburg, North West University, Imperial College of London and the Engineering Council of South Africa.

The diversity of our engineering team enables us to collaborate in a way that strengthens our skills needed in the research and development environment. We encourage the sharing of knowledge and experience to ensure that Southern Medical is able to gain from each individual's unique thought-process and ideas.

Southern Medical performs the complete engineering process inhouse; from defining the problem, conducting clinical research, conceptualising, prototyping, testing, developing, manufacturing, processing, implementing and post-market feedback. Defining the problem typically involves obtaining design inputs directly from surgeons. Clinical research includes an extensive search of published articles to qualify and quantify risk and performance requirements adequately. Often multiple design and testing loops are required to obtain the quality and performance results that we pride ourselves in. Finally, to ensure we

meet regulatory requirements and customer satisfaction, we keep a close tab on customer feedback and case outcomes.

Each member of the engineering team is exposed to every aspect of the engineering path, this allows them to gain a broader perspective of design problems which ultimately leads to better solutions. Consequentially, Southern Medical can be seen as a portal for young engineers to grow in experience and skill.

Once a design is complete the items need to be precisely manufactured, inspected, cleaned and sterilised according to stringent specifications. We have a world-class manufacturing and processing facility that enables us to produce globally competitive products. Being a proudly South African company with successful South African staff, it shows that there is no need to emigrate.

We believe in the future of our country and local talent therefore we welcome vacation work students to join us in their semester breaks to meet their work experience needs.

We further welcome shadow students from high schools who wish to learn more about our industry before they choose their careers.

There has been a notable trend with the majority of students and scholars who approach us being female, showing a more inclusive future in engineering.

Who can describe biomedical engineering at Southern Medical better that the engineers themselves? Here are a few testimonials from the team.

MATTHEW TRUSLER

Junior Biomedical Design Engineer

"The world of biomedical engineering is one of the most innovative fields to be in. The technologies developed are constantly changing and adapting to the requirements of doctors, patients and all those involved in the health care profession. Southern Medical uses clinical data to better understand and design for world class patient and surgical outcomes. Every day I learn more about different surgical approaches and the regulatory requirements necessary to bring devices to market"

JANA ROSSOUW

Biomedical Design Engineer

"Biomedical engineering presents an opportunity to use technology as a means to contribute to the health and well-being of society, which makes it an incredibly fulfilling career choice. Southern Medical is one of the few companies that offer orthopaedic implants that have been designed and manufactured locally. It is a privilege to be part of a team of engineers that not only strive to deliver excellent work, but are lovely people that are truly a joy to work with."

MART-MARI

Quality Assurance

"The new and innovative ideas that form part of Biomedical Engineering led me to want to be part of a biomedical engineering team to be able to merge different principles. I have an interest in the human anatomy and want to aid in the progression of humanity when it comes to health care.

Engineering principles are implemented through problem solving. Material standards, for example, and the implementation of the standards on the raw materials, plays a big role in the biocompatibility and integration with human tissue."

JANU BOTHA

Junior Biomedical Design Engineer

"Working at Southern Medical as a Biomedical Engineer has awarded me the opportunity to design and create spinal implants that can help people relieve pain and improve their ability to function during day-to-day activities. Biomedical engineering is a fast-paced field which allows me to continuously work on improving our products in order to offer the highest quality, state of the art spinal implants at Southern Medical."

JONATHAN CAINE

Biomedical Design Engineer

"The work of a biomedical engineer is both highly rewarding and stressful. Designing spinal implants is a serious responsibility not to be taken lightly. The devices we design are used in procedures which have the ability to alleviate debilitating pain, at the same time, if errors are made the repercussions can be severe for the patient. As every patient and surgeon are different, we need to be thorough, methodical and accurate in our work."

ELSMARI WIUM

Biomedical Design Engineer

"I relish the constant challenges of engineering and I love the methodical, analytical manner in which engineers approach all problems. Biomedical engineering is a just specific application of engineering. It allows me to do what I enjoy while directly benefitting society. It is satisfying to know that the devices we design at Southern Medical have the potential to improve someone's health and quality of life. Biomedical engineering is also a really exciting, ever-evolving field with many opportunities for innovation, especially with recent technological advances."

DALENE STYGER

Quality Department Manager

"What I love about being involved in the biomedical engineering field is that it requires constant learning. We research the use of new materials and manufacturing methods as part of our product development and these new technologies are verified and validated as part of the product approval process. It is a highly regulated industry and we're involved in sterile packaging design and validation, sterilisation validations, clean room design and everything in between. Technical aspects related to cleanability of instrumentation for effective decontamination as well as the design of instrumentation sets for optimal steam penetrations are all part of the day-to-day activities associated with our types of devices. The design of pre-clinical test programmes and inspection processes are also required to ensure we meet the fine tolerances specified.

My role has changed over the years from being part of the design team to ensuring that the company operates within the framework of a certified quality management system. I oversee the regulatory product approval process and it requires an understanding of all aspects in the design, manufacturing and processing of these devices in order to effectively communicate with the relevant regulatory authorities. It is overall a very rewarding field to work in."

RAINE FOUCHE

Technical Department Manager

"I have a great appreciation for the engineering process and enjoy being a part of every step along the way. It is truly fulfilling to be able to design and develop an implantable device to have it commercialised and help the people who need it. Everyday I am motivated by being a part of an engineering team who work and grow together and I look forward to our future innovation." wn

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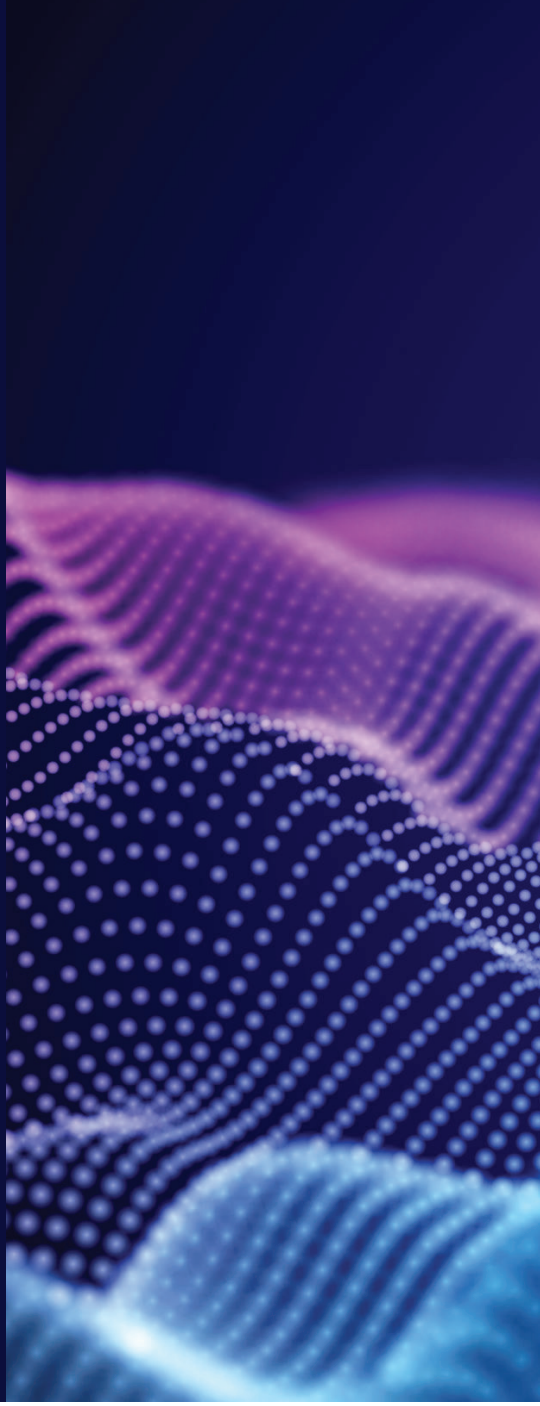
Information Technology and Operations Technology: Beyond Convergence



Information Technology (IT) is defined as hardware, software, and communications technologies that focus on data storage, recovery, transmission, manipulation, and protection. Operations Technology (OT) is defined as hardware and software that detects or causes a change by directly monitoring and controlling physical devices, processes, and events.

Key differences in the purpose and functionality of IT and OT are reflected in Table 1.

TRADITIONAL SECURITY PRIORITIES AND APPROACHES

IT's focus is on protecting intellectual property and company assets, prioritising confidentiality above integrity and availability. OT's focus is on productivity, maintaining 24/7 operations, and achieving high overall equipment effectiveness, prioritising availability and control over integrity and confidentiality.

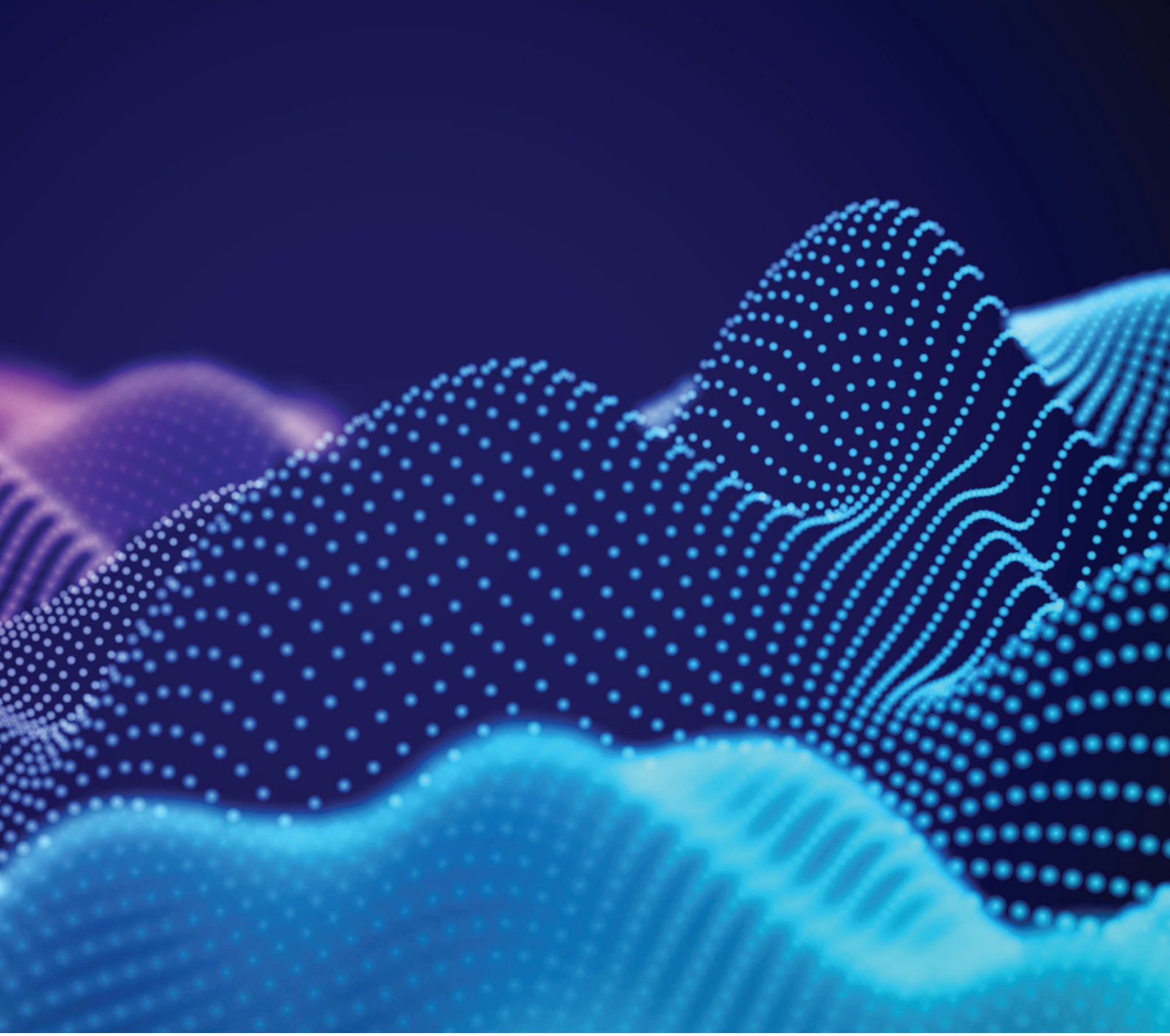
Simply put, IT strives to protect data first; OT strives to protect assets first. IT networks usually feature strict authentication protocols and access policies, while OT networks are simple to access, but the physical machines are more closely guarded.

When cybercriminals target IT environments, they're typically after money, but they're working to disrupt operations when they target OT environments. When a threat is detected in an IT environment, teams will entirely shut down access to the area. However, in an OT environment where productivity is king, teams typically keep operating and attempt to isolate the threat.

A comparison of security-related priorities and approaches is shown in table 2.

NEW CONCERNS FOR A NEW WORLD

IT systems are historically used to manage complex data and information flow, but today's OT environments leverage them to manage complex



physical processes. As a result, industries are safer, more efficient, and more reliable than ever before—but these technologies bring more security risks to facilities and operations.

Attempts to disrupt operations, steal intellectual property, and affect the quality or safety of production are steadily increasing as more cyberattacks target critical infrastructure and industrial assets. Threat actors are using IT techniques to access OT systems, and they're using OT systems that are poorly defended to get access to corporate IT networks. In many ways, cybercriminals are taking advantage of the disconnects—and, in some cases, the distrust between OT and IT teams.

Historically, IT and OT cybersecurity have been considered separately for several reasons:

- IT cybersecurity was the first focus area for threat actors
- OT environments used to be isolated and "off the grid"
- IT prioritised confidentiality and protection of data over availability and control of systems
- Upgrades and patches are handled very differently because of access and uptime constraints
- IT teams are not experienced in the operations or control of OT systems
- Within many companies, IT staff and OT staff are functionally, and often physically, separate and uncoordinated

Today's interconnected world means that IT and OT can no longer consider security separately. This new dynamic has resulted in unfamiliar challenges

TABLE 1	Information Technology (IT)	Operations Technology (OT)
Primary Function	Process transactions, provide information, support people	Control or monitor physical processes and equipment
Focus	Programming, adjusting, augmenting, and re-programming to fit the evolving needs of networks, applications, and users	24/7, continuous, precise control and monitoring of machines and processes
Architecture	Enterprise-wide infrastructure and applications; generic	Event-driven, real-time, embedded hardware and software; custom
Examples of Systems	Office PCs, printers, web/app/ data/email servers, TCP networks	Industrial Controllers (PLC, DCS, SCADA) and I/O Hardened PCs and Servers Industrial Networks
Examples of Devices	IoT-enabled: tablets, smart phones, etc.	IIoT-enabled: sensors, cameras, embedded systems, robots, analyzers, etc.
Connectivity	Corporate network, IP-based	Control networks, hardwired and IP-based
Data Traffic	Converged network of data, voice, and video	Converged network of data, control, information, safety, and motion
Communication	User-centric	Machine-to-machine
Performance Requirements	High bandwidth, delay-tolerant Rebooting, Retrievable Back-up acceptable	Low bandwidth, real-time Outages unacceptable, redundancy is required
Update Frequency	High	Low
Interfaces and Networks	GUI, web browser, terminal, keyboard	Electromechanical, sensors, actuators, coded displays, hand-held devices

for both areas:

- IT must now account for a greater scope of impact from attacks, including physical safety risks
- IT must learn how to manage outdated, and often custom-designed systems that aren't easily updated, patched or configured
- OT must now account for risks that aren't controllable by the machines or the processes
- OT must learn how to protect data as well as physical assets, as more and more traditionally closed systems like utilities and aviation come online

Because of the ever-increasing connectivity in industrial environments and the resulting security complications, these challenges won't be solved quickly or easily. In fact, according to the World Economic Forum's 2019 Global Risk Report, cyberattacks disrupting operations and

TABLE 2	Information Technology (IT)	Operations Technology (OT)
Security Priorities	Confidentiality, Integrity, Availability	Control, Availability, Integrity, Confidentiality
Access Control	Strict network authentication and access policies	Strict physical access but simple network device access
Cyber Criminal Motivation	Monetization	Disruption
Threat Protection	Shut down access	Isolate but keep operating
Maintenance	Multiple support sources; 3–5 year component life; Modular, accessible components; IT staff or contracted service in place	Single vendor support; 15–20 year component life; Remote components, hidden access; No full-time dedicated IT staff
Upgrades	Frequent patches and updates; Automatically pushed during uptime	Carefully planned and tested; Scheduled during downtime or not done at all
Primary Players	CIO and IT	Engineers, technicians, operators, managers

critical infrastructure are among the top five global risks.

Recent, high profile attacks have demonstrated the severe consequences of cybersecurity incidents. For example, the 2017 malware NotPetya spread from the servers of an unassuming Ukrainian software firm to some of the largest businesses in the world.

Within a matter of hours, the worm had crippled the operations of several multinational companies, resulting in more than $10 billion in total damages.

Blurring Lines with Intention: Moving from Isolation to Convergence to Integration Coordination, cooperation, and ultimately integration of IT and OT security can help prevent or reduce the likelihood of cyberattacks.

A 2017 Gartner report estimated that about 60% of organisations are still in the initial research and sharing phases of their integration efforts between IT and OT.

Most companies are just beginning to dialogue, and they still need to align their practices and strategies, integrate their systems and infrastructures, and optimise their ecosystems for continuous improvement.

When IT and OT teams do come together to discuss enterprise security, many organisations find that these priorities emerge:

- Implementing industry-adopted standards and best practices across the enterprise
- Requiring devices and systems to be certified as standards-compliant
- Identifying and authenticating all devices and machines within the system—in plants and in the field—to avoid rogue or unverified devices being used to gain access
- Encrypting communications between devices to ensure data privacy and integrity
- Enabling remote upgrades with satisfactory protections in place to ensure integrity and safety

While these conversations are a good start, it is essential to make IT and OT security integration a corporate priority. Increased collaboration—driven by intent and thoughtful strategy or risks and consequences—will be the only answer to future cybersecurity challenges. wn

New Control Technique Combines Servo Performance With Step Motor Cost

When it comes to step motors, a new drive technique called stepper servo is making everything old new again and winning back machine designers who may have relegated step motors to the category of low cost but low performance. This technique is powerful because it can use a generic non-custom step motor yet extract much more performance out of it. This is accomplished by adding an encoder and operating the motor as, effectively, a commutated two-phase Brushless DC motor.

An encoder is needed means that truly low-cost applications will not be good candidates for stepper servo. But for applications that would otherwise have a Brushless DC motor, stepper servo is increasingly being considered as an alternate approach.

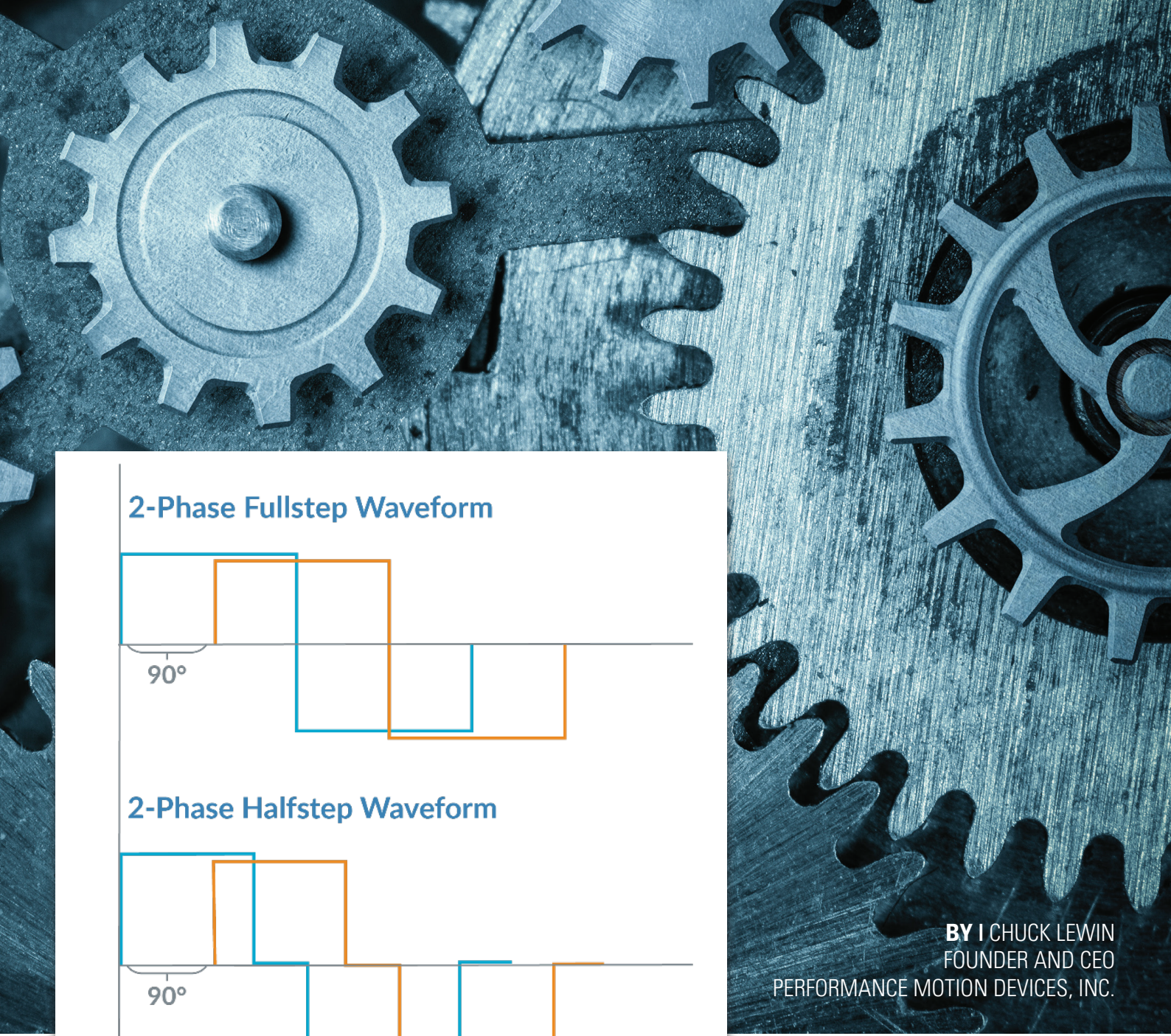
In addition to offering a lower cost-solution than a comparable Brushless DC motor, stepper servo can outperform brushless motors in areas such as acceleration rate and torque output. This makes it a candidate for applications such as high-speed point-to-point moves, textile equipment, coil winding, high-speed electronic cams, and more.

So how does stepper servo work? To answer this, we will start with a quick review of traditional step motor control schemes and then dive into how stepper servos are different and what they can do for today's machine designer.

YOU HAD ME AT FULL STEP

Step motors are popular first and foremost because they are easy to use. They do not require an encoder to maintain their position, and unlike DC Brush or Brushless DC motors, they do not require a servo control loop when used for positioning. Their advantages are low cost, high torque output, and brushless operation, and their main drawbacks are vibration, noise, and a limited speed range.

Figure 1 shows traditional waveforms for driving a step motor. Step motors are a multi-phase device, meaning multiple motor coils are electrically excited to create motion. Most step



BY I CHUCK LEWIN
FOUNDER AND CEO
PERFORMANCE MOTION DEVICES, INC.

Figure 1: Traditional Step Motor Control Waveforms

motors have two phases, but more exotic configurations such as 3-phase or 5-phase also exist.

In the world of step motors, the phasing techniques that the amplifiers employ are given unique names such as full-step, half-step, and micro-step control. These different techniques refer to the number of power levels applied to each motor coil during an electrical cycle. The motor moves forward or backwards when the external controller alters the electrical phasing with whichever drive method is used.

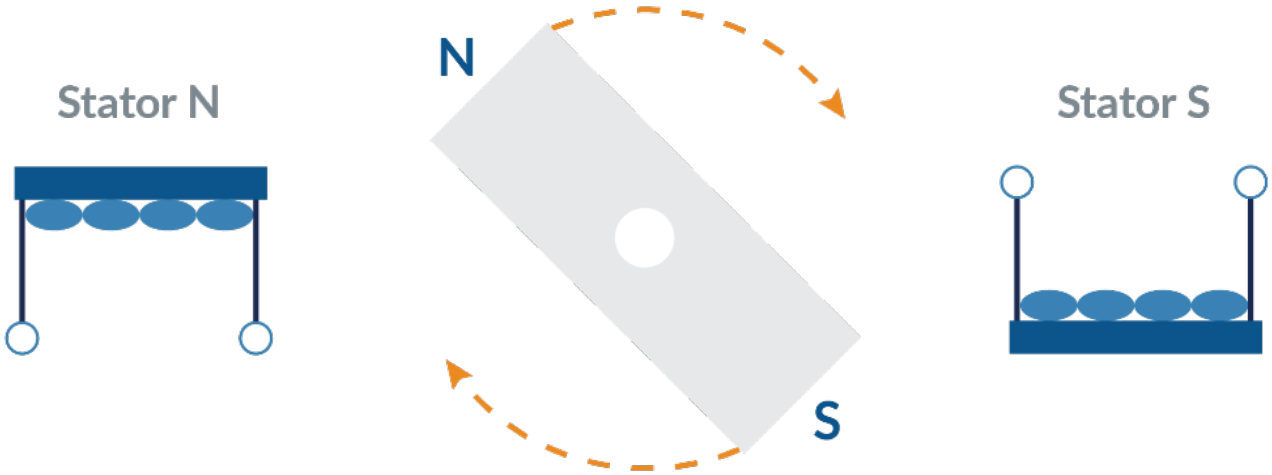


Figure 2: Spinning Bar Magnet Model for Step Motors

Step motors are usually constructed with 1.8 mechanical degrees per full step (90 electrical degrees). So this means a 1.8-degree stepper has 200 full steps per mechanical rotation. In addition to 1.8-degree step motors, other configurations exist, such as .9 degree and 7.2 degrees.

IN THE VALLEY OF THE B-FIELD

Now let's look at what's happening inside the motor and understand in more detail how a traditional step motor is operated.

Figure 2 provides a simple magnetic model of a step motor. The rotor can be considered a spinning bar magnet that interacts with an externally controlled magnetic field (the stator). The rotational torque generated is zero when the N-S rotor field aligns with the stator N-S magnetic field (also called a B-Field) and maximum when the two fields are at an angle of 90 electrical degrees from each other. It's worth noting that the actual internal construction of a step motor looks nothing like this, but it's still a helpful way to understand the motor operation.

When the stator coils are driven with current, a sinusoidal force 'valley' is created, which drives the step motor to settle at a specific position. The more current that is driven through the coils, the greater the depth of the force valley. In this force profile of hills and valleys, no mechanical torque is generated wherever the curve is horizontal. Wherever the curve is the steepest, the generated torque is the largest.

As Figure 3 shows, the motor settles to the 'bottom' of the force profile in a traditional step-motor drive scheme. The net rotational motor torque generated is zero because the motor is at an equilibrium point. This explains why position can be maintained in a step motor without an encoder or servo loop.

The controller moves this valley forward or backwards by changing the stator phase via the external coil connections to create motion. The motor rotor then 'falls' forward or backwards, maintaining itself at the bottom of the force valley in response. Think of a ball settling to the bottom of a trough.

DESPERATELY SEEKING SMOOTHNESS

As convenient and straightforward as this scheme is, it has several drawbacks. Here is a quick rundown:

- **Indeterminate Accuracy.** The actual position of the settled rotor is the sum of the internal equilibrium-restoring force and whatever external forces on the rotor may exist. Therefore in a given application or load, the exact actual profile path will vary on a small scale.
- **Mid-Range Instability.** Going back to the ball metaphor, when the phase angle is changed abruptly, the rotor will advance but tend to ring around the equilibrium point and finally settle into the new phase angle. Usually, this settling process, which happens very rapidly, is not a big problem, but when the natural ringing frequency equals the commanded step rate, a phenomenon called mid-range instability can occur, resulting in a dramatic reduction in available torque at that specific operating speed.
- **Lost Steps.** A sufficient external

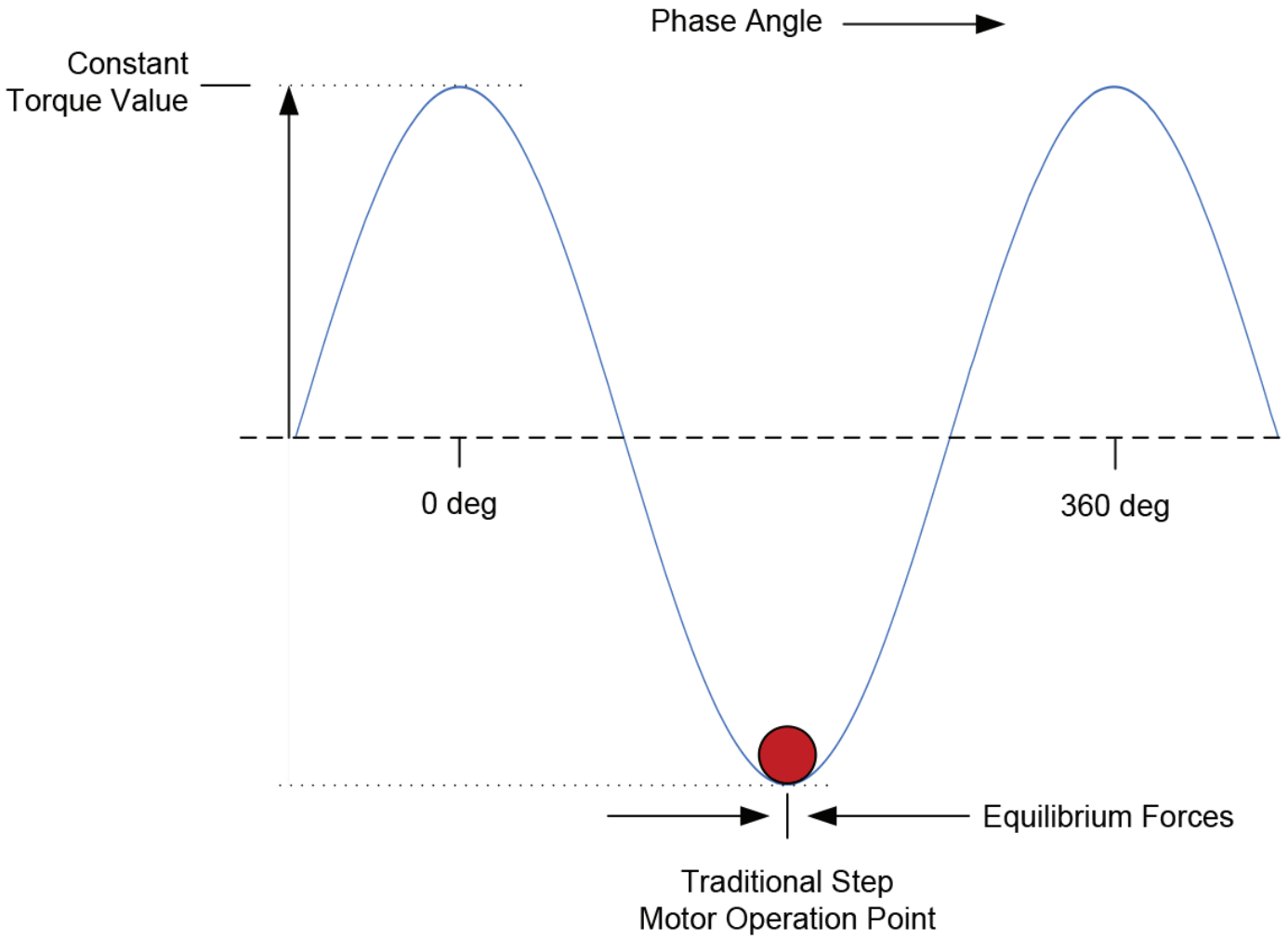


Figure 3: Traditional Step Motor Drive Scheme

force can push the rotor from its equilibrium position up and over the force profile curve and into the next valley. This phenomenon is called losing steps and is often a run-away effect once it starts, meaning the rotor falls further and further behind the commanded profile and eventually comes to a halt.

- **Excess Heat.** The motor is operated at a torque level sufficient to handle the worst-case motion profile to combat the phenomenon of lost steps. This means that the programmed torque is higher than is needed at all other times, generating excess heat.
- **Noise.** Step motors are noisy during motion for a few reasons. If a full step or half step drive scheme is used, the square edges of these coil drive signals excite resonances (read that noise) in the rotor. Another reason is a large number of electrical cycles per mechanical rotation. Moving the rotor forwards or backwards requires the controller to constantly cycle the command voltages up and down for each phase, which induces noise in the coils and, therefore, the motor.
- **Vibration.** All of the factors listed above for noise can also generate vibration. But particularly with a micro-stepping drive, there is a phenomenon that may generate little noise but can create a fair amount of vibration. Due to the geometry of the stator/rotor teeth (a feature of all step motors) and peculiarities of the resultant B-fields, the relationship of drive signals to translated motion is never perfect. In other words, a plot of commanded position and actual measured position is not an exact straight line. This phenomenon results in rhythmic vibration during motion.
- **Low Top Speed.** To position accurately, step motors move only a small amount for a corresponding advancement of the coil command waveform. A standard 1.8-degree step motor requires 50 complete electrical cycles per single mechanical rotation. By comparison,

a four-pole Brushless DC motor requires just two electrical cycles per mechanical rotation. Motor coil inductance limits how fast the phasing can be changed, and therefore step motors tend to have much lower maximum speeds than Brushless DC motors.

YOU HAD ME AT STEPPER SERVO

Now let's delve into the stepper servo technique, sometimes also called closed-loop stepper operation (a bit ambiguous term because it is also used to describe a traditional step motor control scheme that uses an encoder to verify the final position, thereby 'closing the loop).

Stepper servo operation is different in three key ways from regular step motor operation.

1. The first is that it requires an encoder to be attached to the step motor, one with a reasonably high resolution. For standard 1.8-degree step motors, you will want an encoder with no less than 2,000 counts per mechanical rotation, and for 7.2-degree step motors, 500 is a bare minimum.
2. The second difference is that stepper servo operation runs the motor like a Brushless DC motor and commutates the phase angle using the actual encoder position rather than the commanded position. Redrawing our force diagram, the figure below shows how commutated phasing means the step motor is operated at the steepest part of the force valley rather than at the equilibrium point.
3. The third difference is that rather than being constant, the height and phase angle of the waveform is continuously varied based on the output of a position PID loop, which is used to servo on the commanded position. Again, this is the same as how a Brushless DC motor is operated.

What are the advantages of operating a step motor this way? There are many:

- **No Lost Steps.** One immediate advantage is that losing steps is no longer a concern. Operated as a servo motor, the encoder determines the step motor's location, so the problem of losing steps no longer applies.
- **Less Heat.** A second advantage is that stepper servo operation runs the motor more efficiently, which means less heat generated. Commutated motors output just the amount of torque needed to achieve the desired motion profile, while traditionally controlled step motors are driven at a sizeable constant current that must be

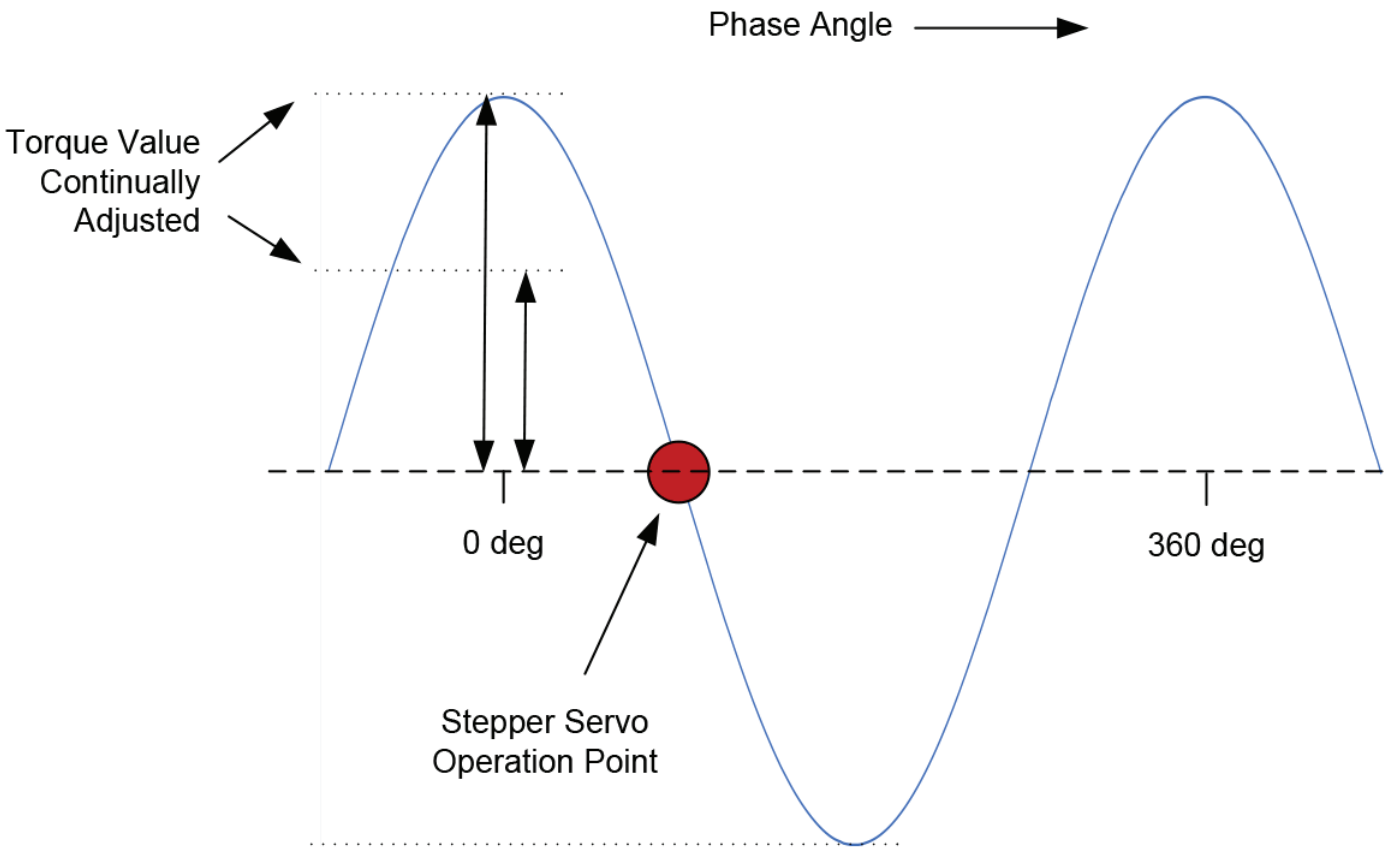


Figure 4: Stepper Servo Operation Point

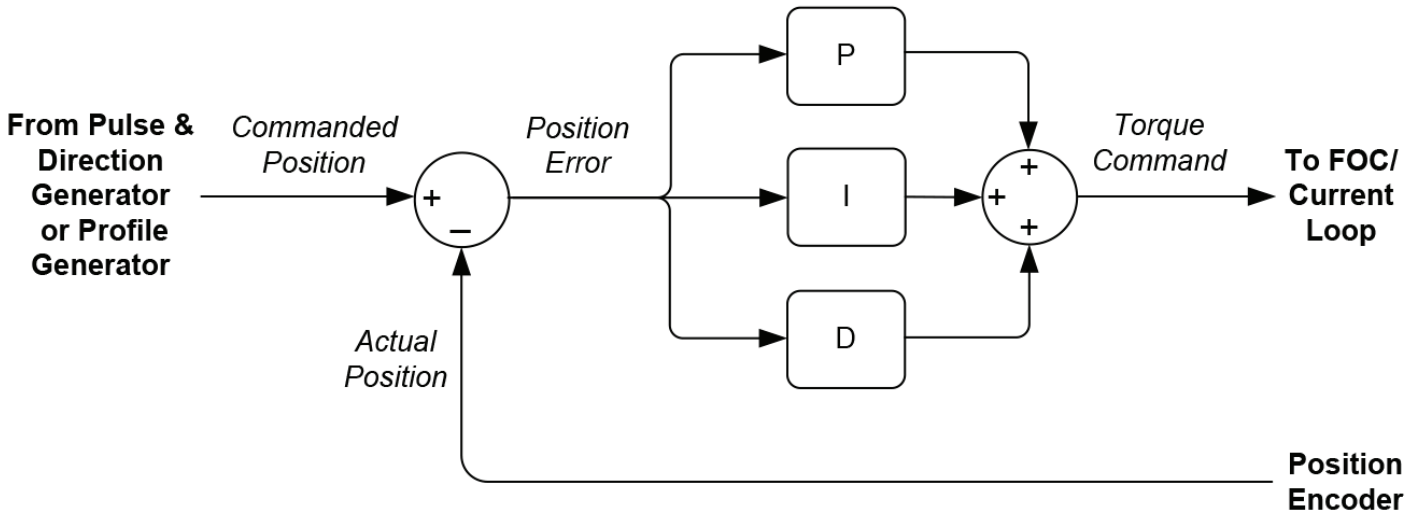


Figure 5: PID Control Loop

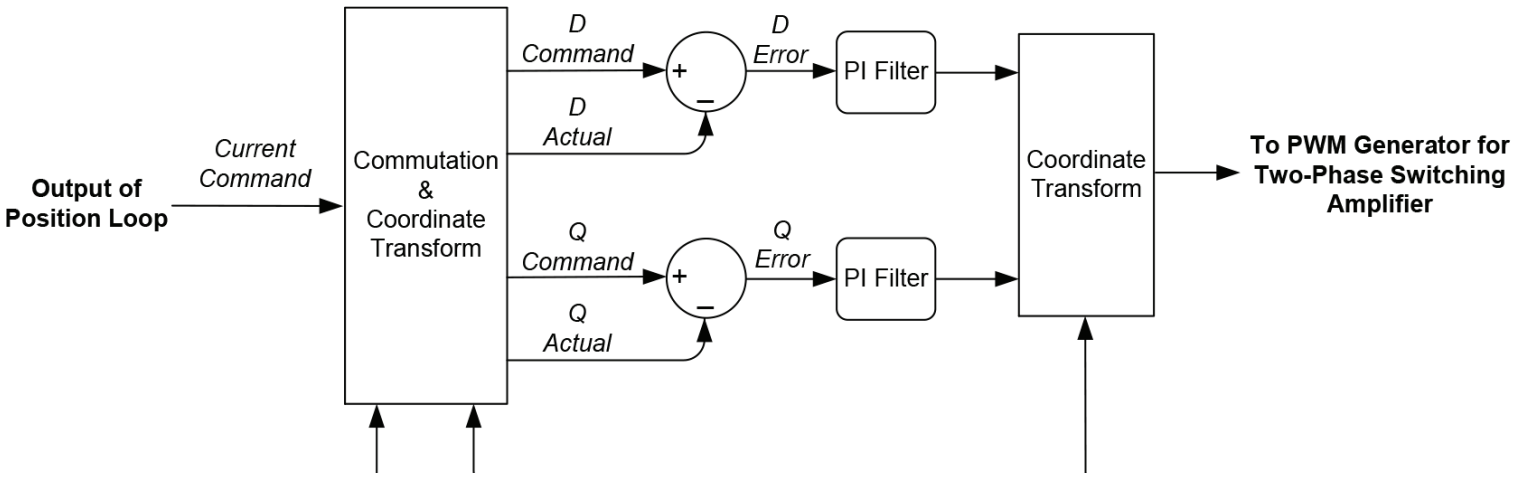


Figure 6: FOC Current Loop Diagram

sufficient to handle the worst-case motion.

- **Accuracy.** Accuracy here has two dimensions. Since the encoder explicitly measures the location of the motor, the vagaries of determining the actual rotor settling position that comes with a traditional step motor are eliminated. The second is that the positioning accuracy becomes unlinked from the motor's degrees per step rating (for example, 1.8-degrees/step) and the resolution of the micro-stepping scheme. With a stepper servo, the theoretical position resolution is determined solely by the resolution of the encoder. Therefore the same motor could achieve 2,000 resolvable locations per rotation or 1,000,000 resolvable locations depending on the encoder.
- **Velocity Smoothness.** Another significant advantage is improved velocity smoothness. Because a traditional step motor controller doesn't explicitly measure and control the rotor position, the rotor angle tends to bounce around a bit as external forces influence it. The same motor operated in stepper servo mode can achieve much more accurate velocity tracking.
- **Noise.** With the stepper servo technique, the motor generates much less noise than a full-step or half-step drive and even less noise than a micro-stepping drive. While not as quiet as a typical Brushless DC motors, stepper servo kills the classic step motor noise problem.

WE'RE GONNA NEED A BIGGER ALGORITHM

The control scheme used with the stepper servo looks quite different from the control scheme used with traditional open-loop step motor controllers. These traditional controllers often use relatively simple current control techniques such as fixed off-time PWM (Pulse Width Modulation) and do not explicitly command the current during all phases of the

motor's electrical cycle. In particular, an uncontrolled decay mode (sometimes selectable as fast decay or slow decay) is used to decrease the current in the coil.

While good enough for most traditional step motor controllers, this will not work well for stepper servo controllers. Stepper servo controllers instead borrow the control schemes used with a Brushless DC motor and explicitly control current through all phases of the generated waveform.

This control scheme has three elements:

- A position PID loop
- A current loop
- A switch-mode amplifier
- A current sense controller

As shown in figure 5, the PID loop inputs a commanded position, either from an external pulse & direction source or an internal profile generator, and uses the measured encoder position to generate a position error. After filtering via the PID, a current command.

Current control can be accomplished in a few ways, but increasingly Field Oriented Control (FOC) is used even for step motors. While often associated with Brushless DC motor control, FOC has significant benefits when controlling step motors, including higher top speed and more efficient operation. Figure 6 illustrates the control flow of the FOC scheme. The output of the FOC algorithm is the specific PWM commands for each phase of the bridge.

The control scheme shown in Figure 7 inputs the PWM commands and outputs explicit high/low switch commands for two bridges, each consisting of four switches in an H-Bridge configuration. In addition to the PWM command itself, other parameters of the MOSFET switch, such as recharge time and shoot-through protection timing, are also entered into the controller.

The current is measured using dropping resistors connected to the ground leg of each switch circuit. Leg current sensing is more complicated than fixed off-time PWM control, requiring a unique algorithm to combine simultaneous measurements from multiple sensors. But it has the benefit of allowing explicit, highly accurate control of the motor coil's current regardless of which sector of the waveform is being executed.

Despite the more advanced motion control technique employed with stepper servo versus traditional step motor control, the cost of these electronics have come down so much that the cost of the controls is a diminishing (but not negligible) concern. Far from requiring a PLC, module, or entire control board, ICs that can handle all aspects of stepper servo control are now readily available for $20 or less.

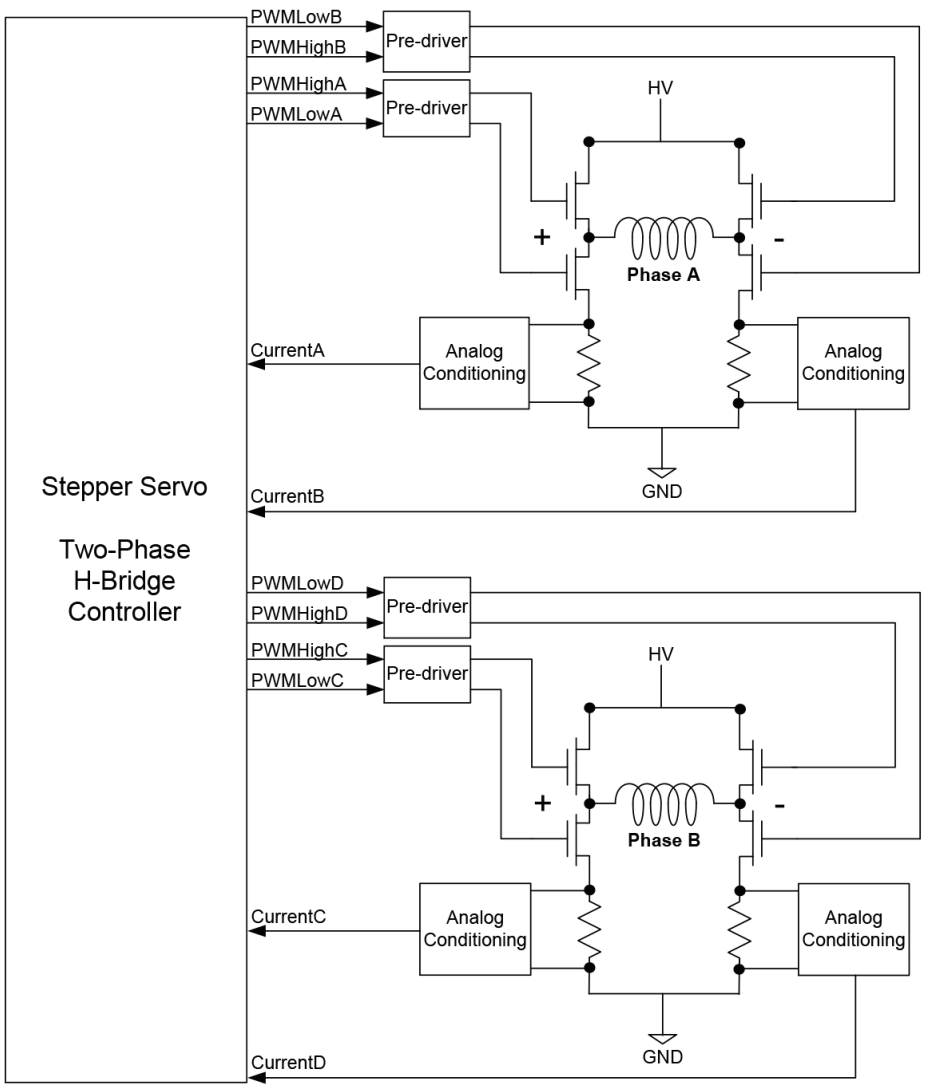


Figure 7: Bridge Control and Current Sense Scheme

TRADING UP

A stepper servo can be incorporated as needed for brand new machine designs if the performance and economics are beneficial. But for existing designs that already use a traditional pulse &

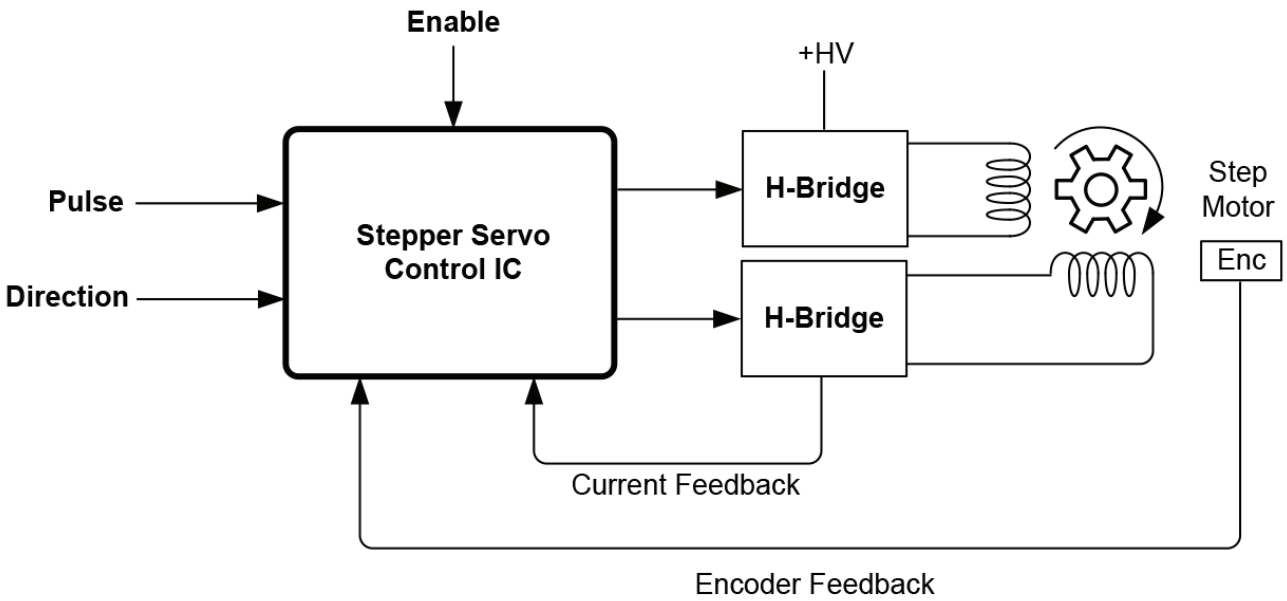


Figure 8: Stepper Servo Pulse and Direction Control

direction scheme and amplifier.

Luckily new ICs have been released, which can help upgrade an existing step motor control system for stepper servo operation. These products input a pulse and direction input stream and encoder and provide amplifier outputs compatible with a fully controlled H-bridge current control scheme. Many of these motion control ICs even provide FOC current control.

ICs such as this that let you plug in a 'black box' function for converting a traditional step drive to a stepper servo scheme make upgrading an existing system relatively easy without rewriting the profile generation software. These ICs also tend to come with Developer Kits and Exerciser software making it easy to do side by side comparisons of the old system with the new stepper servo based system.

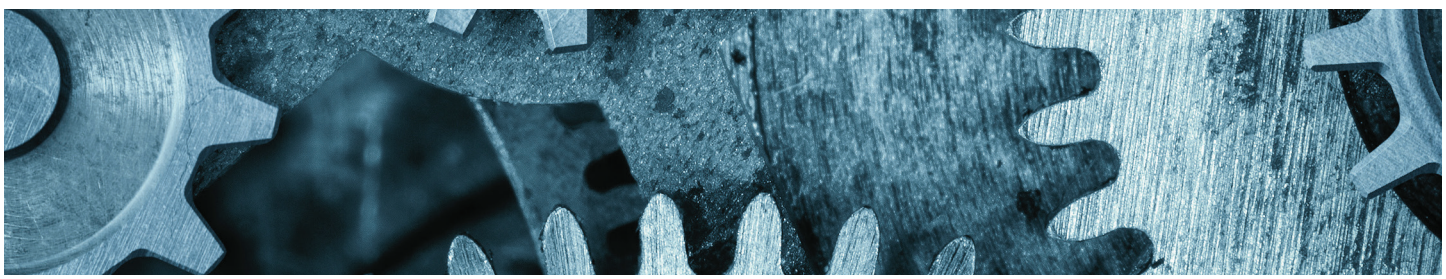
IS A STEPPER SERVO FOR YOU?

Hopefully, you have enjoyed this technical briefing on the up and coming stepper servo control mode. Although it has been on the scene for more than ten years, it is only in the last few years, with the availability of cost-effective and high-resolution encoders and dedicated low-cost stepper servo ICs, that this technique has started to see more widespread adoption.

Nevertheless, each engineer must determine whether stepper servo has a place in their machine design. Because of the need for an encoder, stepper servo is not a good match for basic low-cost motion applications where a regular step motor will do. Also, in high-speed applications, the Brushless DC motor is still the go-to choice.

But in cost-sensitive applications that require high torque output and rapid acceleration, step motors controlled with a stepper servo technique represent perhaps the best solution on the market right now. These applications include pick & place machines, coil winding, die bonding, embroidery, textile equipment, etc.

Should you use a stepper servo in your next design? As always, the details of your application will dictate the correct design choice. But without question, machine designers should be aware of what the stepper servo control scheme can offer because it is one of the most critical developments in motion control in the last ten years. wn



ROBOTIC PROCESS AUTOMATION

Automation of Processes to Enhance the Human Component of Work 4.0.

Most organisations today understand the importance of investing in Robotic Process Automation (RPA). But on a practical deployment level, RPA projects are live and dynamic, naturally requiring fine-tuning and updates to ensure smooth and successful project implementations.

BY | LAURA BORGHESAN | DANILO VALDATI
KIRAN KUMAR | PIERLUIGI PLUVIANO

Use the right approach, technologies and methodology is the key to a successful RPA project. Herewith are a few steps for choosing the right processes relevant for RPA, discover the value of RPA and define the identity of the right partner that can stay with you in an RPA transformation path.

WHAT IS RPA AND ITS CLASSIFICATION?

The Institute for Robotic Process Automation (IRPA) defines RPA as the application of technology. This technology allows employees in a company to configure computer software or a robot to capture and interpret the existing applications for processing a transaction, manipulating data, triggering responses and communicating with other digital systems.

RPA emulates a "virtual human" and takes artificial intelligence and expert systems to a higher level. The ability of a software robot to adapt to circumstances and situations, compared with traditional automation systems, making it eligible for almost any function in an organisation, in any sector. RPA holds the top position in any company's information technology infrastructure. It drives the application software more smartly as a human employee would do, with the same access rights. This allows any organisation to implement the technology quickly and

efficiently without changing underlying systems and processes.

As markets and technology change and evolve, so do systems and processes. RPA enables companies to react quickly, without recoding or reconfiguring projects or developing new interfaces. RPA in one form or another will be around for a long time for this reason.

In short, RPA is an automation framework. However, it is not desktop software client automation like scripting, screen scraping or macros, which are easy labels to categorise or diminish or dismiss its impact. These labels also make it easy to "understand" where it fits in the technology stack. RPA framework drives smarter customer service by integrating with leading cognitive computing technologies such as AI, Machine Learning, OCR, NPL, enabling RPA a major enabler in a Digital Transformation era.

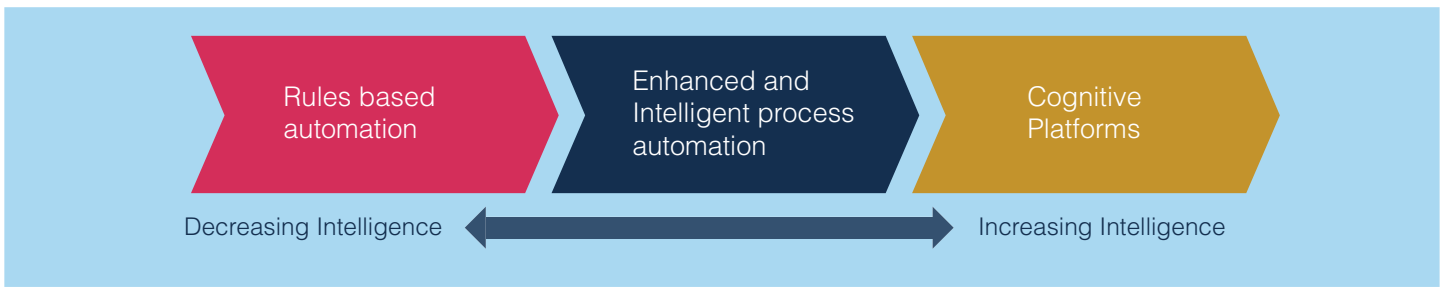


Figure 1

RPA CLASSIFICATION

There are three classes of RPA technology. The first one is basic process automation, which focuses on automating tasks that depend on structured data (data in spreadsheets, CSV and XML). Easier implementation and management of Class I automation is increasingly adopted.

Class II, or enhanced and intelligent process automation, works mainly with unstructured data as input (e.g., email and documents). This type of automation can learn from experience and apply the knowledge to process different requirements. The third class, of cognitive platforms, can understand Customers'Customers' queries and execute tasks that previously required human intervention.

HOW DOES IT WORK?

Users, employees today are generally under pressure to navigate volumes of content and perform multiple tasks. Such tasks are not only demotivating people, but they also open the door to error.

Advanced process automation solutions enable you to:

- Identify inefficient, automatable processes.
- Optimise these with guidance messages in dynamic context popup for next-best-action and real-time training, decision nodes.
- Simple design of intuitive, unified desktop with quick links to data for accurate information to help humans work more efficiently, accurately and faster.

While Robotic Process Automation - also referred to as Unattended Automation, can also be thought of as a virtual employee. Server-based RPA automate complete processes that do not require human judgement or intervention. RPA works with your existing applications, process-independent and thus carries out structured processes automatically. No changes have to be made to existing systems – RPA does the job just like your employees do. Thus RPA can automate various processes by industry and by role, including invoice processing, report generation, employee onboarding and many more. With Robotic Process Automation, business processes are carried out quickly, without errors and fully automatically.

The unique collaboration of the human and virtual workforces reinvigorates humans to focus better and access creative thinking.

By creating Collaborative Automation solutions with a combination of Smart Virtual Assistant and Robotic Process Automation, this approach to human-bot interaction, people are not out of the loop, and the robot is at the person's service. This creates empathic automation flows between humans and bots following the idea and approach to deliver automation.

Level	Types of RPA technology	Description	Estimated cost saving
Class I	Basic process automation	Macros, screen scraping and business workflow technologies in the presentation layer; not integrated into the IT system.	10%–20%
Class II	Enhanced and intelligent process automation	Technologies using natural language processing; able to understand unstructured data and apply it to process automation.	35%–50%
Class III	Cognitive platforms	Cognitive computing systems that essentially attempt to solve problems in the same way as humans, by learning from experience and acting on that learning.	>60%

Table 1: Classes of RPA technology and estimated cost savings

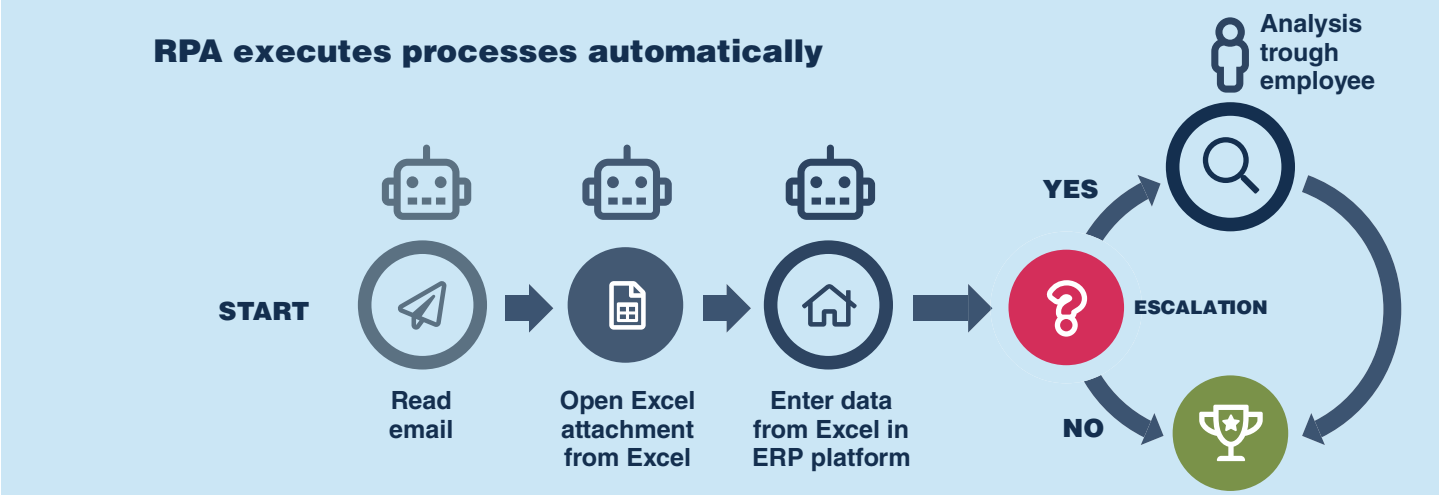


Figure 2

WHAT DOES RPA MEAN FOR YOUR ORGANISATION?

An RPA project allows the organisation to simplify its operational processes and improve the use of human capital by automating repetitive activities with low added value or presenting high risks of operational errors and, consequently, enhancing those with higher added value.

RPA solutions thus become part of the process of innovation, digitisation and transformation of a company. With the launch of RPA projects, the company organisation can achieve the following objectives:

1. Detailed knowledge of the processes carried out by the operating structures and the measurement of the commitment of the resources, valuable tools for each assessment concerning the organisational choices and the presence of possible improvement interventions.
2. Review, in a short time and with measurable results, of the business processes.
3. Dissemination of the digital evolution culture makes it possible to identify opportunities for simplification and automation of activities.
4. Implementation of a system of organisational efficiency measures, reusable over time.
5. Agility in the development of automatic procedures according to a little invasive process of information systems and IT professionals' low involvement.
6. Possibility of synergistically combining RPA and other technological platforms, such as BPM, Document Management and specific tools such as Document Capture.

THE VALUE OF RPA

DECREASED OPERATIONAL COSTS

Offshore outsourcing has been the favoured business strategy for reducing operational costs for the past few decades. This is because labour is costly in western countries compared with developing countries such as India, Bangladesh, Vietnam, and the Philippines. US multinational firms hired nearly 2.4 million offshore employees and cut 2.9 million jobs in the US between 2000 and 2010.

Offshore has its costs, but it is not nearly as high as payroll within the US. RPA technology has proven to cut the cost of a full-time offshore equivalent (FTE) to half.

One of the most potent benefits of RPA is the scalability of its usage across industries: it can work 24 hours a day for 365 days a year with 100% accuracy.

DATA ANALYTICAL ABILITY

The software robot generates process logs whenever it executes work. These contain many management information (MI), which can be further analysed for improved decision-making. This is possible at both the micro and macro levels of business processes. As processes are micro-managed, this would enable companies to track gaps and deploy measures to optimise further. In addition, through process mining methodologies and tools, it is possible to introduce the concept of "Process Intelligence", i.e. the collection and presentation of data for strategic decision-making support on processes. The ability to extract data and build reports enables an in-depth view of the process, scenarios and processing times, exceptions and service levels. This Process Intelligence gives management a holistic view of how productive or unproductive process flows work, which path was the quickest and efficient - it means a best practice has been detected as a model to be replicated - or which path

was slow and required attention or a re-design or a new automation step.

IMPROVED REGULATORY COMPLIANCE

Regulatory compliance is essential for companies expanding their operations globally. A fully RPA automated process would enable them to track every step and systematically document them, and this helps companies be more compliant with industry and audit regulations.

Moreover, with the Attended Automation, users are guided in real-time, in a context manner, to ensure that they fully comply with the company's specific policies and procedures.

INCREASED EFFICIENCY

A software robot can work all day, every day a year, and does not require any time off. Typically, a single software robot can replace two to five FTEs. Software robots can execute more work in less time, 24/7, delivering results with 100% accuracy, thereby gaining control of resource requirements during peak processing periods.

INCREASED EMPLOYEE PRODUCTIVITY

Employees can devote their time to complex tasks, adding value to the existing processes, while software robots handle repetitive, tedious jobs. They can be involved in activities that call for greater human intervention, including personal interaction, problem-solving and decision-making processes.

This all adds to employee productivity and benefits the organisation on a broader scale. When appropriately used, process automation can empower users and reduce process errors dramatically.

REDUCED ERROR RATE AND DELIVERY RISK

Software robots virtually eliminate processing errors if a process is optimised correctly and its subprocesses are mapped. However, they require testing, training, and governance to achieve desired outputs.

INCREASED CUSTOMER SATISFACTION

Automation results in more efficient and error-free processes, giving employees more time for direct interaction with customers, enhancing their experience, improving customer satisfaction and building their relationship with the company.

WHICH PROCESSES ARE RELEVANT FOR RPA?

Organisations are constantly identifying processes that can be automated. The best candidates for RPA have the following three key characteristics:

- Actions are consistent, with repeated steps.
- Template-driven, with data, repetitively entered in specific fields.
- Rules-based to allow decision flows to alter dynamically.

Figure 3 illustrates the effective use of RPA by individuals and teams.

The approach should be assessment-oriented through direct process observation and analysis - see Fig 4. The framework is based on several steps:

1. Processes analysis to obtain a detailed activities map.
2. Time measurement of the processes using the observation and the resources interview.
3. Analysis results to find the RPA complexity and the potential benefits.
4. Creation of a decisional heatmap of the eligible processes for RPA.

STEPS IN AN RPA JOURNEY

Every journey is unique, reflecting strategic priorities; timelines are also unique, varying following process complexities, resourcing and compliance requirements. However, we identified these three stages as part of every RPA evolution process.

1. PILOT

This first step does more than proving how RPA can boost success, and it allows the organisation to decide the role the RPA tool should play on their Digital Transformation journey.

The enterprise must first identify the right automation partner with talent and competence before selecting and implementing the technology.

At a glance, key activities include:

- Selecting the partner which will bring you on the right track of the Digital process transformation using RPA building an automation team and selecting the internal RPA champion.
- Running the processes analysis with one or more operational areas, looking at the manual activities, checking with users their expectations having RPA and creating empathy discovering to-be processes

defining an RPA implementation model for the organisation.

- Identifying which operational area, which processes and sub-processes would be the most candidates to automate and prioritise them defining one as a Pilot candidate.
- Developing frameworks—deployment, communication, and governance.

According to the organisation's implementation model, an automated

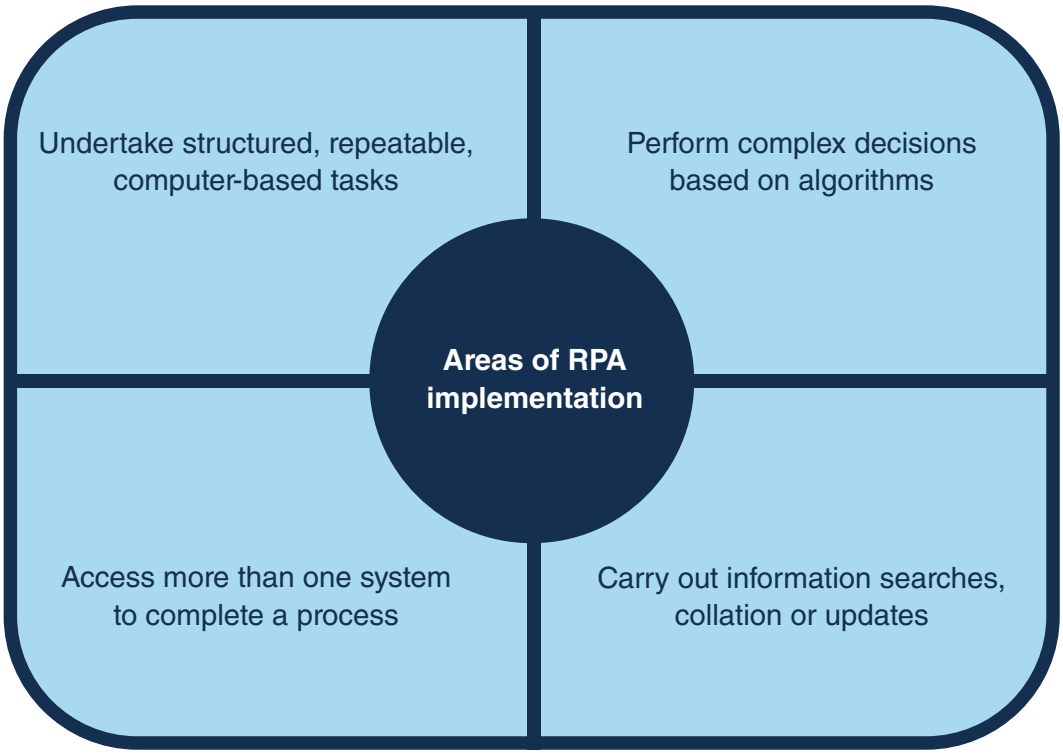


Figure 3: The effective use of RPA by individuals and teams

Figure 4: Process observation and analysis

process is run into production for the first time. This means the organisation and RPA partners apply defined requirements, a detailed solution design, test scripts and cutover/ handover plans to the selected process.

Its exit criteria monitor pilot performance. In addition, all internal and external stakeholders are surveyed for feedback. This input is the basis for documenting lessons learned and revising methodology and frameworks before ramping up.

2. RAMP-UP

The primary focuses of this step are:

- Optimising the management of the newly deployed virtual workforce.
- Establishing best practices.
- Go forward with different processes based on the prioritisation scale.
- Measure automated processes and identify steps for continuous improvement.
- Continuing to grow the internal automation team and its expertise.

During the ramp-up phase, champions should accelerate activities designed to identify further RPA opportunities within the organisation and showcase process automation successes to a broader business audience.

3. INSTITUTIONALISE

This final step aims to establish best practices for robotic processes

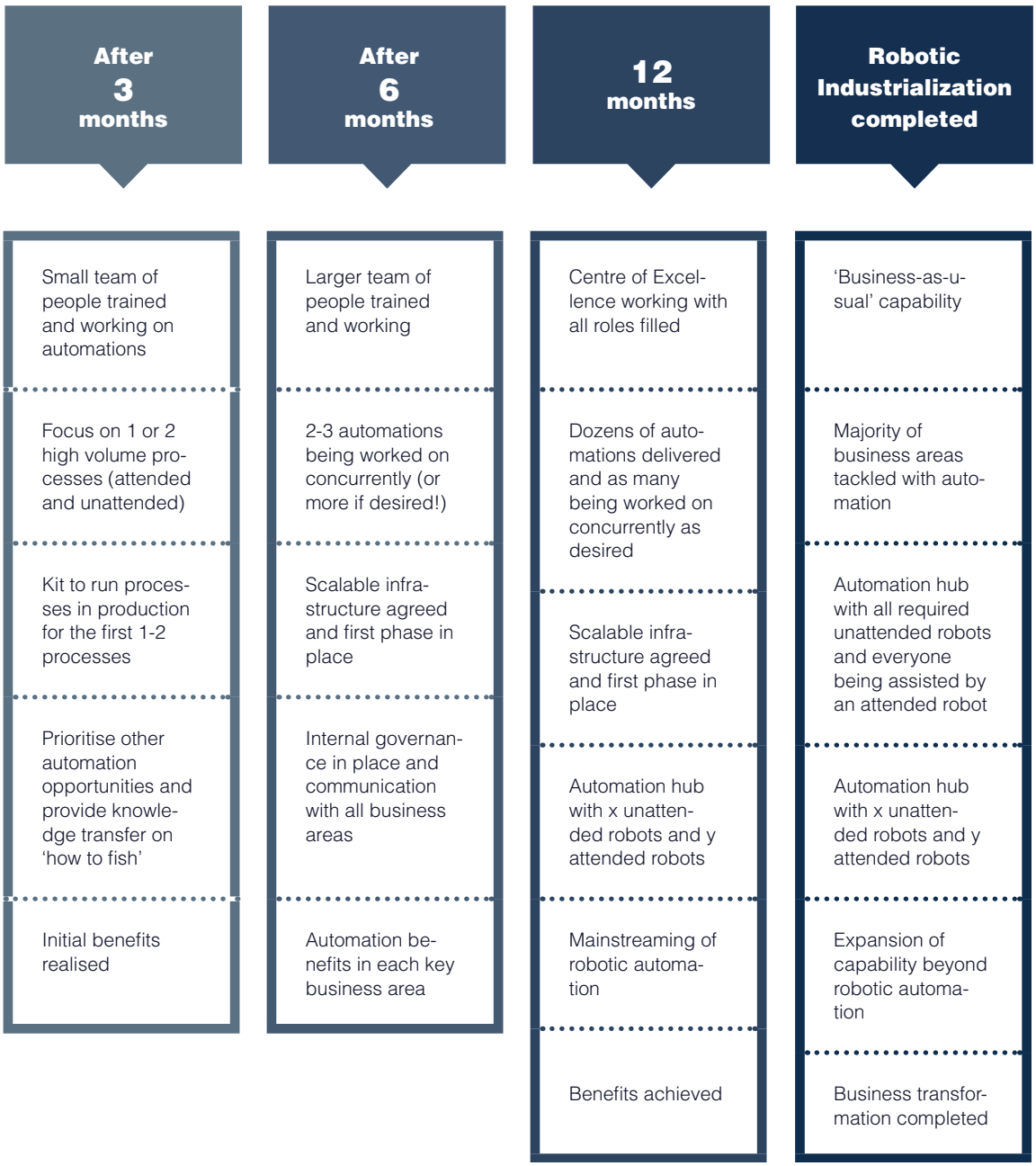


Figure 5: Long term COE Journey: how to build it

automation as a baseline activity within the organisation. Specific examples include governance board to manage the process automation pipeline demand, disaster recovery and business continuity plans, continuous improvement based on Lean Six Sigma with the automation team.

Beyond including these practices into the organisation's culture, this moment should also include a continual evangelising of RPA benefits based on existing implementations while promoting RPA as a critical performance objective across all business lines.

HOW WILL RPA EVOLVE IN THE FUTURE?

The big question is: Where is RPA headed?

The development of RPA technologies has already come a long way from the days of simple screen scraping, and RPA continues to transform how many companies approach their business activities, especially when it comes to scaling and streamlining processes.

It's a superior technology that has made its way to the forefront for the benefits it provides and the ease at which these benefits can be obtained.

Yet, the market is expected to evolve even further, and more innovative RPA solutions are predicted to emerge. The use of classic Robotic Process Automation is now considered mainstream and no longer confined to the back office.

In a race to satisfy ever-increasing and more sophisticated Customer demands, global businesses acknowledge the need to expand their digital services and capabilities. With this in mind, it is no surprise that the market has seen steady growth in the adoption of RPA solutions, which is predicted to reach a market value of BN 98$ globally by 2020.

Industry analysts expect the combination of RPA solutions with even more intelligent technologies has great potential for widespread adoption across all industries.

Machine learning and cognitive computing, for example, are technologies that involve learning on the part of the computer or software beyond their initial programming, much like a human would respond in similar scenarios.

These platforms can deal with unforeseen errors and exceptions in a business process, learning from and adapting to previous actions and experiences.

Unlike traditional automation, they can apply judgment and creativity to their work, which will essentially allow companies to automate enhanced visibility, transparency, communication, and collaboration across their value chain.

It only seems natural for instant chat and Robotic Process Automation to contribute to the customer self-service revolution. Robotic automation can bring more cognitive intelligence to chatbots by executing bespoke customer requests fully integrated into back-end systems.

This deepens the cognitive ability of the chatbots to handle a greater volume of customer requests in real-time. The emergence of more intelligent chatbots is just the start of expanding the 24-hour customer self-service domain, giving customers the flexibility to interact with service centres within a timeframe of their choice.

With the addition of RPA to increase speed and provide process automation support, the journey of machine learning and the development of even more intelligent technology will only be rapidly accelerated. The days of cognitive automation are on the horizon.

According to a Forbes prediction, 38% of organisations believe that AI and robots will be "fully implemented" in their companies within five years.

Software robots are already able to automate simple, repetitive processes. By combining RPA with these intelligent platforms, they will soon be able to improve their performance and make complex decisions with little intervention or programming by continually learning from human input.

The human workforce still plays a critical role in service operations. While intelligent cognitive robots perform customer-S and back-office tasks, the human workforce is fully present to deal with more complex, high-value-driven issues.

This can make companies more agile and responsive, crucial in today's increasingly global and complex marketplaces.

More is yet to come. AI, Cognitive and RPA as a combined group of tools can achieve organisations' goals of optimising business activities and address IT challenges in the digital age or industrial 4.0 revolution. wn

Rare-Earth Elements

The first rare-earth element identified was discovered in the island village Ytterby (Outer village) Sweden by Finnish chemist Johan Gadolin in 1794. This was the single richest source of new element discoveries ever found. Swedish chemist Anders Gustaf Ekeberg confirmed the element discovery the following year and named it yttria (yttrium oxide) with the mineral named gadolinite. Gadolinite, sometimes known as ytterbite, is a silicate mineral consisting of the silicates of cerium, lanthanum, neodymium, yttrium, beryllium, and iron.

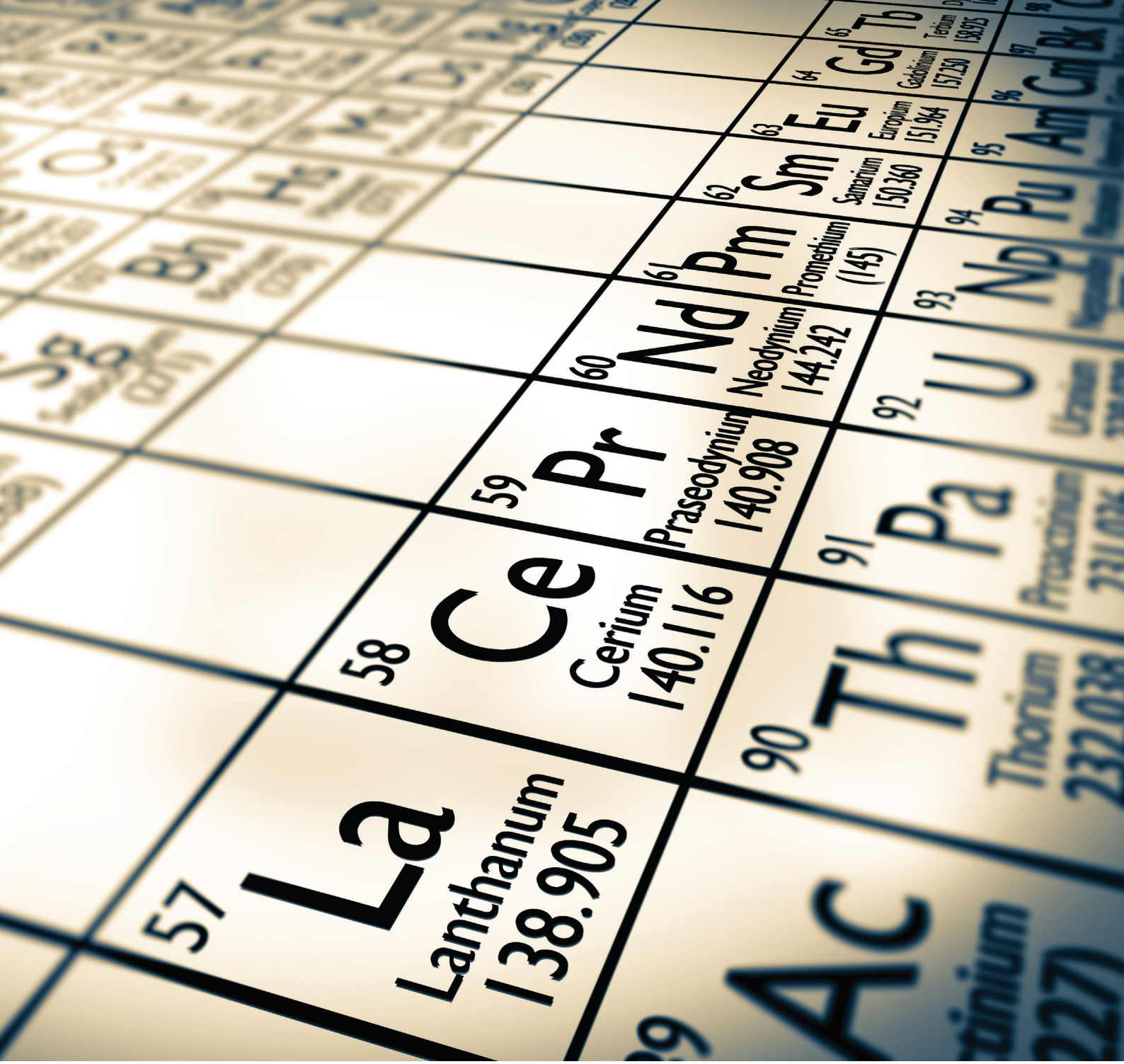
COMPILED BY | DUDLEY BASSON

The chemical elements yttrium (Y), terbium (Tb), erbium (Er), and ytterbium (Yb) are all named after village Ytterby. The rare earth elements have no biological significance, but they have great electric, magnetic, catalytic, and optical properties, making them vital to modern hi-tech engineering.

The rare-earth is made up of scandium, yttrium and the fifteen elements of the lanthanide series. The rare-earth is not all 'rare', some are as abundant as copper and nickel in the earth's crust, but they are not found in concentrated form and are widely distributed and mixed with other lanthanide element oxides.

Refining and separating the rare-earth is complex, and it requires nitric and sulphuric acids and produces large quantities of toxic and radioactive waste on a horror story scale. All rare-earth ores contain less than 10 per cent rare earth oxides (REO) and must be concentrated to about 60 per cent before being processed further. See Table 1.

Elements lanthanum to europium is regarded as 'light rare earth' and gadolinium to lutetium as 'heavy rare earth'. Some periodic table versions have different placement for Sc and Y.



Click here to see a report giving an in-depth study of the rare earth elements, including the ore deposits around the globe and the physical, magnetic and chemical properties.

For a comprehensive report on the world's rare-earth element availability, click here.

Click here for a musical setting of the periodic table.

The elements have been set to the well-known can-can tune from Offenbach's "Orpheus in the Underworld".

Didymium is a mixture of the elements praseodymium and neodymium. It is used in safety glasses for glassblowing and blacksmithing. See Table 2.

A Neodymium magnet is an intermetallic compound of neodymium, iron and boron as Nd2 Fe14 B.

Future engineering use of neodymium permanent magnets has put neodymium demand on an accelerating scale. For more detail on neodymium magnets, click here.

Promethium is extremely rare as it is radioactive with a half-life of only 17,7 years. It is found in trace quantities as a decay product of europium and uranium, and it is also produced in minuscule quantities in reactors.

H																													He
Li	Be																							B	C	N	O	F	Ne
Na	Mg																							Al	Si	P	S	Cl	Ar
K	Ca	Sc															Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y															Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Re	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Dg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

Table 1: The rare earth elements are Sc, Y and the 15 elements of the Lanthanide Series.

No.	Name	Applications	ppm
21	**Scandium Sc**	Light aluminium-scandium alloys for aerospace components, additive in metal-halide lamps and mercury-vapour lamps, radioactive tracing agent in oil refineries.	22
39	**Yttrium Y**	Yttrium aluminium garnet lasers; red television phosphors; high temperature superconductors; dental tooth crowns; jet engine alloys; coatings in engines and gas turbines; electroceramics in fuel cells; ceramic electrolyte in solid oxide fuel cell; jewellery; high temperature ceramics and cement; yttrium iron garnet microwave filters; phosphors for coating fluorescent tubes and LEDs; spark plugs; gas mantles; additive to steel, aluminium and magnesium alloys; cancer treatments; camera and refractive telescope lenses; battery cathodes.	33
57	**Lanthanum La**	High refractive index and alkali-resistant glass, flint, hydrogen storage, battery-electrodes, camera and refractive telescope lenses, fluid catalytic cracking catalyst for oil refineries.	39
58	**Cerium Ce**	Chemical oxidizing agent; polishing powder; yellow colour in glass and ceramics; catalyst for self-cleaning ovens; catalyst for oil refineries; ferrocerium flints for lighters; coatings for turbine blades.	66,5
59	**Praseodymium Pr**	Rare earth magnets; lasers; carbon-arc lighting; colourant in glass and enamels; additive in welding goggles; ferrocerium flint products; dopant of fluoride glass in fibre optical amplifiers.	9,2
60	**Neodymium Nd**	Rare-earth magnets, lasers, violet colours in glass and ceramics, didymium glass, ceramic capacitors, reluctance motors of electric vehicles, wind turbine alternator permanent magnets.	41.5
61	**Promethium Pm**	Nuclear batteries, luminous paint.	
62	**Samarium Sm**	Rare-earth magnets, lasers, neutron capture, masers, control rods of nuclear reactors.	7.05
63	**Europium Eu**	Red and blue phosphors, lasers, mercury-vapour lamps, fluorescent lamps, Nuclear Magnetic Resonance relaxation agent.	2

Table 2

No.	Name	Applications	ppm
64	**Gadolinium Gd**	High refractive index glass or garnets; lasers, X-ray tubes, Bubble (computer) memories; neutron capture; MRI contrast agent, NMR relaxation agent; magnetostrictive alloys such as Galfenol, steel and chromium alloys additive; magnetic refrigeration (using significant magnetocaloric effect); positron emission tomography scintillator detectors; substrate for magneto-optical films; high performance high temperature superconductors; ceramic electrolyte used in solid oxide fuel cells; oxygen detectors; possibly in catalytic conversion of automobile fumes; cancer therapy; MRI contrast agent.	6.2
65	**Terbium Tb**	Additive in Neodymium based magnets; green phosphors; lasers; fluorescent lamps (as part of the white triband phosphor coating); magnetostrictive alloys such as terfenol-D; naval sonar systems; stabilizer of fuel cells; solid state electronics; sonar systems.	1.2
66	**Dysprosium Dy**	Additive in neodymium based magnets, lasers; magnetostrictive alloys such as terfenol-D; hard disk drives; nuclear reactor control rods.	5.2
67	**Holmium Ho**	Lasers, wavelength calibration standards for optical spectrophotometers, high power magnets.	1.3
68	**Erbium Er**	Infrared lasers; vanadium steel, fibre-optic technology; nuclear reactor control rods.	3.5
69	**Thulium Tm**	Portable X-ray machines, metal-halide lamps, lasers; superconductors.	0.52
70	**Ytterbium Yb**	Infrared lasers, chemical reducing agent, decoy flares, stainless steel, stress gauges, nuclear medicine, monitoring earthquakes; portable X-ray machines.	3.2
71	**Lutetium Lu**	Positron emission tomography – PET scan detectors, high-refractive-index glass, lutetium tantalate hosts for phosphors, catalyst use in refineries, LED light bulbs.	0.8

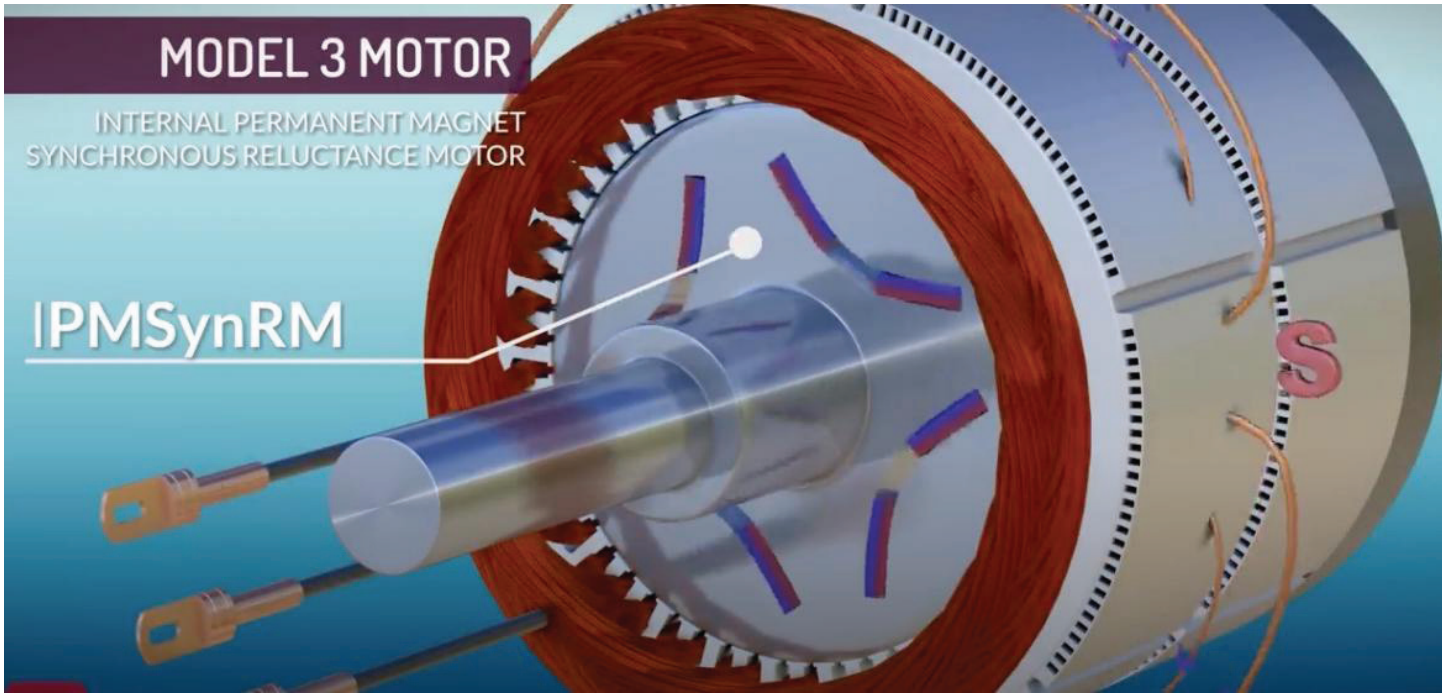
Table 2

Terfenol-D is a magnetostrictive alloy made from terbium, iron and dysprosium, and used in applications where magnetostriction can be put to advantage as in underwater acoustics. Galfenol is a magnetostrictive alloy of iron and gallium, which may be doped with gadolinium.

Click here to see a BBC report on the horrific and environmentally disastrous refining of rare earth metals.

The proliferation of enormous wind turbines is continuing at a phenomenal

GE Haliade-X direct-drive permanent magnet alternator and nacelle



Tesla vehicle reluctance motor with neodymium magnets embedded in the rotor

rate. The largest offshore turbines have now reached 16 MW. The use of permanent magnet alternators in direct drive offshore turbines is highly advantageous for reducing maintenance by eliminating a gear train. These alternators each require several tons of magnets.

Electric vehicles are set to replace fuel-powered vehicles at an accelerating pace and will be produced in their millions. This will require neodymium magnets for reluctance motors on a vast scale and will also require vast battery production.

The previously used induction motors required liquid rotor cooling through the shaft; and however, the rotors of reluctance motors have no electrical activity and require no liquid cooling.

Watch this video for the reluctance motor's design, operation, and magnetic flux circuit: 12:00 mins.)

The Tesla Model S "Plaid" made its debut on Thursday, 10 June 2021.

The vital and strategic requirements for rare-earth metals will require addressing the single-supplier situation which exists at present. Several countries have rare-earth production facilities, but none have been able to compete with China which now dominates the market.

Several exotic names represent crucial components in technologies, including smartphones, flat-panel TVs, hybrid cars, and wind turbines. The elements' rapid rise from lab curiosities to helping supply the hearts of modern electronics has put a strain upon existing supply chains. Experts worry that any supply disruptions could slow the pace of innovation. Countries worldwide have begun racing to secure new reserves, boost recycling and find material substitutes for these energy-critical materials.

Click here for a detailed look at China's rare-earth industry.

Local state-owned enterprises dominate the Chinese rare-earth industry, private firms and centrally owned state firms.

In northern China, the rare-earth industry is dominated by the Inner Mongolia Baotou Steel Rare-Earth Hi-Tech Company. In southern China, China Minmetals is the dominant player in the region. Other significant players include the Aluminium Corporation of China Limited and China Non-Ferrous Metal Mining. In 2020, China produced 140 000 tons of rare-earth.

China has two state research facilities that provide specialised research into rare-earth elements. The Rare Earth Materials Chemistry and Applications State Key Laboratory, associated with Peking University, and the Rare Earth Resource Utilization state key laboratory are located in Changchun, Jilin province.

The Chinese rare-earth industry also has two journals that publish research in rare-earth minerals: the Journal of Rare Earth and China Rare Earth Information (CREI) Journal. These journals are

published by the Chinese Society of Rare Earths, established in 1980 by Chinese rare earth researchers.

Rare-earth can be found in uranium mining tailings, which means countries rich in uranium, such as Kazakhstan, are likely to find them. Kazakhstan is globally the largest uranium producer and exporter, and as the world's ninth-largest country, there are plenty of new places to look for rare earth.

Kazakhstan produced 42% of uranium worldwide supply from mines in 2019, Canada 13% and Australia 12%. The Covid-19 pandemic has severely impacted worldwide mining.

Increased interest in a green economy and critical minerals leads to new mining and investment opportunities in Tanzania, such as the ASX-listed rare earth mining company Peak Resources Ngualla project.

"The Ngualla project is based on one of the largest and highest-grade undeveloped neodymium and praseodymium deposits in the world," says Peak Resources MD Bardin Davis.

The project aims to become one of the world's lowest-cost, fully integrated rare-earth producers.

"Our goal is to develop the Ngualla rare earth project, which is going to deliver multi-generational benefits to the community and the people of Tanzania while providing robust returns to our shareholders," says Davis.

The project entails the construction of a mine and concentrator, which is projected to produce an annual 32 000 tons of concentrate at a grade of 45%.

Ngualla is a weathered carbonatite area with a high-grade bastnaesite (one of a family of three carbonate-fluoride minerals) zone, which is important because it is low in acid consuming elements as radionuclides. This supports lower acid consumption in the refining process and a more efficient flowsheet while avoiding issues with elevated levels of thorium and uranium.

South Africa's Steenkampskraal rare earth mine is situated in the Western Cape, and the mine reserves contain all fifteen lanthanides rare earth. The mine has one of the highest grades of rare earth elements (REE) in the world. It has a Mineral Resource Estimate (MRE) of 605,000 tons at an average grade of 14,36% and a total rare-earth oxide (TREO) including Y2O3 for 86 900 tons.

The NI 43-101 Mineral Resource Estimate includes 15 630 tons of neodymium, 4 459 tons of praseodymium, 867 tons of dysprosium and 182 tons of terbium. The combined grade of these four crucial rare earth ores is 3,49%, higher than the total rare-earth grades in most other deposits. Thorium reserves have been estimated at 148 000 tons. Click here for info and video of the Steenkampskraal rare earth mine.

Steenkampskraal was the world's largest producer of rare earth minerals. Between 1952 and 1963, Anglo American mined the deposit primarily for radioactive thorium, used as fuel in nuclear reactors in Britain, Germany and America.

Anglo American shut the mine when nuclear reactors worldwide switched to uranium. Uranium and thorium are elements of the Actinide Series.

There is the potential to increase further the resource within and beyond the current mining rights area. The neodymium grade, on its own, is

RARE EARTH PRODUCTION 2020		
COUNTRY	**RESERVES MILLION TONS**	**PRODUCTION TONS**
China	44,0	140 000
US	1,5	38 000
Greenland	1,5	
Myanmar		30 000
Australia	4,1	17 000
Russia	12,0	8 700
Madagascar		8 000
India	6,9	3 000
Thailand		2 000
Brazil	21,0	1 000
Vietnam	22,0	1 000
Burundi		500
Afghanistan	1,3	
Kazakhstan		
Tanzania	0,89	
South Africa	0,60	(2 700)

2,58% which is higher than the total rare-earth grades in most other rare earth deposits.

Efforts are being made in the US to rebuild a domestic supply chain.

The recent past provides cautionary tales, such as Molycorp, which reopened the longstanding Mountain Pass mine in California in the early 2000s, only to go bankrupt in 2015.

MP Materials bought the mine and restarted production in 2017. The Las Vegas-headquartered company is vying to restore the domestic rare earth supply chain from mine to magnet. It is hedging its bets on neodymium-praseodymium, with the hope of becoming the lowest-cost producer.

One of the company's largest customers is Shenghe Resources, a Chinese company responsible for processing, distributing and refining, which also owns a stake in the company. According to Reuters, the connection raised some concerns among DOE scientists, but government funding has continued for a rare-earth separation facility.

Shenghe Resources distributes the concentrate produced at Mountain Pass to refiners in Asia, "capabilities that simply do not exist at scale in the West", according to an MP Materials spokesman.

Ultimately, the company, which went public last year through a SPAC (Special Purpose Acquisition Company) merger, plans to "restore the full rare earth supply chain" to the US, the spokesman said, including refining, separation and magnet-making by 2025, as the domestic electric vehicle market ramps up production.

Another key player is Lynas Corporation, one of the largest processors of rare-earth outside China. This Australian mining company, which operates a separation facility in Malaysia, recently received $30,4 million in funding from the Pentagon to build a Texas light rare-earth processing facility. They earned another contract with Blue Line Corp., also based in Texas, to build a heavy rare earth separation facility.

A Lynas spokeswoman referred to the new facilities in an email to CNBC (Consumer News and Business Channel) as an "essential foundation" for renewing downstream metal making and implementing magnet manufacturing into the US. She wrote that diversifying outside the Chinese magnetic materials supply chain is vital to create competitive markets and meet the growing demand for 21st-century technologies.

While companies like Lynas and MP Materials are eager to ramp up the domestic supply chains, extracting rare-earth is a complex process due to a combination of environmental, technical and political factors. Many regions, including the European Union, have an abundance of these resources but lack the expertise that other countries like China have in processing ore and magnet production.

The rare-earth industry has come under fire for environmental concerns. Many rare-earth elements reside among mineral deposits with radioactive materials that can leach into the water table. Mining, processing and disposal can also contribute to ecosystem disruption and release hazardous by-products into the atmosphere.

The proliferation of electric vehicles will result in a considerable increase in battery production. Lithium-ion batteries do not contain rare-earth elements but do contain about 3% of cobalt. Much effort is being made to develop cobalt-free batteries, which will also significantly reduce the cost.

Cobalt is also used in computers, cell phones, high-performance alloys for jet engines and turbines, orthopaedic prostheses, alnico magnets and dentures. New research on the sodium-ion battery has been announced, and this contains no lithium, nickel or cobalt. Another new development is the iron-air battery, but this will not be suited to vehicular use.

There are significant human rights issues in the use of cobalt which is mainly supplied from the Democratic Republic of Congo (DRC), where there is a proliferation of 'artisanal' mines using forced child labour. It is estimated that there are as many as 100 000 artisanal miners in the DRC, and there are approximately 23 international and local mining companies active in the DRC.

Forced child labour is widely condemned, causing ethical mining companies to refuse dealings with the artisanal miners. The prices for artisanally mined minerals have fallen due to Covid-19, plunging the involved communities even deeper into poverty. There is no simple solution to this problem.

Watch a video of DRC artisanal mining (4:45 mins.).

The DRC supplies over 70% of globally produced cobalt and copper, diamonds, tantalum, niobium, lithium, tin and gold. It is widely known to be globally the wealthiest country in terms of its vast untapped mineral resources, estimated to be worth US$24 trillion.

Mountain Pass REE mine in California

We have here the bizarre situation that the country has fabulous wealth below ground and abject poverty above ground.

Studies in 2018 reported a significant high-grade lithium deposit estimated at 1,5 billion tons of lithium spodumene (lithium aluminium inosilicate), which will be significant to the expected vast increase in vehicle battery production. The Congo river, the second largest globally, provides almost unlimited water supply and vast hydroelectric potential.

The minerals ranked as most critical by the United States, Japan, Republic of Korea, and the European Union, including the United Kingdom, are as follows: Rare-earth elements include neodymium, gallium, indium, tungsten, platinum, palladium, cobalt, niobium, magnesium, molybdenum, and antimony lithium, vanadium, nickel, tantalum, tellurium, chromium and manganese. South Africa is very well endowed with several of these minerals.

A largely untapped source of strategic minerals is to be found in Afghanistan, which has enormous reserves, including copper, cobalt, gold, platinum, chromium, aluminium and lithium, and rare earth, estimated at $1 trillion. It remains to be seen what transpires in this troubled country.

Despite the enormous potential demand for neodymium magnets in wind turbines and electric vehicles, development in this direction is not a foregone conclusion. Further development may depend on the establishment of secure material supply chains. Most wind turbines operate satisfactorily without direct drive alternators, and most electric vehicles still operate with induction motors. Suppose rare-earth minerals are to be mined and refined on an increasing scale. In that case, international legislation will be required to ensure that pristine ecosystems are not destroyed by mining, and adequate measures must be in place to ensure that the hazardous waste material from refining rare-earth is adequately and safely dealt with. Sending rare-earth ores for refining in countries with lax pollution control is not an acceptable solution.

An effective Cyber Recovery strategy is key to recovery from ransomware attacks

South Africa is an attractive target for cybercriminals for a number of reasons, and the last few years have seen a sharp rise in high-profile ransomware attacks.

BY | LOURENS SANDERS
SOLUTION ARCHITECT AT INFINIDAT

One of the key motivations driving this volume of attacks is the fact that data is a de facto currency and an extremely valuable commodity on the black market. While backup is a critical component of data protection, when this backup is also encrypted by malicious software, companies are often left with few options other than to pay the ransom.

Therefore, an effective Cyber Recovery strategy, which enables businesses to get back up and running without having to give in to criminal demands, is the key.

RANSOMWARE ON THE RISE

The rapid adoption of digital transformation, Artificial Intelligence (AI) and the Internet of Things (IoT) has left vulnerabilities in security. In the wake of the pandemic, is has been a challenge to roll out cutting-edge technology, while also addressing the specific aspects of security that should be done in conjunction.

As a result, this has made local businesses appealing targets for strategic attacks. According to Kaspersky, South Africa ranks third in the world for the highest number of users experiencing targeted ransomware attacks. There was a 767% increase in targeted ransomware from 2019 to 2020, while general ransomware attacks decreased by 29%.

HELD TO RANSOM

Another concerning trend highlighted by Kaspersky is that 42% of ransomware victims in South Africa paid a ransom in the hope of getting their data back, because they do not have the appropriate systems in place to recover on their own. While almost half of victims surrender to paying the ransom, less than half get their data back, which perpetuates the cybercrime cycle.

Backup solutions have been the mainstay of data protection for many years, but they are no longer sufficient. Standard backups do not provide a high level of granularity and can also take some time to recover. They are also a one-dimensional approach to data protection. If that data is corrupted, infected or otherwise compromised, businesses are left stranded. Cybercriminals are increasingly targeting backup solutions, so although data backups remain essential, they are of no use in a targeted ransomware attack because the backups themselves are also encrypted and held to ransom.

HOLISTIC, STRATEGIC

When a data loss event occurs, for whatever reason, the goal is to restore a business to an operational state, where key applications and services are made available as quickly as possible. Without a holistic strategy, which addresses security gaps and allows businesses to recover their data, mitigating the risk of a ransomware attack is all but impossible.

A comprehensive Cyber Recovery strategy is necessary to allow for numerous options for recovery from multiple copies of your data, including snapshots, clones, replicas, or actual backups. This not only addresses the need for enhanced granularity when backing up and recovering, it also protects key applications and services. This enables recovery in the shortest time frame possible, with multiple recovery points to choose from. Furthermore, a thoroughly implemented strategy ultimately ensures your data protection environment will not be compromised by ransomware.

RESTORATION IS THE KEY

The ability to restore data in the case of loss, damage or compromise, especially from a cybersecurity-related incident, is essential to business continuity. Ransomware fees and downtime could end up sinking a business, whereas with an effective restoration and recovery strategy, the impact is minimised because there is always a validated, uncompromised copy of data available.

Today, more than ever, it is critical to adopt best practices around data protection strategy, incorporate processes that validate backups and test restores, and ensure proactive monitoring and alerting to detect anomalies.

Purpose-built data protection technologies offer the ability not only to protect production data, but keep those copies safe and reliable for recovery – a critical requirement in a world where cybercrime is on the rise. wn

Cyber Security

What role would Cyber Security play in standardisation to ensure the increased resiliency of our national electrical grid, and how would this impact different parts of the economy and society?

BY I ZUKO MZEKANDABA (ESKOM - SENIOR ENGINEER)

In the context of a six-pack 600MW power generating site, I have often wondered about the topic at hand. We have upgraded our legacy power generating sites to entail Substation Automation Systems (SASs) to reap the benefits of remote plant control, monitoring, event recording and the interoperability of IEC 61850.

However, this comes with its curveball called cyber security. I found myself wondering about a criminal that would breach or infiltrate cyber security (this is too ghastly to contemplate) and open our generator circuit breakers. For a six-pack 600MW power generating site, this would mean a loss of 3600 MWs generating capacity. While drafting this article, I read the South African Power Utility National Control morning report that Friday and the evening peak was forecasted to be 30945 MW. God forbidding should we experience a cyber-attack at one of the power generating sites that would lead to a loss of 3600 MWs generating capacity (depending on energy reserves). This would immediately bring us to the introduction of load shedding. Stages of load shedding are well published and available to the public; therefore, I will not expand on this further. As an apprentice at the South African Power Utility, I came across a Generator Basic Engineering Training Manual that stated the all generating machines are connected or synchronised in parallel to a large (National) Grid. This applies to the article at hand, and I had to know it for an exam on generating machines to explain some related concepts such as generator excitation etc.

Another training document defines load curtailment and load shedding as the following "The load reduction obtained from customers who are able and willing to curtail usage of power. These loads are to be curtailed within 1 hour of the instruction being issued by National Control (via the Distributor Network Management Centres)" and "The load reduction obtained by manually shedding load at convenient points on the distribution system within 10 minutes of the instruction being issued by National Control", respectively. "When the system (National Electricity Grid) is tight, and supply is constrained, then this causes a slow decline in frequency". So I ask myself the question: "what role would Cyber Security play in Standardisation to ensure the increased resiliency of our National Electrical grid", my answer is "a significant role". We need to prevent multiple unit trips and unwanted access to our communication networks when we return from a multiple unit trip incident at our legacy power generating sites. Therefore Cyber Security standardisation will ensure the increased resiliency of our National Electrical Grid. Like in any

engineering design, standardisation also assists in easier maintenance, operation, and engineering.

To comply with the South African Grid Code, for National Electricity Grid resilience purposes, i.e. generating machines are contracted to participate in Instantaneous and Regulating Reserves and are put on Automatic Generator Control. There is an extensive geographical distanced operational technology communication network between legacy power generating sites and National Control (using IEC 60870-5-101 protocol) to achieve Automatic Generator Control (between the generating site Electrical and Control & Instrumentation systems we use IEC 60870-5-104). The question is whether or not the cyber security for this activity is standardised across all legacy power generating sites to improve and ensure the resiliency of our National Electrical Grid. What is pleasing is that the South African Power Utility has a standard for operational technology titled "Cyber Security Standard For Operation Technology", which captures the use of Virtual Private Networks (VPN) that provide secure internet connections. This is relevant today more than before as we enter into level 4 lockdown, and an increasing number of employees will access generating plant information from home. In some special conditions, employees will even be able to execute plant commands from the comfort of their homes. For example, when I was writing this article, I accessed the South African Power Utility National Control morning report via a VPN connection.

However, my personal favourite for governance documents that aim to standardise cyber security has to be "Information Security – Information Technology /Operational Technology and Third-Party Remote Access Standard". It gives some assurance or ease for managing outside organisational access to the power generating site operational technology communication network. I realised many things when I sat down and started gathering my thoughts around the topic at hand. In the past, the South African Institute of Electrical Engineers, wattnow magazine published an article stating that South Africa is losing the little cyber security skills it has to other foreign nations. Retaining these cyber security skills is of national importance to maintain and improve a resilient National Electrical Grid. Furthermore, during my time as an electrical engineering student, just over ten years ago, data integrity in communication networks was taught at university level, as we thought about encoding, encryption, decoding, decryption, to name a few. Therefore, I think cyber security should be taught

at university level to ensure that there is an over flux of cyber security skills in the country, as local talent keeps on being recruited overseas, all of this to maintain and improve a resilient National Electrical Grid.

I find it fitting here to provide definitions for Operational Technology before raising my next concern on cyber security and its immediate impact on ensuring increasing resiliency of our National Electrical Grid.
The definition is an extract from "Cyber Security Standard For Operation Technology", a governance document in the South African Power Utility when it comes to matters of this nature.

"Operational systems which form part of South African Power Utility's plant/ network assets, and which could by design, maintenance or operation directly fail these assets to meet their purpose and performance criteria, where:

1) **Operational systems:** are all systems (including electronic, telecommunications and computer systems and components) that process, store or communicate operational data or information.
2) **Part of:** means contribute to the asset meeting its purpose and performance criteria.
3) **Plant/network assets:** are any part of the "built environment" utilised by South African Power Utility to run its production, delivery and logistics processes, including generation, transmission and distribution of electricity, etc.
4) **Directly:** means in real-time or near real-time e.g. would include supervisory control systems, but would exclude spares ordering applications (even though these could eventually fail the asset).
5) **Purpose and performance criteria:** The "design to", "maintain to", and "operate to" criteria that are generally specified formally."

A majority of Operational Technology (OT) is intentionally separated from Information Technology (IT). However, plant areas such as the Energy Measurement Data Acquisition System (EMDAS), which provides historical data reporting and real-time visualisation of power generation and consumption, merges both OT and IT with installed cyber security devices such as firewalls in between OT and IT.

The real-time visualisation of power generating product sales and if these values are tempered with it would negatively impact the National Electricity Grid since they are used for production bidding, perhaps electricity forecasting. This is also of great concern because it is said that hackers use cookies (which store information) to find credentials or hack a database on the internet.

With multiple users having access to the real-time visualisation of power generated, we need to move away from using one common password for different websites, work login credentials, or save our passwords on the internet or intranet. Although an Act Management of passwords or cyber security best practices for passwords will go a long way in preserving a resilient National Electricity Grid.

To further expand on the realities of cyber threats, although on the IT domain, Professor T. Marwala wrote in one of his books, "According to a 2019 Mimecast report, 88% of South African organisations had experienced a phishing attack in the previous twelve months". Cyber-attacks are a reality in the country, and the National Electrical Grid is no exemption to these attacks.

E.Etim and O. Daramola wrote that "generally, the informal sector is the means of survival for poor people in slums ..." in looking at how this impacts different parts of the economy and society.

I found it fitting to start by looking at the so-called informal sector or economy. Primarily because these are people surviving on hand-to-mouth, at times voiceless, and mainly with no reserves of resources, they also contribute to the economy, accounting for 6% of GDP (Gross Domestic Product) in 2014.

The Labour Caucus in the Jobs Summit Small and Microenterprise Support working group revealed that "Statistics South Africa's non-agricultural labour force data show that 4.5 million people are in informal employment. Four hundred thousand of these workers are employed in the formal economy but under precarious conditions, another 1.3 million as domestic workers, and 2.8 million in the informal sector. Further interrogation of informal sector data shows that own account workers largely constitute it – street and spaza shop traders, taxi drivers, construction workers, educare providers, waste recyclers, tailors, shoe repairers, bush mechanics, among others".

I want to argue that in the informal sector, especially with the alarming youth unemployment rate, job seekers who use internet cafes amongst others are dependent on electricity for survival and are instantaneously and negatively impacted by load shedding. I have seen some of these negative impacts with my own eyes. I believe we cannot afford to have another contributing factor towards load shedding in the form of a non-resilient National Electricity Grid that is vulnerable to cyber-attacks. It is

often said that there are societies in the country that remain side-lined and marginalised, and I believe they will be most hit by a National Electricity Grid that is not resilient. To ensure that I am understood, GG Alcock once wrote that "race does not determine to understand", and my deduction based on context is that poverty does.

Secondly, A. Goldberg research in 2015 found that on a conservative estimate of R716 million has been invested by retailers in backup power generation. This takes us away from the profits in a sector that is said to be one of the largest industries in the South African economy, accounting for 14.8% of GDP (Gross Domestic Product) in 2014. In the electrical engineering field, it is known that backup power generation has standby time, be it batteries or diesel. These I have observed to be a majority in the retail space. I, therefore, would like to argue that load shedding or loss of generating capacity arising from cyber-attacks would result in prolonged outages that we have yet to experience in the country.

I argue this because I have recently witnessed a mutual financial services company in South Africa that focuses exclusively on graduate professionals experience a cyber-attack at the beginning of March 2021. This cyber-attack lasted for over a month. For example, during that period of a cyber-attack on their systems, I could not even update my short term insurance which is the car insurance at the mutual financial services company. Imagine if that happens to our National Electricity Grid? I don't want to be a doom monger, but as my predecessors had predicted that the South African Power Utility would struggle to supply electricity to the country at some point, it is also my prediction that if we do not standardise in cyber security practices, the National Electricity Grid will be hard hit. It is of paramount importance that we have a standardisation cyber security that would ensure the increased resiliency of our National Electricity Grid because if we don't, we will hamper our already struggling economy.

We all know the link between a struggling economy or struggling growth in GDP and inflation rate, which increases the cost of living, affecting all societies in South Africa. Professor T. Marwala writes in one of his books states that "the CSIR (Council for Scientific and Industrial Research) has estimated that the cumulative cost of load-shedding to the economy in 2019 was between R59 billion and R118 billion". I cannot stress enough that we cannot afford to have another contributing factor to load shedding in the form of a non-resilient National Electricity Grid that is vulnerable to cyber-attacks.

Lastly, I would like to touch on the critical economic sector, finance, real estate, and business services, contributing around 22% to GDP. General government services follow this at 17%, and then the wholesale, retail and motor trade, catering and accommodation sector at 15%. Manufacturing is fourth, at 14%.

It is not rocket science that all the sectors mentioned above are positively impacted by the resiliency of our National Electricity Grid. This should be noted since they are the backbone of our economy. In line with this article, I would like to expand on manufacturing as a large electricity consumer. As an example of social development, consider the historical influx of people to a South African cosmopolitan city with more than four million people due to the then gold rush. "It is located in Gauteng, the smallest of the country's nine provinces, which contributes around 40% to South Africa's GDP". Therefore I would like to argue that social development in towns and cities in South Africa is dependent on industrialisation or manufacturing. Industrialisation or manufacturing consume large amounts of electricity and is dependant on electricity for their production. Therefore, not standardising cyber security to ensure a resilient National Electricity Grid will negatively impact industrialisation or manufacturing. This directly negatively impacts the economy, and as I have argued, this will also negatively impact the social development in various affected societies.

The article is simply a glimpse at how I view cyber security and the National Electricity Grid as I navigate through my daily deeds and execute my functions at a generating power site.

K Nyakanyanga wrote an article in 2020 that stated that "cyberattacks cost South Africa more than R2.2 billion a year", which I once shared as a safety topic to my colleagues to be alert when sharing their information on the internet and warning against phishing emails. It is also my view that South Africans needs to pay special attention to cyber security threats.

As electrical engineers, we need to protect and preserve the resilience of our National Electrical Grid, as this has a direct impact on the country's economy and social development. In alignment with National Key Points Act 102 of 1980, which states that "If it appears to the Minister at any time that' any place or Declaration of area is so important that its loss, damage, disruption or any the or immobilisation may prejudice the Republic; or whenever he considers it necessary or expedient for the safety of the Republic

Point, or in the public interest, he may declare that place or area a National Key Point". Our National Electricity Grid are a National Keypoint, and their safeguarding against cyber-attacks are of national importance.

Therefore the concerns raised in this article ought to be acted upon swiftly by all involved in the field. As our electrical plants are upgraded, or new plants are built, digital transformation will bring cyber security challenges; therefore, as electrical engineers, we need to continually identify cyber security risks and formulate mitigating strategies or technologies. Other considerations in mitigating against the threats of cyber security are VPN white-lists and Cyber Security simulation tests. For example, on the morning after I completed writing this article, I learned about "over frequency incident" (frequency going up to 50.5Hz) that occurred in the National Electrical Grid, visible to all the connected generators synchronised the National Electricity Grid. One of the newly upgraded generating machines was tripping spuriously on frequency protection function, thus reducing the power generating capacity on the day.

In closing, my point is that a single incident, be it cybersecurity-related or not on the National Electrical Grid, affects numerous generating machines. The last thing I did before submitting this article was to search for IEC cyber-security standards, and the following were prominent ISO/IEC 27001 and IEC 62443. The South African Power Utility has always been an advocate of using technology in line with the world best practices.

Therefore I will be examining the IEC cyber security standards to see if my concerns raised are not already addressed. I also feel that the IEC cyber security standards will make for some riveting bedtime reading. wn

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20/10/2021	KZN Webinar
25/10/2021	Project Management for Engineers
26/10/2021	Substation Design and Equipment Selection
26/10/2021	Rotating Machine Section webinar
27/10/2021	Photovoltaic Solar Systems
27/10/2021	70th Bernard Price Memorial Lecture 2021
28/10/2021	HV Measurement & Testing

NOVEMBER 2021

DATE	TITLE
02/11/2021	Construction Regulations from a Legal Perspective
03/11/2021	Fundamentals of Power Distribution
03/11/2021	Incident Investigation & Root Cause Analysis
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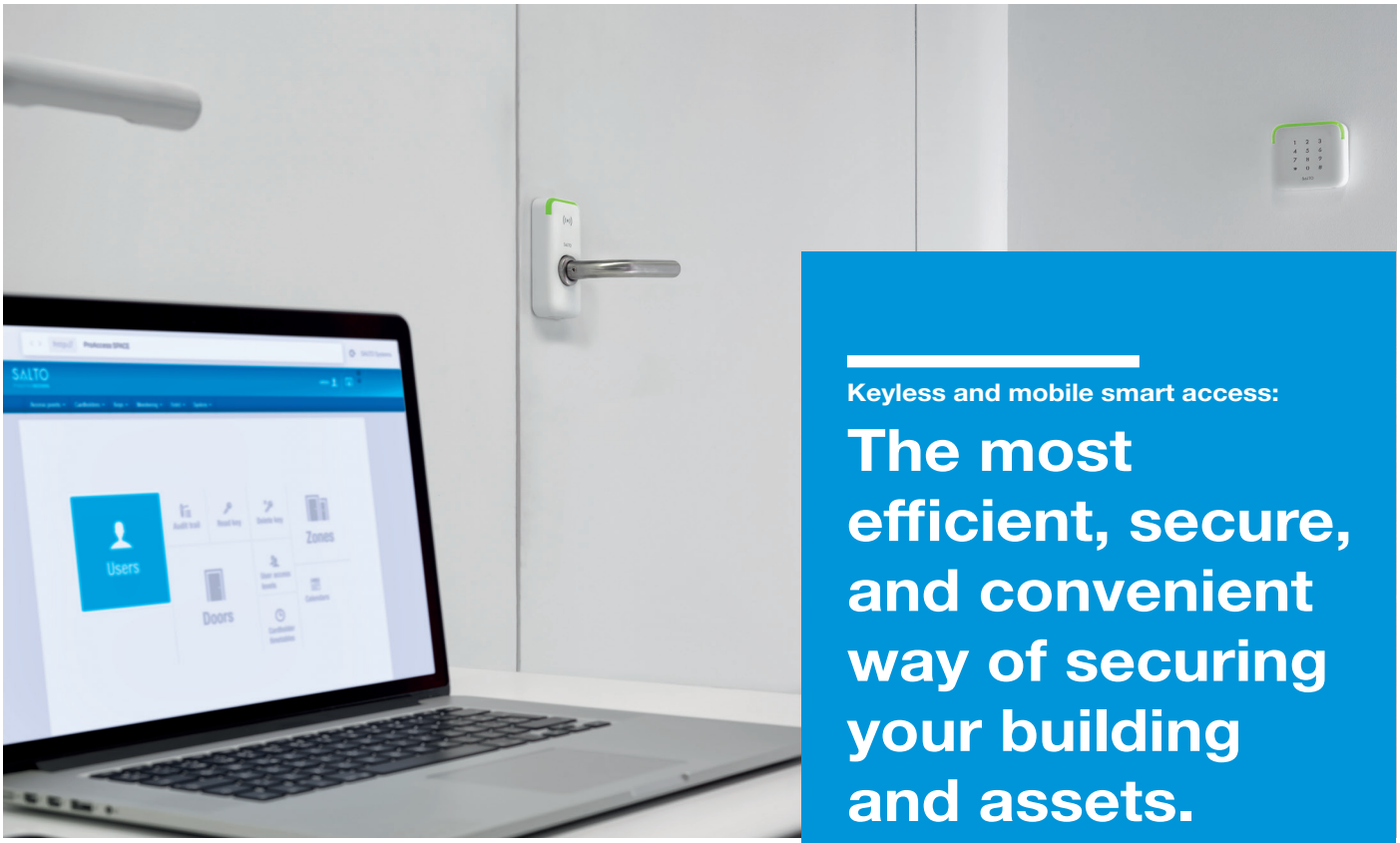

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