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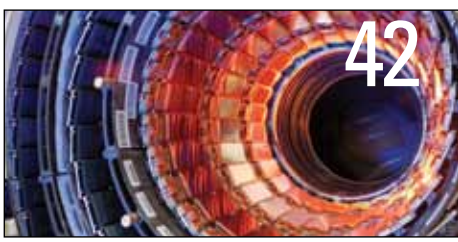

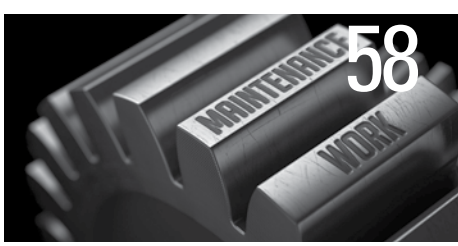

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With Spring around the corner, it seems that people are also starting to find life again – with an obvious spring in the step! It is easier to get up in the mornings, and to most people it will mean getting their bodies ready for the beach, maintenance and repair is at the order of the day.

That is so for everything in life. This issue focuses on Power Plant Maintenance. The feature articles give you more insight into the maintenance process. Page 20 sees an article on the new approach Eskom has implemented in managing their Transmission & Distribution assets.

Page 28 gives us a paper on "Alternator Stator Core Testing during Maintenance Outages", written by David Tarrant. This paper explains two basic theories on basic techniques for assessing the condition of the core, whether high or low power testing is applied.

Dudley Basson has written another masterpiece on the Large Hadron Collider, which was built by CERN (Conseil Européen pour la Recherche Nucléaire). You will find this on page 42.

Page 48 features a nuclear article, discussing the strategies on increasing the storage space of spent fuel pools, if a shutdown is to be avoided.

Onto SAIEE news.

The annual SAIEE Banquet will take place on the 21st of October 2016 at the Wanderers Club, Illovo, JHB. There is currently an early bird discount running - book and pay for your tickets before the 16th of September and pay only R500 p/p. Thereafter, the tickets will cost R600 p/p. Contact Gerda Geyer (geyerg@saiee.org.za) to book your seat.

Herewith the September issue, enjoy the read…

Minx

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TC MADIKANE
2016 SAIEE PRESIDENT

August has marked a year without load shedding in South Africa. Eskom is patting itself on the back for keeping the country's lights burning, thanks to the power utility's rigorous plant maintenance programme. The reduced load demand is also a contributing factor.

Our **watt**now theme for this month is "Power Plant Maintenance". According to Eskom, the adherence to regular scheduled maintenance is managed through the Tetris Planning Tool, which schedules outages based on forecast demand and maintenance requirements. I encourage you to read the interesting articles contributed by our members …

On the 17th of August 2016 I attended the Consulting Engineers of South Africa's (CESA) AON Engineering Excellence Awards. I was able to witness the South African Engineering version of the Oscars. The cream of the crop of the engineering industry gathered in a night filled with glitz and glamour to celebrate, honour and reward engineering excellence. I urge our members, especially those in the consulting industry, to showcase Electrical Engineering projects where innovation, quality as well as outstanding workmanship is displayed, and to put forward those projects to CESA to be considered for awards next year.

Our ***#ploughback*** campaign in August focused on various aspects but, I think a special mention is deserved about the decision taken by the SAIEE to ensure that we continue contributing to tertiary education in South Africa by offering more bursaries to deserving students from disadvantaged families, especially in rural areas. We all know the pressure that is being imposed by students with ***#FeesMustFall*** campaign.

We can't sit back and think that the government is going to solve this tremendous task on their own. I am very pleased that SAIEE is taking a leading role in this regard. We once again ***#makeithappen*** by offering more bursaries using the President's purse fund.

We are not only offering bursaries, but we also ***#ploughback*** by providing mentorship to Bursary beneficiaries for continuing support in their studies. Thank you to our past Presidents for their vision in creating this critical avenue for investing to the future of our country.

Soon it will be that time of year where we have an opportunity, as Electrical Engineering Practitioners, to share with our spouses what we do, how we network with colleagues and clients, celebrate achievements by the way of giving awards to fellow Engineers, and enjoy the evening at our annual banquet and awards ceremony. This will take place on 21st of October 2016 at the Wanderers Club in Illovo, Gauteng Province. I encourage our members to diarise this prestigious event in our calendar. There is an early bird special of R500 p/p if you book and pay before the 16th of September, thereafter the price is R600 p/p. Come join me at this event - I'm looking forward to meet you.

TC Madikane
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ACTOM High Voltage Equipment's first order

Nick de Beer (right), Product Manager, Instrument Transformers, and Etienne Venter, Design Engineer, Voltage Transformers, of ACTOM High Voltage Equipment stand next to a compact 132kV voltage transformer, which is substantially smaller than the conventional units around it, as the picture shows.

ACTOM High Voltage Equipment's (HVE) first contract for manufacture and supply of compact 132kV voltage transformers (VT's) was awarded to it recently by leading infrastructure company Consolidated Power Projects (CONCO) for supply to Tshwane Metropolitan Municipality.

HVE developed the new competitively priced and efficient compact VT in-house and introduced it into the local market in 2015. The new product is 35 to 40% smaller than the conventional unit and is accordingly about 15% lower in price.

The compact VT's are available with standard porcelain insulators or glass-core and silicon composite insulators – the latter being pollution-resistant and less subject to damage than the conventional product.

The contract to HVE, awarded by CONCO early this year, is for manufacture and supply of 12 compact VT's fitted with porcelain insulators. The VT's form part of a range of HV equipment Tshwane Municipality has ordered under a three-year frame contract it awarded to CONCO last year.

"It was fortunate for us that we completed development and testing of the compact VT when we did as it comfortably comes in at the right price as quoted by CONCO to Tshwane Municipality on their frame contract. We couldn't have accepted the order for our traditional VT's at that price," commented Nick de Beer, HVE's Product Manager, Instrument Transformers.

Executive Mayor unveils Lufhureng Substation

The Executive Mayor of the City of Johannesburg, Cllr Parks Tau (left) and the MMC for Environment and Infrastructure Services, Cllr Matshidiso Mfikoe (right) unveiled the plaque at Lufhereng Substation near Soweto

The Executive Mayor of the City of Johannesburg, Cllr Parks Tau unveiled the building of the Lufhereng Substation recently. The R260 million construction of this substation will enable City Power to provide additional electricity capacity for new and existing customers in the areas that are to be supplied by this substation and related infrastructure.

The substation's generation capacity of 125 MVA will supply over 22 500 properties. The investment follows the COJ budget allocation from MMC of Finance in the City of Johannesburg, Cllr Geoffrey Makhubo earlier this year.

Sicelo Xulu Managing Director of City Power said, "*The new substation of Lufhureng will increase the security of electricity supply in Johannesburg. New technologies installed include compact switch gear using gas for insulation, which will reduce fire hazard.*

Security lighting and access control will monitor all movement in and out of the substation, to help minimise vandalism, theft and equipment damage. This will enable City Power to operate more efficiently will further ensure business continuity and boost our ability to keep the lights on for the residents of Johannesburg."

Single Controller Detects 15 Different Gases

Developed to meet specific requirements for gas monitoring at fixed locations, the locally manufactured ESI Smart Sensor incorporates unique design features that effectively address the shortcomings of conventional sensor instrumentation.

This unit features a localised display of sensor information. A single controller can measure 15 different gases; typically including oxygen (02), carbon dioxide (CO2), flammable gases such as methane (CH4) and combustible gases such as carbon monoxide (CO).

The Smart Sensor can also accommodate other sensors with analogue outputs, such as air velocity sensors or smoke detectors.

Ingress protection on the Smart Sensor exceeds IP56 and the instrument carries SANS IEC 60079 Part 0:2005, SANS IEC 60079 Part 11: 2007 and IEC 60529 (IP code) approvals. Also certified as EXia T4 Intrinsically Safe, the unit's dimensions are 265 x 150 x 60 mm and it weighs 1.8 kg.

The ESI Smart Sensor is available from Booyco Electronics.

The ESI Smart Sensor incorporates unique design features that effectively address the shortcomings of conventional sensor instrumentation.

Royal HaskoningDHV Triumphant at CESA Awards

Royal HaskoningDHV was victorious at last night's CESA Aon Engineering Excellence Awards cleaning up in the Projects categories with 3 awards and their Young Professionals won the award for the Job Shadow Competition.

In the category for Engineering Excellence for projects with a value of greater than R250 million the Braamhoek Consultants Joint Venture (BCJV) comprising GIBB, Royal HaskoningDHV and Knight Piésold won the Award for the Ingula Pumped Storage Scheme for Eskom.

Royal HaskoningDHV won the award in the category for projects less than R50million for the National DST/Mintek NIC Cleanroom Facility for the Department of Science and Technology. In the category for projects with a value between R50 and R250million they received a Commendation for the Condale 33/6.6 kV Substation for Mogale City Local Municipality.

These prestigious awards held at Vodacom World in Midrand on the 17th August this year were a celebration of innovation, quality, outstanding workmanship and professionalism in the industry. The event is a platform to showcase the important role that infrastructure plays in the sustainable development of our country.

The Awards focus on consulting engineers and their clients who participate in or initiate projects that promote the advancement of our nation and the people of the continent.

Salani Sithole, Royal HaskoningDHV Managing Director speaking as part of the Braamhoek Joint stated, *"An incredible milestone was achieved this year when the Ingula Pumped Storage Scheme started generating power. This peaking hydropower station will contribute significantly towards economic growth by alleviating power shortages during peak demand times - something South Africa so desperately needs".*

The Ingula Pumped Storage Scheme is a multi-billion-rand project located near Van Reenen in the Little Drakensberg and has a generating capacity of 1332MW. The development of Ingula is a true example of how infrastructure development and nature can work together to enhance economic growth to everyone's benefit.

WATTSUP

DEHN Africa introduces earthing and short-circuiting device

When earthing and short-circuiting equipment using aluminium-cable instead of copper-cable for railway systems, switchgear installations or overhead lines, the advantage of the weight-reduced cables becomes immediately evident.

The new aluminium earthing and short-circuiting device (single-pole, 70mm²) from DEHN Africa is considerably easier to transport and use than conventional devices. In the past, high copper prices led to material theft and damage, meaning that the new earthing and short-circuiting device with aluminium cables offers huge cost saving and convenience potential.

The new offering from DEHN Africa comes in a variety of different models, including an earth clamp for overhead contact lines and clamp for railway tracks with tommy bar; an earth clamp for overhead contact lines and clamp for railway tracks with ratchet; a universal clamp (T Pin Shaft) and universal clamp (Handle); a conductor clamp and universal clamp (Handle); ball head caps (Ø25 mm); a universal clamp (Handle) and clamp for railway tracks with tommy bar; a universal clamp (Handle) and clamp for railway tracks with ratchet; and with universal clamps (Handle) on both sides.

Thus, earthing and short-circuiting kits can be fitted with the available clamps using diverse combinations to fit the required function.

Kinkelder saw blades: Cutting at its best from Elquip Solutions

Elquip Solutions seeks out the latest industrial technology to supply to the South African market. As an established local provider of quality global electrical, automation, mechanical and consumable products as well as capital equipment, the company aims to provide quality at all times to its customers. In the current economic downturn, it is also equally concerned with providing them with the best value for money.

As such, Elquip represents and distributes many well-known industrial brands, which are synonymous with quality and value for money, locally. One of these is Kinkelder, a family-owned business based in the Netherlands, with a focus on saw blade manufacture dating back 55 years.

"We have successfully represented Kinkelder and supplied their blades to the local market for over a decade now. Their superior quality is a perfect match with what we always aim to achieve at Elquip," says Mike Cronin, Managing Director of Elquip Solutions.

Cronin, delighted with the assortment of blades on offer says: *"Kinkelder blades can not only cope with an assortment of material, but also have blades suitable for many types of sawing machines: from the lighter sawing machines to the automatic variety".*

"We are really excited to be able to offer, along with valued and long-standing expertise, blades customised to our customers' requirements, which provide them with any production needs," Cronin concludes.

Mike Cronin
Managing Director | Elquip Solutions

SA Energy Solutions Provider Sheds Light on Independent Power Programme

Eskom's recent reluctance to continue with the Department of Energy's (DoE) independent power producers programme (IPPP), which was globally acclaimed as a successful and innovative initiative, has raised several questions. The most pressing of which is the potential effect that this will have on South Africa's energy future.

This is according to André Agenbag, Head of Business Development at Energy Partners – a leading energy solutions provider in the country, who says that there has been some debate around the possible reasons behind the utility's decision not to enter into further agreements with IPPs. *"Detractors often correctly claim that wind and solar power can be inconsistent and unpredictable, but these concerns are manageable as part of a larger energy portfolio."*

Agenbag explains that the program is divided into a number of subcategories including renewable energy, coal power, gas power, co-generation and others. *"This combined portfolio is not only more environmentally friendly, but will also ensure a consistent power supply and lower costs."*

While Eskom is not a decision maker in the IPP program, the company remains a major stakeholder and as such it does have the potential to delay its roll-out, he adds. *"Eskom is unable to completely block the programme, but may attempt to stall the process through additional red-tape and costs. This will have an array of negative consequences such as lack of foreign investment, less renewable energy in the grid and, worst case scenario, could lead to another period of load shedding."*

Agenbag continues that Eskom may be reluctant to sign contracts with more IPPs due to the company's recent investment in new coal power stations. *"With the country's economic growth forecast of 0.1% for 2016, the demand for power will follow suit and may lead to a situation where there is a higher supply than demand for electricity. In light of this, it is not farfetched to assume that the utility is protecting its investment by refusing to buy more electricity from independent power producers, but at what cost?"*

He continues, *"Aside from the environmental benefits, IPPs could potentially generate far cheaper electricity than Eskom currently offers and can therefore benefit the economy in the long run. So far the IPP programme has led to R195-billion in direct investment and brought 2,145MW into the grid."*

"In light of the apparent environmental and economic benefits of the IPP programme, all indications are that the continuation and growth of the programme will best serve South Africa's energy needs," concludes Agenbag.

New App lifts the lid on stainless steel's lower life cycle costs

One of the biggest obstacles to the specification of stainless steel in certain applications, is the misperception that it's more expensive in comparison to other initially cheaper options. In the short term, that may be the case but a new world-first App from the Southern Africa Stainless Steel Development Association (SASSDA) is set to lift the lid on the 'bigger picture' - namely stainless steel's ability to ensure far lower overall Life Cycle Costs (LCC).

The benefit of the newly launched App - which is now available on the Google Play (Android) Store and will be available in the Apple iStore by the end of the year - is that it allows for the real-time calculation of the LCC of stainless steel via an easy to use, pre-programmed calculator. This requires the entry of key top-line data, followed by the simple click of a 'Calculate' Button which in turn generates a breakdown of the relevant costs and the ability to e-mail this to the relevant recipients.

SASSDA Executive Director John Tarboton elaborates; *"The App was created to assist engineers to calculate total LCC using the standard accountancy principle of discounted cash flow, so that total costs incurred during a life cycle period are reduced to present day values. This allows a realistic comparison to be made of the options available. In terms of material selection, the APP also enables potential long-term benefits to be assessed against short-term expediency."*

He adds that many months have been spent working out the correct formulas that now form the backend of the app, which has removed the burden of this type of time-consuming calculation from the end user. The SASSDA Life Cycle Cost calculator is also available on www.sassda.co.za.

John Tarboton
Sassda Executive Director

WATTSUP

Cables for Africa

Internationally renowned cable manufacturer Helukabel, is pulling out all the stops at this year's Electra Mining 2016 with a technically orientated stand designed to provide mine operators with correct cabling solutions for their mining requirements.

Managing Director, Doug Gunnewegh, says that the emphasis for this year's exhibition is to show the wide array of cables and accessories that are purpose designed for all mining applications. Whether it be wear-resistant trailing cables at the rock face, chemically resistant cables for process applications, Easy Click compression glands for panel building or any other application, it pays to use the right solutions for the job at hand.

"Rather than simply making do with what is available in the storeroom, we would like to highlight the benefits of using purpose made products that are specially designed for the application, is easier to install and will live up to its stated lifespan.

"Apart from being tailor-made for a wide range of applications, our products are designed and manufactured in Germany and Europe to the highest possible quality standards and bear the necessary approvals for quality," says Doug.

To add an element of interest to the stand, the company will also host wiremen and electrically orientated staff, to compete in a challenge to see who can achieve the fastest times to install a compression gland in a mock-up of an electrical cabinet. Winners will win bragging rights and a chance to take home a good selection of prizes for their efforts. The stand can be visited in Hall 7, at stand number E5.

Business Unusual Revolutionising Electrical Construction

EnI Electrical, part of the Zest WEG Group, is not only on a drive to change the electrical contracting industry, but also the larger South Africa construction landscape.

Its strategy is working considering that the electrical contractor enjoyed a record revenue year in 2015, while recording 404% growth rates since 2010. Importantly, as much as 60% of the company's projects last year comprised repeat customers, but this has come from approaching the construction environment differently.

"One of our success stories is that we are always invited back by our customers. This tells a very important story, especially in construction. In our industry, it also sends a very clear message to us and the market that we are definitely doing something correct," says Trevor Naude, managing director of EnI Electrical.

He says that a major competitive edge for EnI Electrical is its ability to understand its customers and their unique project requirements.

"We are not just supplying a product that meets a specific specification. As contractors, we are delivering something unique. If we do not understand their needs, it is going to cost us money," says Naude.

As he points out, relationships start at boardroom level and they are reinforced by delivery of what was promised by the company's top level management. And, it is for this reason that the management

Trevor Naudé
Managing Director | EnI Electrical

team is known for also participating in the close-out of projects.

Transparency is also key for Naude, who is extremely concerned by contractors' known exploitation of scope changes in projects to their own benefit. *"It is a tumour in the entire construction industry, and therefore a practice we have shunned. We refuse to indulge in this and are on a concerted drive to change this practice through the way we approach our contracts from bidding through to completion of the works,"* he says.

As part of the company's drive to "transform the culture of the local contracting fraternity" even at the operational level, significant time and effort is spent by EnI Electrical in developing its well-known "A-teams" that are headed up by impeccable leaders.

"Any team is indicative of the size of the project, but it is our teams' leadership that is a significant differentiator on a construction site. They are not merely technically competent, as this is a given for any construction team, our leaders understand the business of construction and are effective in multiple areas, which is exactly what is needed to complete projects successfully," he says.

First Generation III+ nuclear reactor in the world provides electricity to the grid

On 05 August 2016 at 00 hours 35 minutes (GMT) Unit 6 at Novovoronezh NPP in Russia, which uses Rosatom's innovative VVER-1200 technology, was connected to the national grid and produced its first 240 MW of electricity. Thus the most important and critical operation – the first trial of generation to the grid – has been successfully completed.

Generation 3+ nuclear reactors are currently being built in the United States and France. However, the Russian Unit 6 is the first to the reach the stage of being connected to the grid. The full-time commercial operation of the Unit 6 is expected to begin at the end of 2016 after reaching 100% capacity and mandatory acceptance testing. Once connected to the grid the unit will operate for at least 60 years. Connection to the grid took place 5 months after the first criticality programme that was started in March 2016.

"This event is our great victory, which crowns a huge amount of work in installation and adjustment of equipment, and complex process operations. It can be stated that all works were done reliably and safely. The operating personnel clearly understands the process, equipment operation safety and reliably," Andrey Petrov, General Director of Rosenergoatom, Rosatom's power generation division.

The connection to the grid was preceded by the turbine start up (approach to planned spin up in idling mode of the turbine generator's rotor) and its trial work in idling. Specialists carried out a large set of checks and tests at different power build up stages, as well as inspection of different equipment was carried out. These measures were necessary to confirm reliability and safety of the power unit in its further operation.

Valery Limarenko, President of NIAEP, Rosatom power engineering and construction division, pointed out: "ROSATOM is the world's largest supplier of nuclear power plants in the global market. Today, we have made our positions stronger. This opens new opportunities for building up our presence in the global market."

The innovative power units of Generation III+ possess improved performance parameters. They are absolutely safe in operation and fully meet the IAEA's post-Fukushima requirements. They feature a large number of passive safety systems, which are able to function even in case of

a plant blackout and without operator's intervention. Unit 6 of Novovoronezh NPP features a passive heat removal system from the reactor, hydrogen recombiners and a core catcher, which are unique and have no similarities worldwide.

The commissioning of power unit 6 will raise the total power capacity of Novovoronezh NPP by 1.5, and will give a boost to the Voronezh regional economy. It is expected that in 2017 additional tax revenues on the property may be about 30,123 mln USD.

WATTSUP

Rosatom to offer a series of new opportunities to SA students

On the sidelines of the PowerGen Africa conference held in Sandton from 19 to 21 July, Rosatom awarded prizes to 8 South African students and schoolchildren who had won the corporation's scientific competitions. The awards ceremony crowned the two-week support program for students and young professionals that gave over 300 young people an opportunity to gain an insight into Russia's nuclear industry and get a hands-on experience and skills, with 10 of them winning a trip to Russia.

At the program's first stage, young South African engineers and nuclear industry workers were selected to participate in the Forsage student forum in Russia held from 10 to 16 July. The forum, organized for the sixth time as a field camp 200 km away from Moscow, was attended by over 600 delegates representing eleven education branches from 20 countries. All Forsage participants took up individual educational programs that included lectures, workshops, business training, seminars, and brainstorms, as well as sports and leisure activities. South Africa was represented by 2 students of the University of Pretoria, 2 young employees of the South African nuclear corporation NECSA and 1 employee of the renewable energy procurement IPP office.

The Rosatom PowerGen exhibition stand witnessed the awards ceremony for the winners of Rosatom's 2 competitions: an academic one in physics and a student projects show on the possible trends in South African nuclear industry development.

The prizes to 3 student essay competition winners - trip certificates to Rosatom's Russia-based nuclear sites - were handed by Rosatom's South African office director Aleksandr Kirillov and Doctor Anthony Sillier, the North-West University programs director. Among the authors of 25 works, the following 3 students of the North-West University's Faculty of Engineering were particularly outstanding:

- 1st prize - Mark Verwey, 4th-year student;
- 2nd prize - Victor Spangenberg, 4th-year student; and
- 3rd prize – Zola Malawi, a bachelor of Vaal University of Technology and a student of Post-Graduate School of Nuclear Science and Engineering of the North-West University.

The winners, accompanied by their academic advisors, will visit Russia and a series of nuclear energy and industrial complex sites, including a nuclear power station, a reactor model, a nuclear power station fuel production plant and many other facilities, and will get memorable gifts.

The winners of the online academic competition in physics which was held in South Africa in 2016 are 2 students of the North-West University's Faculty of Engineering and a secondary school student from Glenvista. They were given their prizes - tablet PCs and certificates - by the director of the ANCO (Rosatom Corporate Academy) international programs center Aleksey Ponomarenko.

Also, from 18 to 22 July, Rosatom conducted a series of lectures in South African schools and universities that touched upon nuclear education in Russia and the specificities of Russian nuclear technologies, in particular, the 3+ generation PWR technology. The lectures took place in the North-West University, the University of Pretoria, the University of the Witwatersrand and Nelson Mandela Metropolitan University.

Rosatom plays an active role in the development of South African educational system. Thus, the company grants students scholarships, holds competitions with trips to Russia as main prizes and gives local universities the equipment needed to conduct laboratory tests.

This effort is backed by execution of several memoranda with the South African Ministry of Energy on cooperation in terms of education and staff training, as well as the memorandum on developing cooperation in the nuclear education field with the North-West University.

From left: Aleksandr Kirillov, Mark Verwey and Doctor Anthony Sillier

Students attending the Forsage Student Forum

Letter of gratitude from Tatenda Gora

I would like to sincerely express my gratitude to the SAIEE for the ISH-SAIEE Postgraduate Scholarship in High Voltage that was awarded to me in 2015. The scholarship went a long way to support the research I was conducting and I am delighted to inform you that I graduated on the 5th of July 2016 and with a distinction!.

The research I conducted was titled "Investigating the influence of altitude (relative air density) on the HVDC breakdown voltage of short rod-plane air gaps". The work included experimental tests at different altitudes (Scottburgh beach ≈ 0 m above sea level (asl), UKZN ≈ 130 M asl and Wits University ≈ 1 740 m asl). In order to simulate higher altitude data, a mini pressure vessel was used and pressure was drawn to simulate altitudes of approximately 1 600 m, 2 100 m, 2 700 m, 3 200 m, 3 800 m, 4 500 m and 5 200 m asl. The gap sizes varied between 0.1 m and 0.4 m.

I presented my research findings at the 19th International Symposium in High Voltage Engineering (ISH) that was held in Pilsen, Czech Republic in August 2015, thanks to the SAIEE scholarship that funded the trip. A picture of me presenting at ISH2015 is below. My findings have also been taken up as a contribution to the Short Gap Taskforce of Cigré WG D1.50 whose work will feed into the revision of the IEC 60060-1 standard on altitude correction factors.

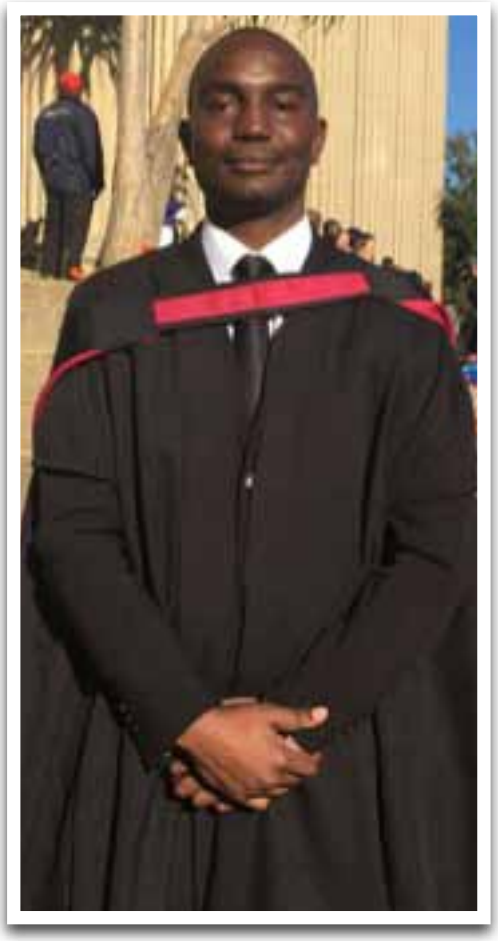
The highlights of my findings are as follows:

Tests between 0 m and 1 740 m asl:

1. IEC 60060-1 altitude correction factors' accuracy improves with reduction in altitude.
2. IEC altitude correction factors confirmed to only apply on altitudes below 1800 m asl. However, the increase in error is apparent as the altitude and air gap length increase.
3. A method introduced by Calva et al to predict the breakdown voltage of a rod plane configuration at any relative air density was discovered in literature and applied to the research. The Calva prediction method accurately predicts the DC breakdown voltage for air gaps within the 5% acceptable error at altitudes up to 1 740 m asl.

Tests between 1 740 m and 5 200 m asl:

1. At simulated altitudes higher than 1 740 m, IEC 60060-1 correction factors are inaccurate (resulting in errors greater than 5%). This confirms that the standard does not apply for altitudes above 1 740 m asl.
2. Each gap size breakdown voltage as a function of altitude has a knee point threshold where the trend changes from decrease of breakdown voltage with decrease in pressure to an increase in voltage with further decrease in pressure. Changes in corona mechanisms were also observed at these thresholds and it is speculated that there is a change in breakdown mechanisms at the thresholds
3. For each gap length, the Calva prediction method can be modified to accurately predict the breakdown voltage at high altitude.



Tatenda Gora

I would like to thank the SAIEE for their support with the scholarship and I hope many young researchers will be enabled through the scholarship.

Sincerely
Tatenda Gora

WATTSUP

OAKWOOD COTTAGE VISITS SAIEE

Our future engineers and SAIEE members with Teacher Maureen (left) and Teacher Tina (right)..

In the spirit of August being Women's month, and that many women are natural nurturers, Minx Avrabos, Managing Editor of the wattnow magazine, hosted a movie day for the pupils of Oakville Cottage.

Oakville Cottage, based in Houghton, caters for 30 children up to the age of 6, attended the special movie day.

Upon arrival, the youngsters were escorted by the Principal, Scarlet Colantoni and Teachers Maureen and Tina into the Council Chamber for the movie. They were each given a party pack and a fruit juice.

Minx explained to the children where they were and what Electrical Engineers do, and how important the profession is to society. At the end of the discussion, after Minx told them that without electrical engineers, they won't be able to watch a movie, have lights or boiling water, they all want to become Electrical Engineers.

When asked why she organised such a day for kids so young, she said: *"We have to start somewhere and where better than so early before primary school. Electrical Engineering is a critical skills and we need to prepare youngsters to study hard and do well in Maths and Science in order to study Electrical Engineering. They are the future who will keep our lights on ..."*

Little Nasri Hessou said with gusto: *"I will travel the world and fix all the engineering problems."*

The children were treated to "The Peanut movie" and was enjoyed by all, young and 'old'.

"The children were SO well-behaved that I will gladly have them over soon again, and then we will take them on a tour of the SAIEE Historical museum" Minx concluded.

WEC Projects Acquires Majority Stake In IWC

WEC Projects (Pty) Ltd, a contractor specialising in turnkey water and wastewater treatment solutions in South Africa, has acquired a majority stake in Industrial Water Cooling (Pty) Ltd (IWC), a company specialising in cooling tower and industrial cooling solutions, IWC announced today.

The partnership is effective immediately and replaces private equity company, MEDU Capital's stake in IWC.

"I am very pleased to announce that we have a new business partner in WEC Projects. I am of the firm belief that in WEC we have found a like-minded business partner that understands the contracting environment in which we operate," comments Roger Rusch, Managing Director of IWC.

Johannesburg-based WEC Projects has been operating as a contractor in the water and wastewater treatment industry since 2002. The company specialises in designing, manufacturing and installing water and wastewater treatment plants, such as packaged potable water treatment plants, sewage treatment plants, industrial filtration plants, submerged membrane bioreactors, reverse osmosis plants, reverse osmosis pre-treatment systems, dissolved air floatation devices and lamella settlers.

WEC Projects are also pioneers in biogas to energy technology, having designed, supplied and installed South Africa's first such plant at a municipal wastewater site. The technology converts wastewater sludge into biogas that is then used to fuel a gas engine that produces electricity. As a result of this technology, municipalities are able to subsidise their electrical costs by what they are able to produce themselves, utilising a waste material that now has significant commercial value.

IWC, originally founded in 1986 as Industrial Water Cooling, specialises in evaporative water cooling, heat exchangers and GRP solutions for numerous applications across the mining, power generation, petrochemical, and water and sanitation industries.

Roger Rusch
Managing Director | IWC

WATTSUP

Dr Rob Stephen of Eskom elected President of CIGRE

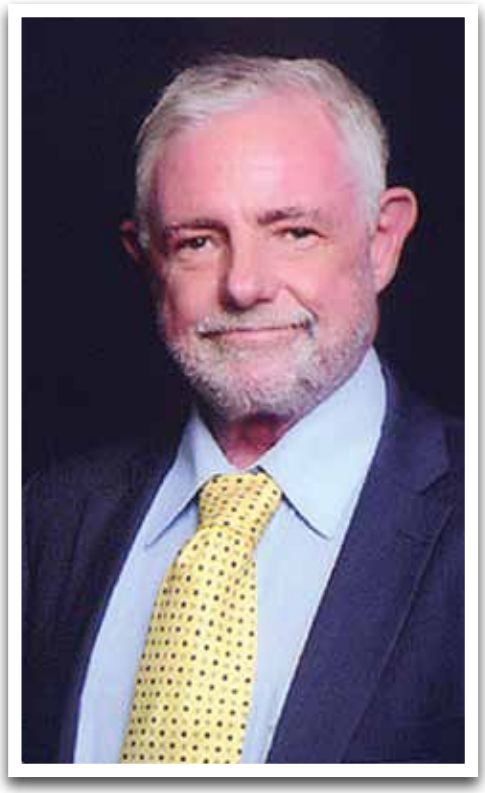
Eskom's Dr Rob Stephen has been elected president of the eminent international organization CIGRE at its biennial congress this week in Paris.

CIGRE is the Council on Large Electric Systems, a non-profit organisation founded in 1921 to advance collaboration amongst owners and operators of electric systems around the world. It has individual membership of 15000 people from 98 countries and is headquarted in Paris, France. It holds a biennial session in Paris which is attended by 3500 engineers from around the world.

Rob is the first African President of CIGRE and his candidacy has been supported on the back of promises to expand electrification in growing regions and to focus on distribution issues. He joined CIGRE in 1988 in a committee responsible for the study of thermal ratings for overhead lines. His worked earned him a Technical Committee award in 1996. He has been a special reporter at CIGRE several times. He has led many working groups, served on the advisory board and authored two chapters in the CIGRE Green Book on overhead line design. Since 2010 Rob has been a member of the Administration Council and has also served on the Steering Committee since then.

At Eskom, he is a Master Specialist on Transmission and Distribution issues. Rob has presented many tutorials on the design of overhead lines and this year presented to 400 engineers in Paris on this important topic.

Rob holds BSc, MSc and PhD degrees in Electrical Engineering and an MBA. He has a GCC and is a registered professional engineer with ECSA and is a Fellow of the SAIEE. We wish Rob a successful tenure at CIGRE. Well done Rob! Felicitations!



Dr Rob Stephen
President | CIGRE

Surge arresters reduce surge and lightning problems by 98%

Surgetek's Copa surge arrester marked the beginning of a new chapter in the company's product offering to South Africa's petrol stations and forecourt control. The Copa surge arrester drastically reduced petroleum companies' down time resulting from power surges and lightning strikes by 98%.

Surge protection must be installed in the petrol dispensers as well as the back office of a petrol station. *"It is absolutely essential that both power and data sources are protected,"* states van As. Petrol station owners want to maximise their running hours and the correctly installed and maintained surge protectors reduces their downtime significantly. Power and data protection should be installed as close as possible to the forecourt controller. Surgetek also developed the HDO 280T – a compact protector for 220 V. These units are fitted in most petrol dispenser throughout the country as they are supplied directly to dispenser manufacturers who install them in their production processes.

The Copa Data Multi Wire has been designed for surge currents up to 10kA. Surgetek supplies surge protection products directly to petrol dispenser manufacturers and forecourt technology manufacturer UCS Technology Services.

South Africa's first community owned solar energy plant switches on in Stellenbosch

The Stellenbosch Waldorf School, in the Western Cape, is now powered by sunshine from a solar energy system that was funded by the school's community and international backers. But this project is far from a charity case, the solar energy system is being leased to the school through dedicated The Solar Energy Co-operative. This has been developed and managed by Cape Town based crowd-funding company, The Sun Exchange.

The funders and members of the project, all 68 of them (and some as young as 7 years of age) are now earning income whilst saving the school money on their energy bills, and dramatically cutting the schools environmental footprint. ZAR 400,000 was raised to pay for the solar energy system, which is set to cut the school's energy bill by nearly 15% and earn the project backers over 10% per annum.

Not only is this the first time a solar plant has been crowd-funded in South Africa, it is the first time that the 'Co-operative' business model has been applied to solving South Africa's energy challenges. This despite being a very common way of delivering clean energy projects around the world. The Co-op model, most commonly used in Agriculture, has been used to help individuals and communities autonomously and democratically address their energy problems. The Sun Exchange is now set to replicate their success throughout South Africa and across the continent, propagating community engagement in an entirely new way; enabling people to save money for the future all whilst helping prevent climate change.

Solar entrepreneur Abraham Cambridge, Founder and CEO of The Sun Exchange tells us why this is happening in South Africa now: *"The time is right in SA for a new way of earning money backed by solar energy. We need to do this for the sake of the planet and to keep the lights on. Helping our Users make money out of the process is simply the icing on the cake. Our platform allows anyone to choose to invest in solar energy where they know their money is being put to work by solar powering a local community. The fact that the national electricity prices are rising so fast just makes going solar make more sense than ever".*

The Sun Exchange used Somerset West solar installer Green4Earth to install the 136 solar panels onto the school's roof. Green4Earth CEO Aldre van Staden has remarked on their involvement: *"The Sun Exchange is bringing to South Africa a way for more people than ever before to be able to access the benefits of solar. We were delighted that Green4Earth and our locally employed installation team have been involved in this landmark project."*

ISH-SAIEE Scholarship

At the beginning of August, the SAIEE Council invited Wits Student recipients of the ISH Scholarship Fund to attend the council meeting, where they were handed ISH Certificates of Participation. Pictured from left: Dr Cuthbert Nyamupangedengu (Wits mentor), Nkosinathi Msimango (student), TC Madikane (SAIEE President) and Darryn Cornish (student).

The growing demand for stable electricity supply in SA, coupled with the ageing Transmission and Distribution network assets, has led the Transmission and Distribution (T&D) business of Eskom to reconsider its approach to asset care. The new approach involves weighing opportunities to maximise value from the electricity network infrastructure against plausible risks.

BY | PRINCE MOYO | PR ENG | FSAIEE
TEBOGO MOKWANA | CERT ENG
ESKOM POWER DELIVERY ENGINEERING

The evolution of maintenance approaches is extensively documented. Eskom, like many other utilities, has come to appreciate that the Run-To-Failure (RTF) approach is the most disruptive and uneconomical method, especially where the consequences of failure are high.

Eskom Transmission and Distribution (T&D) business is in transition from a Time Based Maintenance (TBM) approach to Condition Based (CBM), and Predictive Maintenance (PrM).

Eskom T&D asset care approaches have been developed, based on international best practices. These have been documented and published for internal use as the maintenance engineering standards.

Twenty seven (27) asset classes have been identified

New Approach to Managing Eskom T&D Assets

Figure 1: The oldest transformer (80yr old) in Eskom Distribution Beitbridge substation

New approach to managing assets

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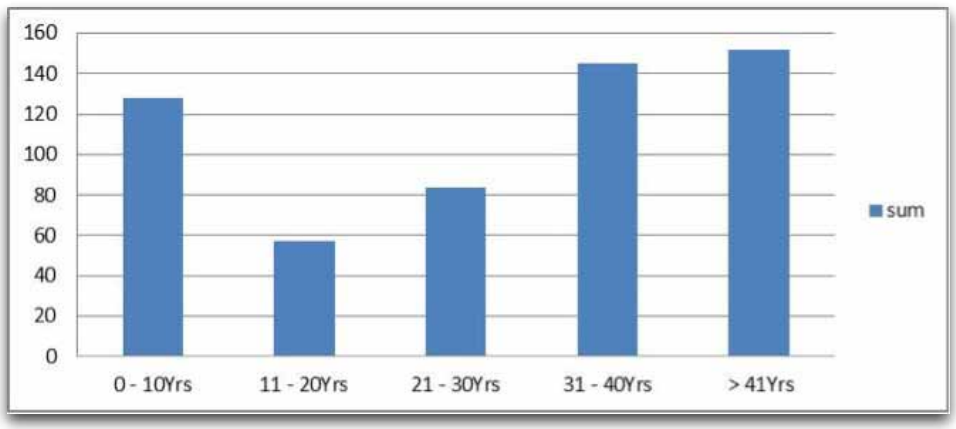

Figure 2: Eskom Transmission transformer age distribution

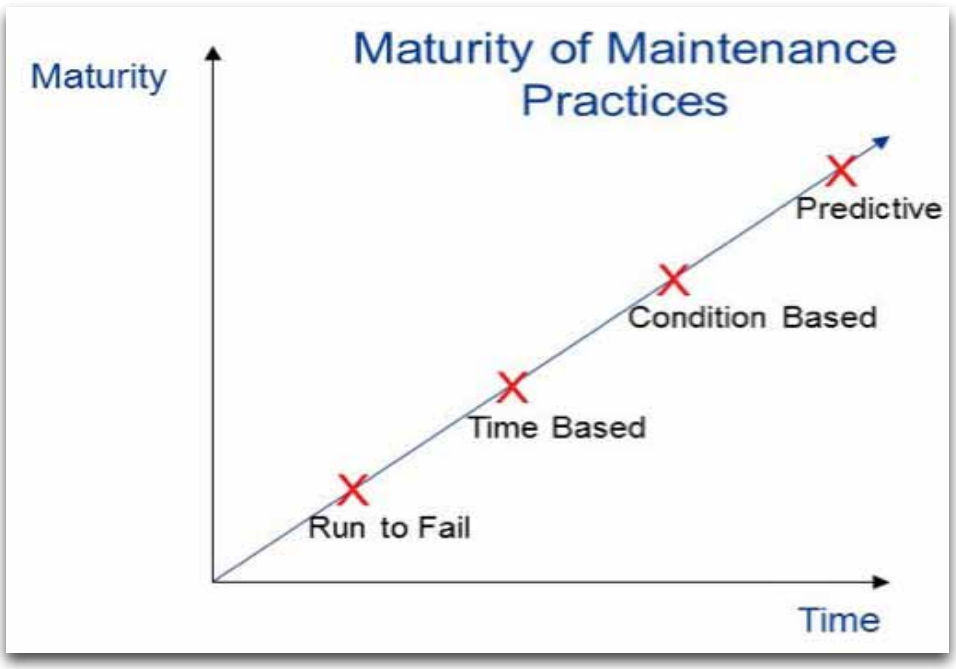

Figure 3: Evolution of maintenance approaches

COMPONENT: PAPER(SOLID INSULATION) FMEA								Criticality assessment			Maintenance determination / recommendation
Ref.	Function/ item	Functional failure	Failure mode	Failure mechanism / cause	Failure effects		Compensating provisions	Probability	Severity	Risk	
					Local	End					
1.1 Paper Insulation	1. To insulate windings	A. Failure to insulate windings	1. Solid insulation breakdown	1. Degradation due to moisture / heat / oxygen	Transformer trip	-Transformer failure -Supply capacity loss	none	10%	R5m – R50m	III	Oil sample analysis for DGA, Moisture and dielectric strength

Table 1: Transformer solid insulation failure analysis

for power delivery assets, such as Power Transformers. Some of the key aspects that this new approach to optimal decision makes on the T&D operational assets includes: doing the right maintenance at the right time, monitoring the performance and health status of assets, replacement of assets directed by 'least cost' models as well as continual improvement in an effort to sustain optimal value from assets.

MAINTENANCE TASK DETERMINATION

The condition of electrical network assets deteriorate over time when deployed. Proactive maintenance actions directed by parameter monitoring are necessary to manage the risk of asset failure. For this reason Eskom T&D has adopted a risk based approach for instituting what maintenance activities need to be carried out.

The process for developing the T&D asset maintenance requirements includes an examination of how the asset could fail whilst in operation; and the identification of potential failure causes along with the associated failure effects. Maintenance tasks are recommended as a risk control measure. The triggers for executing maintenance tasks takes into account influencing factors such as the operating environment, asset functional importance, health status and duty-cycle / loading.

ASSET CONDITIONS RELATIVE TO END OF LIFE

Asset Health Indices (AHI) are developed to provide a snapshot of the technical life condition state of the T&D assets relative to their expected end of life. The formulation of the AHI involves carrying out asset ageing analysis which encompasses asset degradation review, establishing condition

assessment techniques, and setting criteria for end of life.

The asset degradation review provides an insight into asset failure mechanisms, and takes into account both internal and external asset condition degradation factors. The end-of-life criterion involves prioritising condition parameters, and mapping these against the asset end-of-life and condition ratings.

The identified conditions indicators, from the degradation review are selected, taking into account the practicability of condition assessment techniques. These are allocated weighing factors based on their importance in relation to asset end of life. Every two years, Eskom T&D review the asset health status of all major assets and publish AHI reports, which contain recommendations about what needs to be done to address poor performing assets. These asset health reports are a fundamental input into planning for asset replacements and prioritisation.

The technical life analysis alone does not provide a complete picture for optimal replacement decision. Financial implications are also considered through the Condition, Criticality and Risk Assessment (CCRA). This method determines when the most economic point to make asset replacement decisions. The depreciating asset capital investment is compared against the asset risk of failure in Rand terms to locate the "sweet spot".

ASSET PERFORMANCE MEASURES

To ascertain how well the T&D assets are performing, performance measures and trends are established. The network and asset performance targets are set based

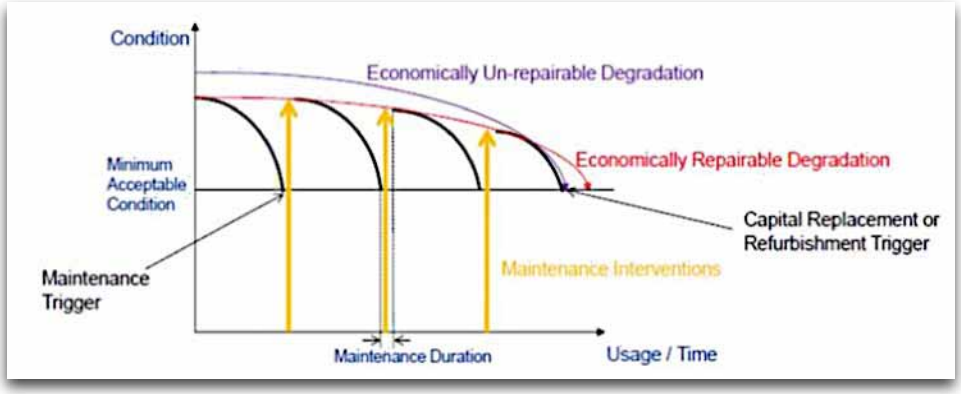

Figure 4: P-f curve

Operating Environment	Harsh (Yes/No)
Is the MV cable system prone to vandalism & theft (safety hazard)?	
Does the MV cable system show deterioration signs due to being installed in highly corrosive (mine acids, high lightning density) environments?	
Is the MV cable system prone to other services excavations and soil erosion?	
If all answers to the above questions are 'No', then the MV cable system is mild	

Table 2: MV cable system operational environment classifications

	Circuit Breaker Condition Criteria	Weight	Condition Rating	Factors	Maximum Score
1	Insulator Condition	1	A,B,C,D, E	4,3,2,1,0	4
2	Grading Capacitor Condition (*)	1	A,B,C,D, E	4,3,2,1,0	4
3	Control and Mechanism Component Condition	2	A,B,C,D, E	4,3,2,1,0	8
4	Foundation, Steel Support and Earthing Condition	0.5	A,B,C,D, E	4,3,2,1,0	2
5	Servicing and Test Results	4	A,B,C,D, E	4,3,2,1,0	16
6	Call outs	6	A,B,C,D, E	4,3,2,1,0	24
Note: Where the design does not include grading capacitors the scoring is adjusted * Maximum Score = 58 (with grading capacitors) * Maximum Score = 54 (without grading capacitors)					

Table 3: Circuit breaker condition assessment criteria

New approach to managing assets

continues from page 23

Health Index	Condition	Description	Requirements
85 - 100	Very Good	Some ageing or minor deterioration of a limited number of components	Normal maintenance
70 – 85	Good	Significant deterioration of some components	Normal maintenance
50 – 70	Fair	Widespread significant deterioration or serious deterioration of specific components	Increase diagnostic testing, possible remedial work or replacement needed depending on criticality
30 – 50	Poor	Widespread serious deterioration	Start planning process to replace or rebuild considering risk and consequences of failure
0 – 30	Very Poor	Extensive serious deterioration	At end-of-life, immediately assess risk; replace or rebuild based on assessment

Table 4: Asset health index scale

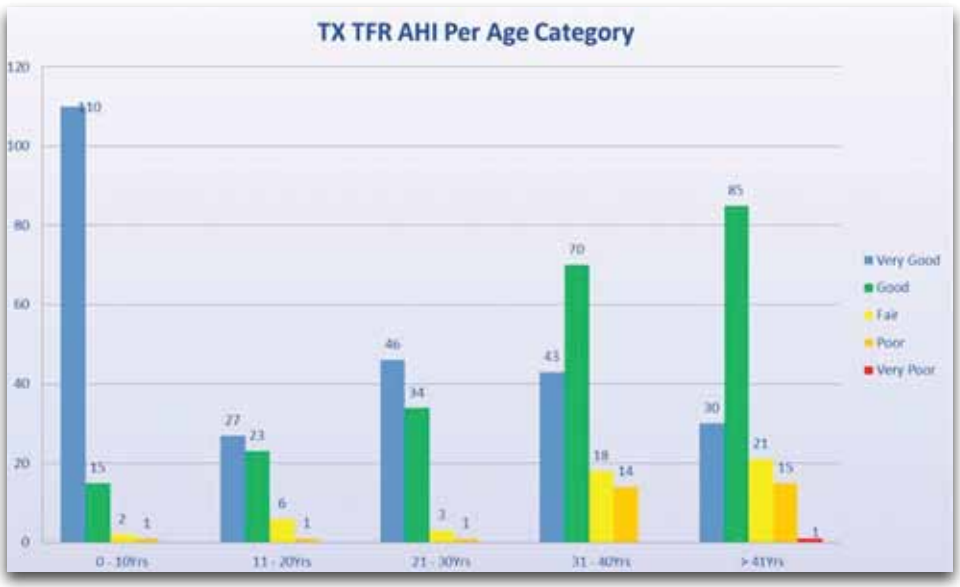

Figure 5: 2016 Eskom Transmission Transformer health status per age category

on business objectives while taking into account historic performance levels.

Network performance is a measure of how well the electricity network performs as a system in order to meet customers expected supply. It involves measures such as system minutes (SM), customer average interruption duration index (CAIDI), supply average interruption duration index (SAIDI) and supply average interruption frequency index (SAIFI).

Network performance is influenced by multitude of factors, including network planning, asset performance, maintainability of assets and the availability of spares. Asset performance is concerned with how well an asset is performing. It considers factors such as the number of asset failures, failure rates and mean-time between failures.

Figure 8 illustrates the asset performance for the 4,142 power transformers, ranging from 1MVA to 160MVA, installed in the distribution network. Figure 9 illustrates the Eskom Transmission system minutes trend over the past 14years. Figure 10 shows an improvement on Eskom Transmission 400KV line failures. Figure 11 illustrates improvement on Eskom Distribution SAIDI performance.

CONCLUSION

Electricity power is the life-blood to economic prosperity. Its reliability and sustainability is reliant on infrastructure that is well cared for. Eskom T&D has taken an opportunity to sharpen its asset care regimes, taking into account international best practice approaches. New maintenance practices, analytical tools and systems are being introduced. wn

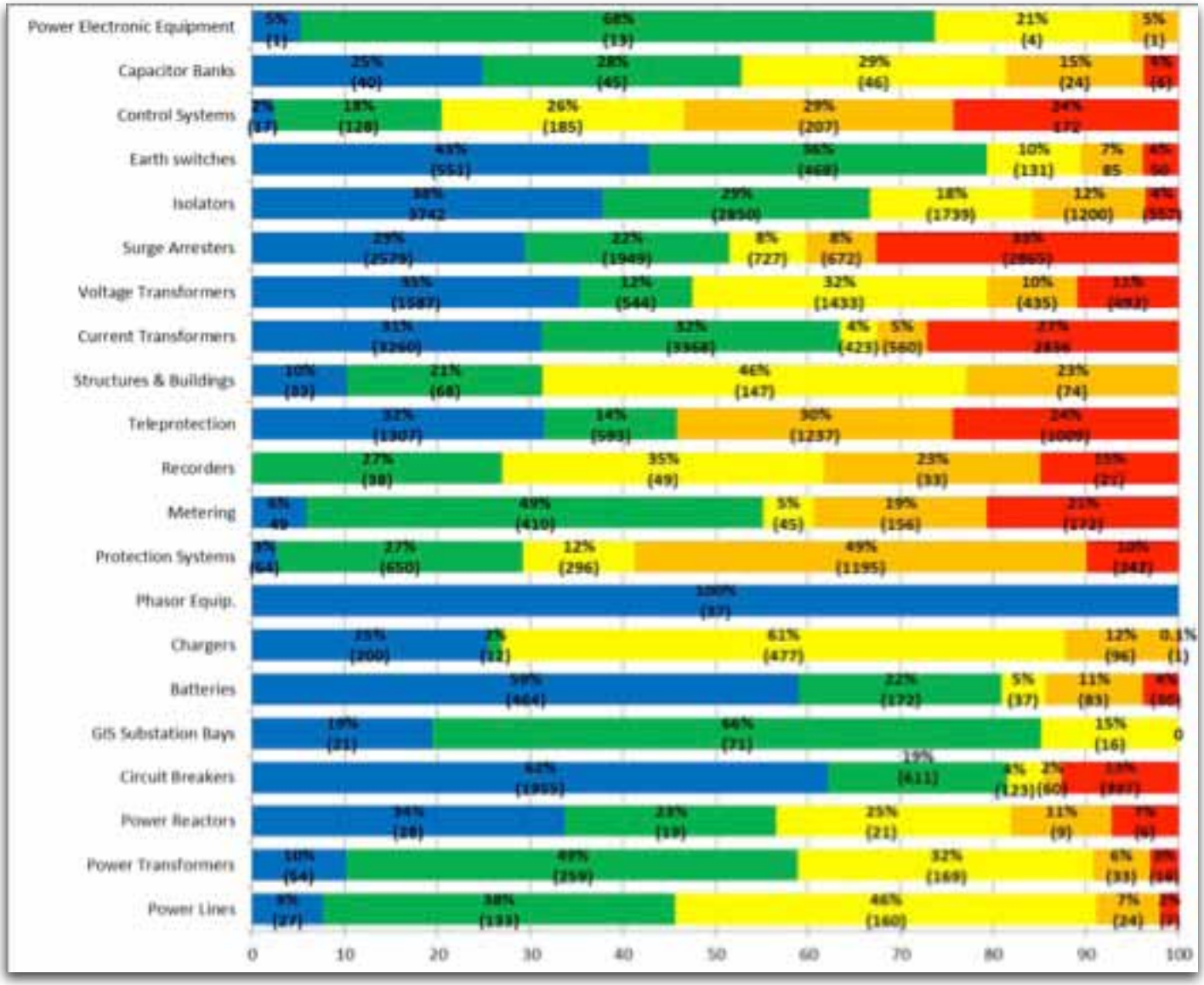

Figure 6: 2014 Eskom Transmission major assets health status

New approach to managing assets

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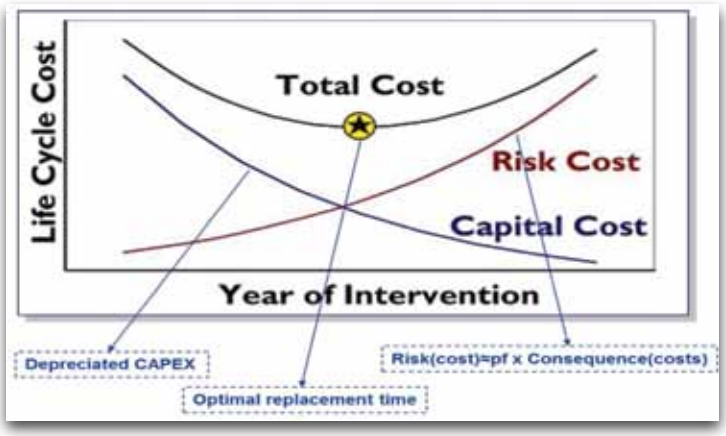


Figure 7: Condition criticality and risk assessment model

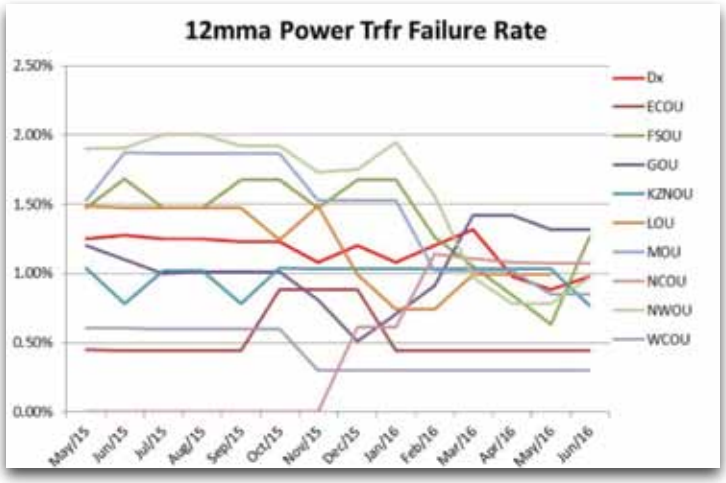


Figure 8: Eskom Distribution Transformer failure rate trend per operating unit along the provincial boundary

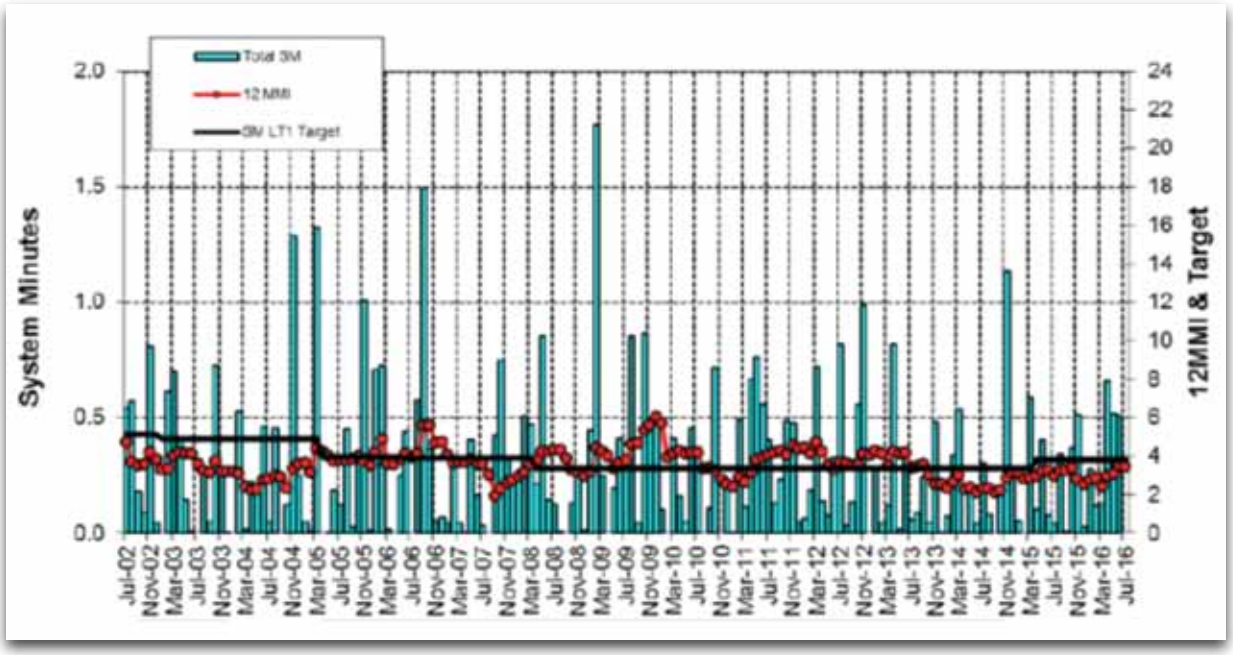


Figure 9: Eskom Transmission system minutes

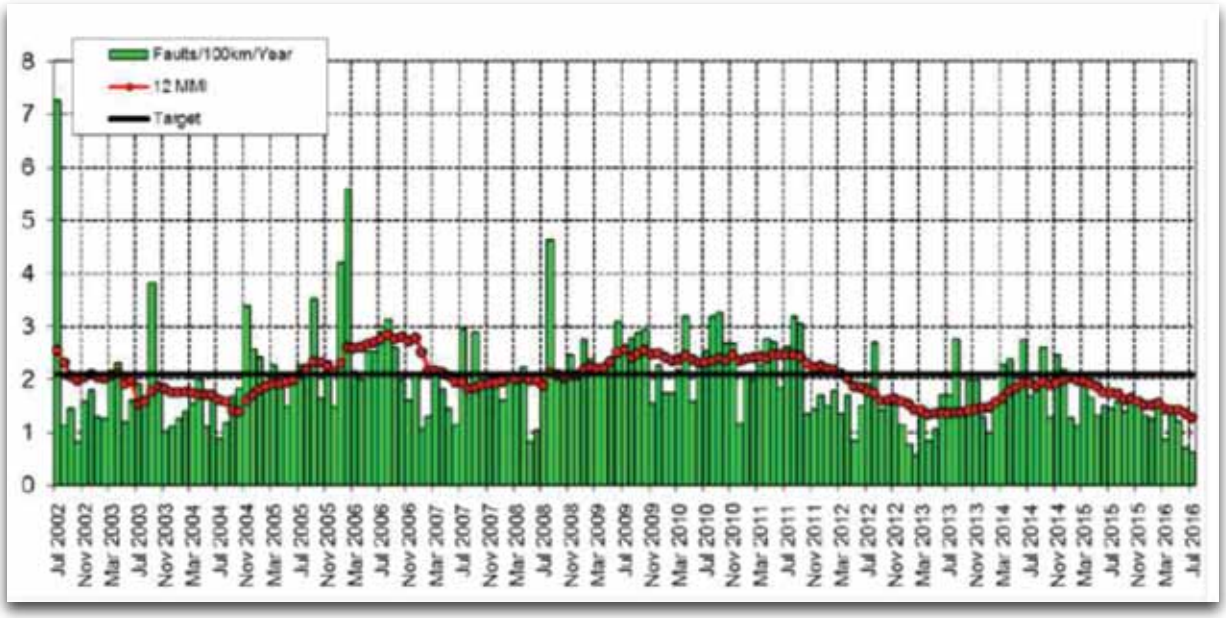


Figure 10: Eskom Transmission 400KV Faults / 100km

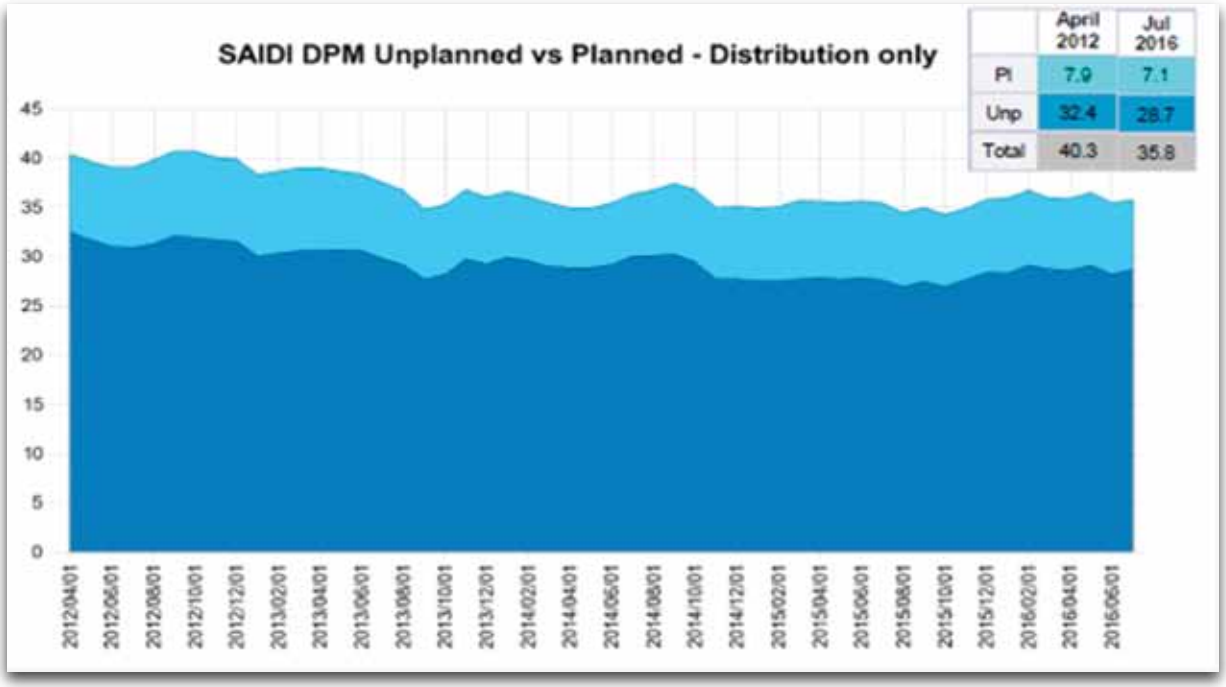


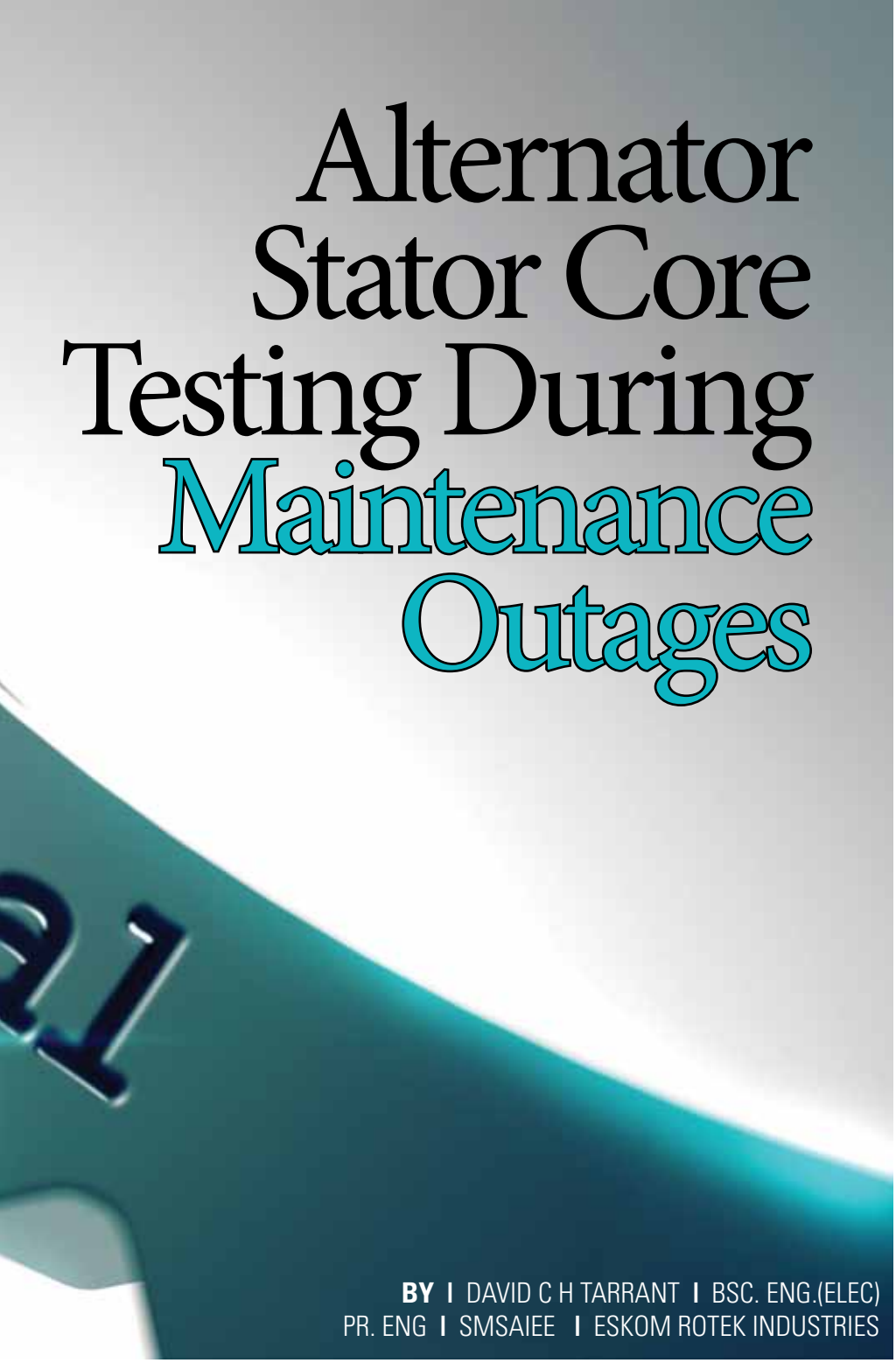
Figure 11: Eskom Distribution SAIDI Trend

Five case studies are presented, on machines ranging in size from smaller than 10 MW to over 600 MW. These show that faults at or near the surface can be easily detected by both test methods, although the EL CID test is significantly quicker, easier and cheaper to execute. Deep-seated faults can be detected using the EL CID test, although there is an attenuation factor down the slot. It is not clear if deep-seated faults will be detected by the rated flux test.

The case studies confirm the EL CID test to be of significant value in assessing stator core integrity. However, it is difficult to prescribe standard acceptance criteria.

Each test must be analysed on its own merit, taking a number of factors into account. Expert/experienced personnel are required to both carry out the test and analyse the results meaningfully.

Alternator Stator Core Testing During Maintenance Outages



There are currently two basic techniques for assessing the condition of stator core inter-laminar insulation off-line – high power (rated flux) testing, and low power (EL CID) testing. The paper describes the basic theory of the two methods without going into excessive detail.

BY | DAVID C H TARRANT | BSC. ENG.(ELEC) PR. ENG | SMSAIEE | ESKOM ROTEK INDUSTRIES

The case study results question the generally accepted maximum fault current level of 100 mA as possibly being too conservative if applied without fuller investigation.

INTRODUCTION

Eskom Rotek Industries is the maintenance wing of Eskom, South Africa's national power utility. With the growth in the country since the mid 1990's, the demand for electricity has increased, and optimum plant availability has become increasingly important – thus the importance of condition assessment inspections during routine maintenance outages is becoming increasingly significant. Whilst Eskom has installed on-line monitoring across its fleet, there is one area on the stator, which cannot reliably be tested, on-line at this stage, namely the stator core.

The two most common tests of stator core integrity are the rated flux test (also known as the loop or ring flux test) and the EL CID test.

This paper looks at the basic theory and method of testing the core, and then presents a number of case studies. Note that the theory/method discussion will be at an overview level, and is not intended to be

Core Testing

continues from page 29

a comprehensive study of the test method itself. The focus of the paper is more on the case studies. Note also that the case studies are not necessarily on machines owned by Eskom, or even on machines in South Africa, as the author has worked on a variety of plants with generation capacity outside of Eskom.

STATOR CORE TESTING

There are a number of possible failure mechanisms on generator stator cores, ranging from general aging through mechanical abrasion, to foreign material failures. It is not within the scope of this paper to discuss these – suffice it to say that sufficient degradation of/damage to the insulation between laminations in the core (inter-laminar insulation) can result in rapid and catastrophic failure of the stator. Even if the heating effect is too low to damage interlamination insulation, localised heating may still cause premature failure of any nearby winding insulation.

The two different techniques for assessing the condition of the inter-laminar insulation are low power and high power inter-laminar insulation tests. These are discussed below.

Low power - Electromagnetic Core Imperfection Detection (EL CID) Test

There are a few types of low-power test, but the one most commonly used/accepted in the industry, is the EL CID test. This was originally developed by the CEGB of the UK in 1978, in response to an excessive number of failures on their 500 MW stators. The testing they were relying on at that stage was the rated flux test; and they wanted an easier and quicker test to replace this. The original in-house EL CID was then commercialized through Adwel (recently bought out by Iris Power), and has since gone through a number of technical revisions, culminating in the Evolution digital EL CID kit.

The basic theory of the test is fairly straightforward, and hasn't changed significantly since the first version of the test. The stator core is made up of a number of thin laminations, typically 0.5mm thick or less, which are insulated from one another, arranged so that the main core flux flows solely in the plane of the laminations. They are insulated from each other to limit circulating currents in the core, which would otherwise cause overheating, breakdown of the insulation and eventually possible core meltdown.

If the insulation between a number of laminations breaks down for some reason or another (e.g. physical damage when removing the rotor, relative movement, foreign objects, poor construction, aging, etc), then current will flow axially, and a path for circulating currents is formed between the fault and the rear keybars. Thus to a large extent, this path depends on whether or not the key bars (building bars) are insulated from the core laminations.

For the EL CID test, an excitation is applied to the core by passing current through a toroidal winding which produces a ring flux similar to that under normal operating conditions, with the main difference being that its magnitude is only 4% of normal

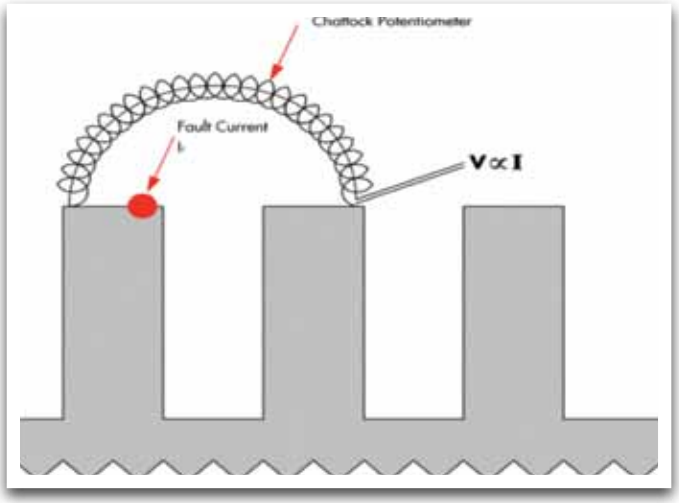


Fig 1: Sketch from EL CID Manual of the Chattock Potentiometer

flux levels. A sensing head containing a Chattock coil is then used to scan the stator bore surface. It detects the magnetic potential developed between its two ends, by both the excitation flux and any extra current flowing in a fault within its span, as illustrated in Fig 1. The coil output is a small ac voltage, which is scaled via a calibration procedure to record as a magnetic potential in milliamps. (Since currents normally cause magnetic fields, they are conventionally recorded as a current.)

Since the voltage (and hence current) induced in a fault is 90° lagging the inducing flux, the two components of magnetic potential (excitation and fault) detected by the Chattock coil are thus 90° out of phase with each other. This effect is used by the EL CID Signal Processing Unit (SPU), which uses a reference coil around the supply winding to detect the phase of the induced excitation current. It contains phase sensitive quadrature detectors to separate out the components of the Chattock signal into two outputs, one termed Phase for the excitation, and the

other termed Quad, which is representative of the fault current in the core.

The Chattock coil is mounted on either a specifically designed manual trolley, or a Robotic Inspection Vehicle (RIV) for ease of manipulation through the core. Also mounted on the trolley/RIV is a distance encoder, which outputs pulses to the SPU proportional to the distance it travels.

This is then used to determine the axial distance of the Chattock coil from the end of the core. The SPU sends this information, along with the Phase and Quad (i.e.fault) current information to a laptop, and the ELAN software then plots traces of the Quad current (on the Y-axis), versus distance from the end of the core (on the X-axis). The test setup is shown in figures 2 - 4.

The main advantages of the EL CID test are the ease of setup and execution (a test on a 600 MW core can be carried out in less than 4 hours) hence low costs, and the fact that the data obtained is quantitative and repeatable, hence can be trended. There are also considerable safety advantages when compared to rated flux testing.

Note that it is critical to get the correct slot numbering when carrying out ELCID tests. This should preferably be obtained from the winding diagram. If no winding diagram is available, the slot numbering chosen must be recorded for future reference. In addition, it is usual to start the test from the exciter end of the machine. If the test is started from the opposite end, this information must also be recorded. This information is critical for trending of results (i.e. comparison of past and present test results).

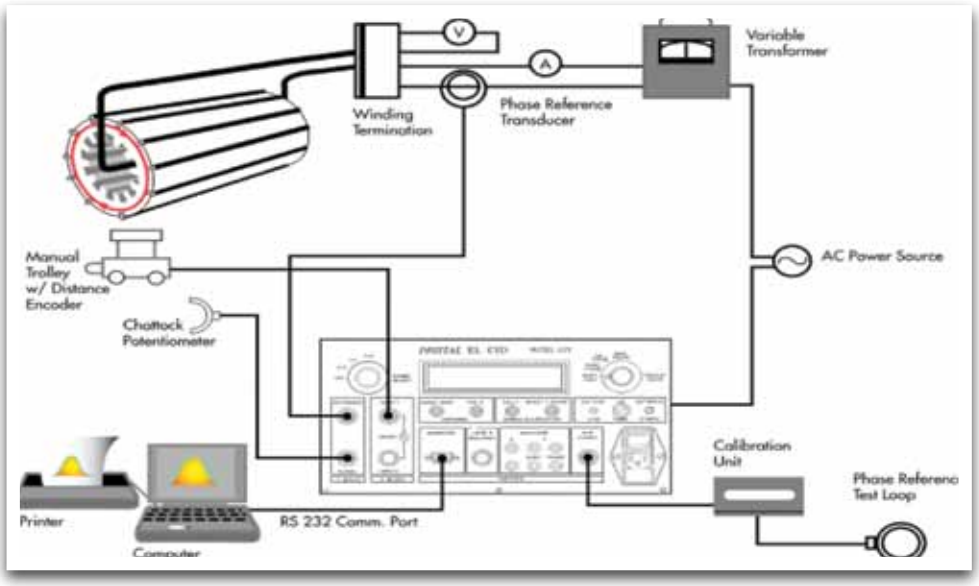


Fig 2: Sketch from EL CID Manual showing EL CID Test Setup

Fig 3: ELCID Test Setup for Rotor In-situ test

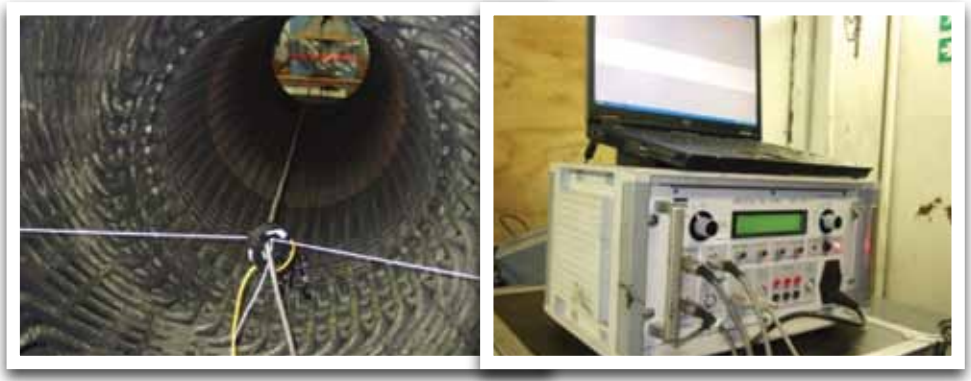


Fig 4: ELCID Test Setup for conventional test

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High Power - Rated Flux Test

This is also called a "ring test" or "loop test". The test is conducted by wrapping the stator core with a toroidal winding as for the EL CID test, and putting sufficient voltage per turn in this winding to excite the core to near rated flux levels. This can require over 1000 V/turn, and sometimes several thousand amperes of current, depending on the size of the core being tested.

The test current is left on for a minimum of 30 minutes and up to 120 minutes. During this time, the core is scanned using a thermal imaging camera for areas where the temperature rise is significantly higher than the ambient temperature rise of the bulk of the core (commonly known as hotspots). One of the problems with this test is that acceptance criteria are hard to define, and different OEMs recommend different criteria. Generally, a hotspot is defined as being 10-20% (or 5-10°C) above the average temperature of the core during the test, but in Eskom's experience 15 °C rises, and even 20 °C rises, have been deemed acceptable by different OEMs.

There are a number of concerns with this test. Setup can take in excess of two days, requiring a number of permits to be taken out, a large high voltage single phase power source is required, preferably not too far from the generator under test, as well as a long length of high current cable, thoroughly supported in the bore along with necessary breakers and controls. All this results in it being a very expensive test. There are also significant personnel and plant safety risks, owing to the high voltages and currents involved.

Another concern is the possibility that, in larger cores with the winding in-situ,

Fig 5: Rated Flux Test Setup on a Hydro Stator Core

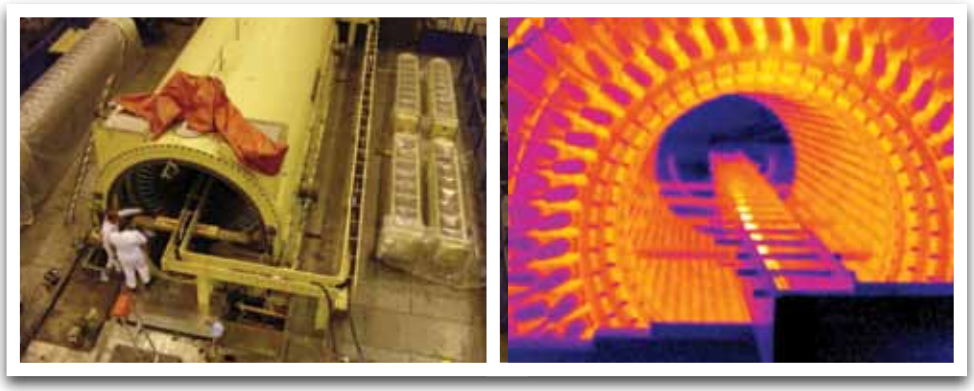

Fig 6: Rated Flux Test Setup and View Through Thermal Camera on a 600 MW stator

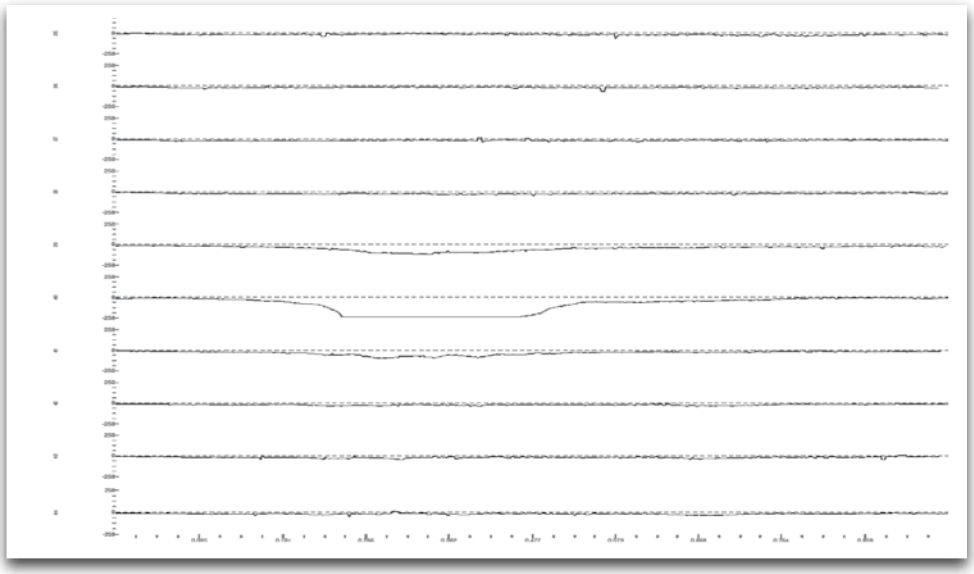

Fig 7: EL CID Overview Results for slots 35 – 45

deep-seated faults will not show on the surface within the relatively short duration of the test, largely because the core is designed as an efficient heat sink, and the heat produced by the fault gets dissipated rapidly. However, as there is no cooling on the core during the test, this heat may result in further localised damage to the inter-laminar insulation.

CASE STUDIES

Small Air-cooled Stator (<10 MW)

During a routine inspection, some signs of darkening of the core surface were observed on a small generator stator. A decision was taken to do an EL CID test, with the following results depicted in figures 5-7.

According to the results printout, it can clearly be seen that in slot 40 (corresponding to the area of darkening) there is a fault indication over a length of approximately 25 cm. This is supported by slight deviations in the traces on either side in the same direction, indicating a fault on the surface of the tooth. A close up of the trace in slot 40 confirms the fault reading of -412 mA.

The latest ELAN software for analysis of EL CID test results includes a useful feature called Core Visualisation, which approximates the view one would get when looking through a Thermal Imaging Camera. In the screen capture below, the range has been clipped at ±100 mA. Note that the area of concern would be just to the right of Top Dead Centre (TDC) when looking from the Opposite Turbine End (OTE), as slot 1 is at Bottom Dead Centre (BDC).

Although the EL CID results give a clear indication that a problem exists in the area, the decision was taken to confirm the results by doing a rated flux test (which is

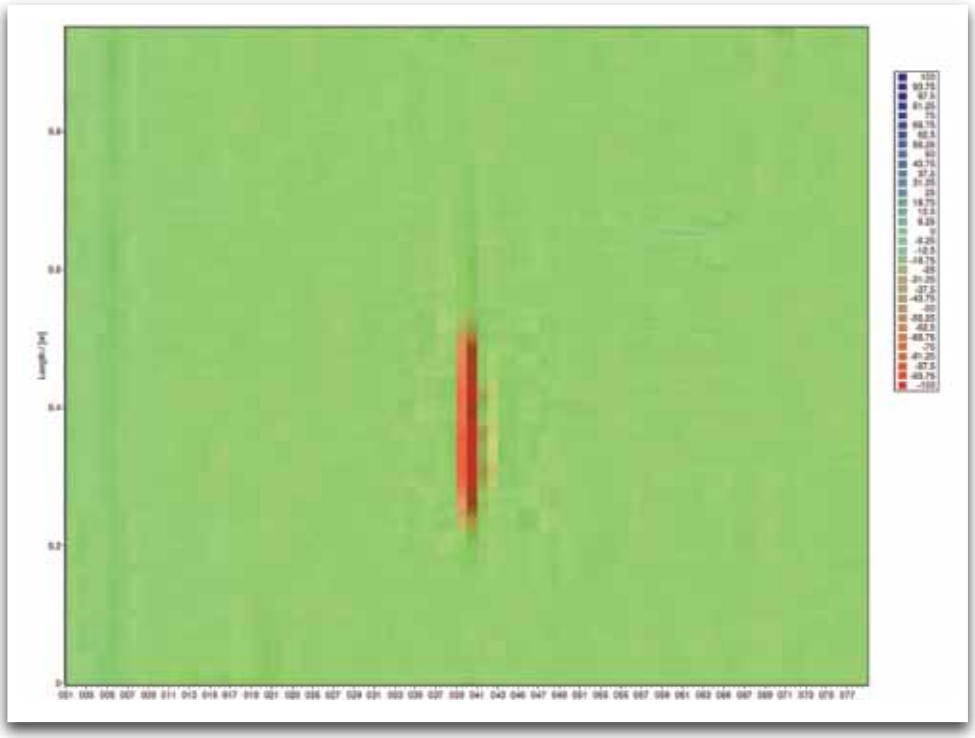

Fig 8: Core Visualisation View

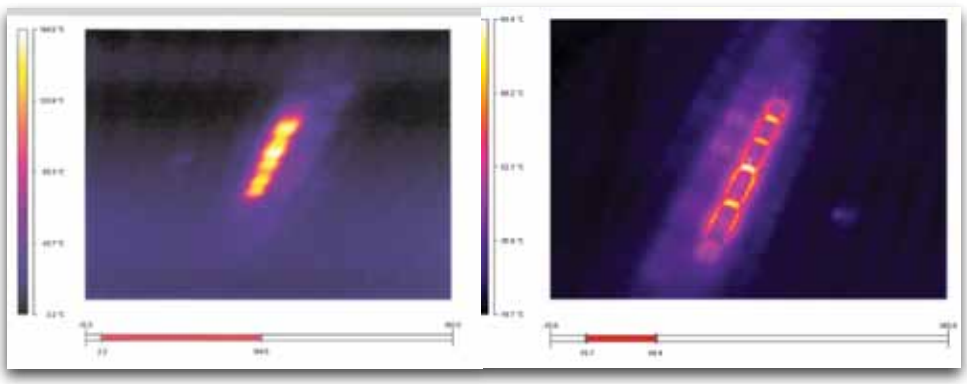

Fig 9: View of slot 40 through Thermal Imaging Camera Before and After a Repair Attempt

less of an exercise on a small machine). The results very clearly confirmed the EL CID results, and the area of overheating can be seen just to the right of TDC (the camera is looking from the OTE):

The temperature recorded is approximately 146°C to 150°C. The ambient is approximately 42°C to 48°C, giving the hot spot a rise of approximately 100°C. Obviously in service there will be a cooling flow over this area, so the actual temperature rise in service will be less.

The second thermal image in fig 10 shows the results after an attempt was made to repair the damage by grinding and etching the surface of the stator tooth in the area. This resulted in a significant improvement, with the maximum scale in the second image being 84 °C. Based on this, and the time factor, the plant owner made the

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decision to return the machine to service without further intervention.

This case study shows an interesting correlation between the two tests, and confirms the effectiveness of both tests in detecting surface faults.

Small Air-cooled Stator (<20MW)

This generator had no known problems, and the EL CID test was done during a routine maintenance outage. As can be seen in figure 10, slots 1 and 2, right near the exciter end, had a clear fault indication.

A close up of slot 1 with the data for slot 2 loaded confirmed that the fault level is approximately 683 mA - figure 11.

Just for interest, figure 12 is the Core Visualisation of the results, showing how easy it is to see the location of any hotspots with this analysis technique.

The first 3 wedges were removed in slot 1, and a small area of overheating was observed

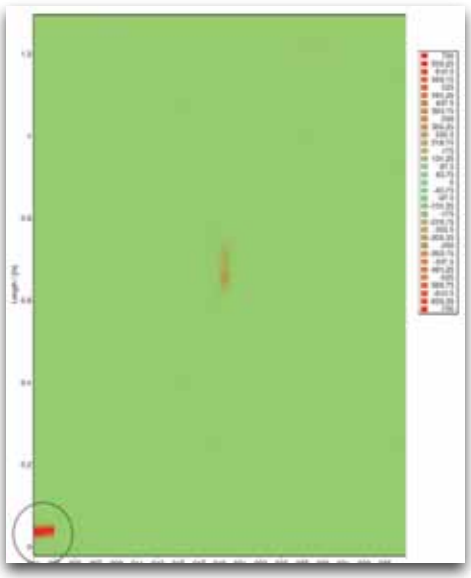

Fig 12: Core Visualisation Printout

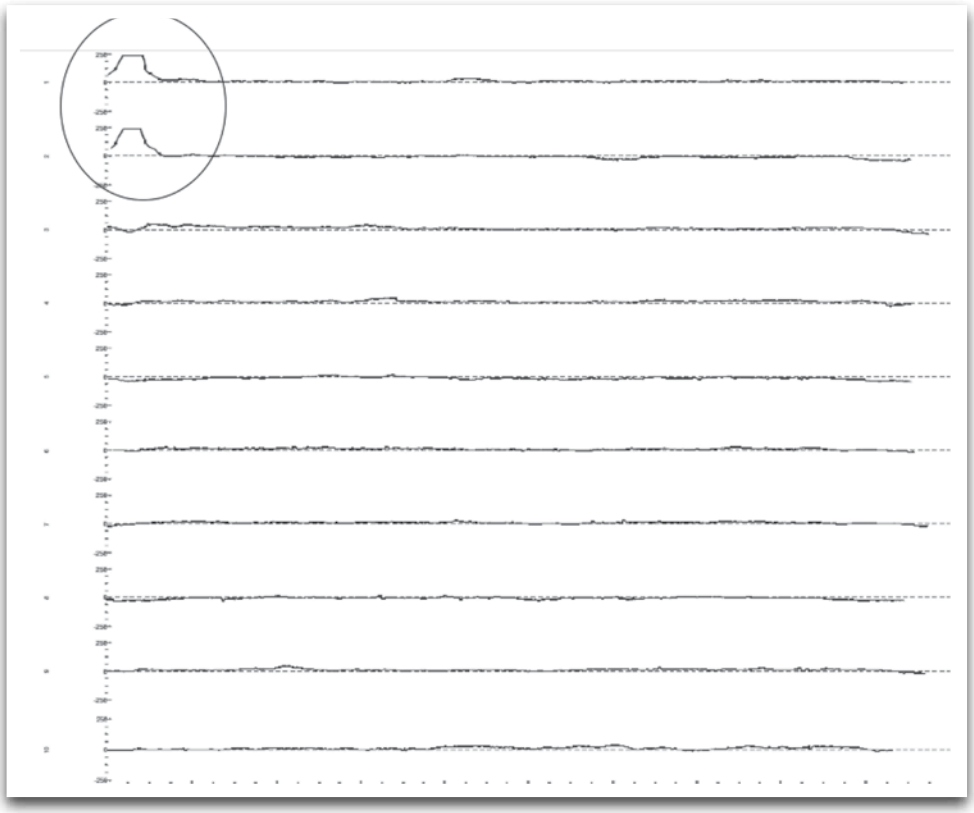

Fig 10: Overview of EL CID Results Showing Fault in Slot 1

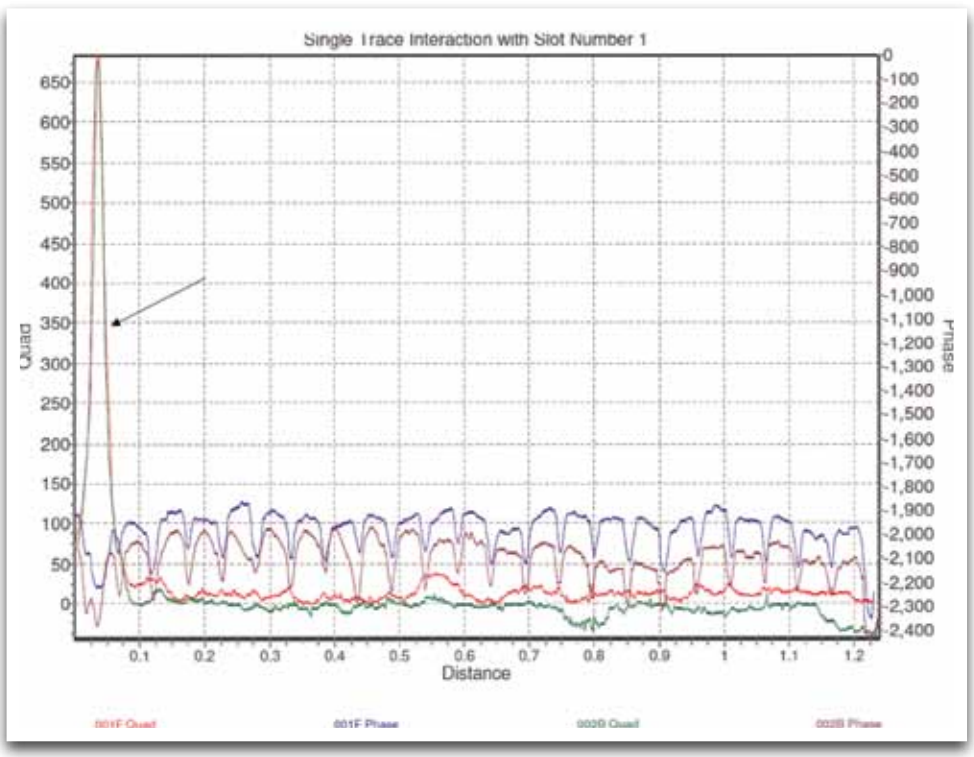

Fig 11: Close up of Slot 1 with Slot 2 Loaded for Comparison.

on the side of the slot beneath tooth 2 in the dovetail groove (unfortunately no cameras were allowed on site and so no photographs of the damage were obtained). Some damage to the packing material on top of the bar was observed. This was replaced, and the hotspot was removed by grinding and etching. The EL CID test was repeated, with the results depicted in Fig 13. The test confirmed that the repair had been successful. Note in figure 14, the Reference Transducer was the opposite way around in the final test, compared to the initial test, hence the phase is opposite. This has no affect on the validity of the results.

This case study shows how effective the EL CID test can be where small, easily repairable core defects are concerned. Had the test not been done, the hotspot would have continued deteriorating, probably to the point where it caused stator bar insulation failure. But detecting it in time allowed for a quick and easy repair to be carried out, restoring the core to full integrity (it is still in service today, 15 years later).

Medium-sized Air-cooled Stator (<100 MW)

This was a test done during routine maintenance on an old stator with significant contamination and rusting in the core. Although no previous tests had been done on the stator in question, previous tests on sister units had found generally high EL CID readings, although with little or no significant deterioration over the years. Overall, the EL CID results do not look good - Fig 15. The core visualization shows how generally deteriorated the core is depicted in figure 17.

The two highest readings were adjacent to slots 17 and 19, and had readings exceeding 1000mA. A thorough visual inspection of the area was carried out, and nothing to account

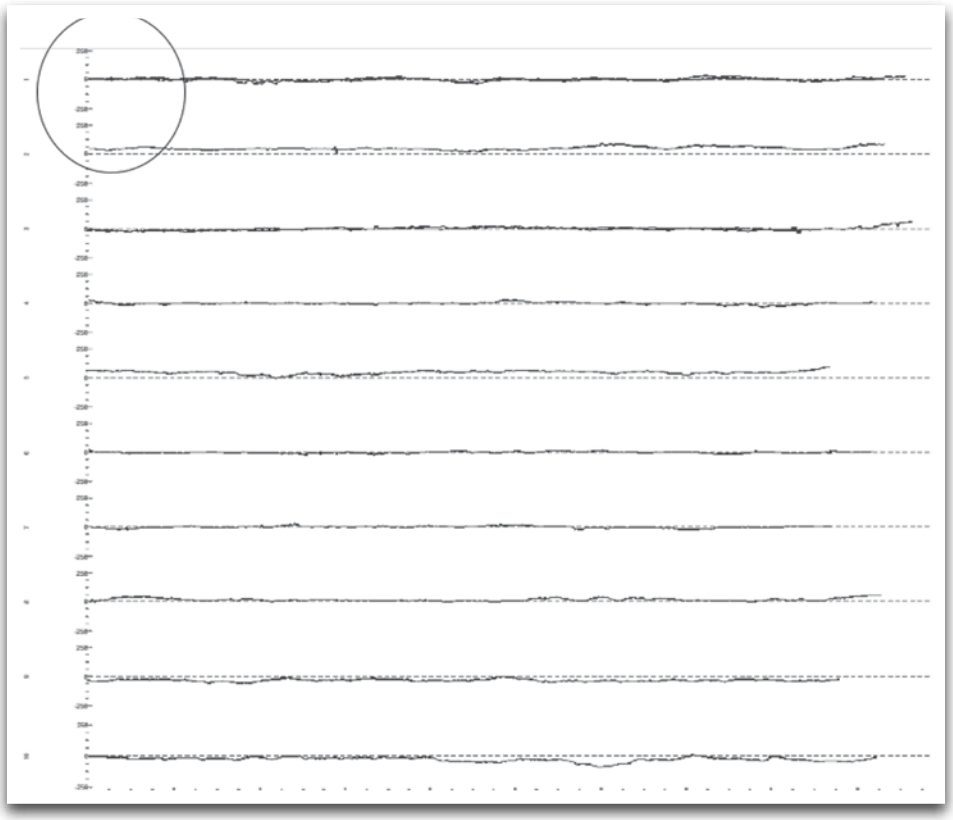

Fig 13: EL CID Results After Repairing the Hotspot.

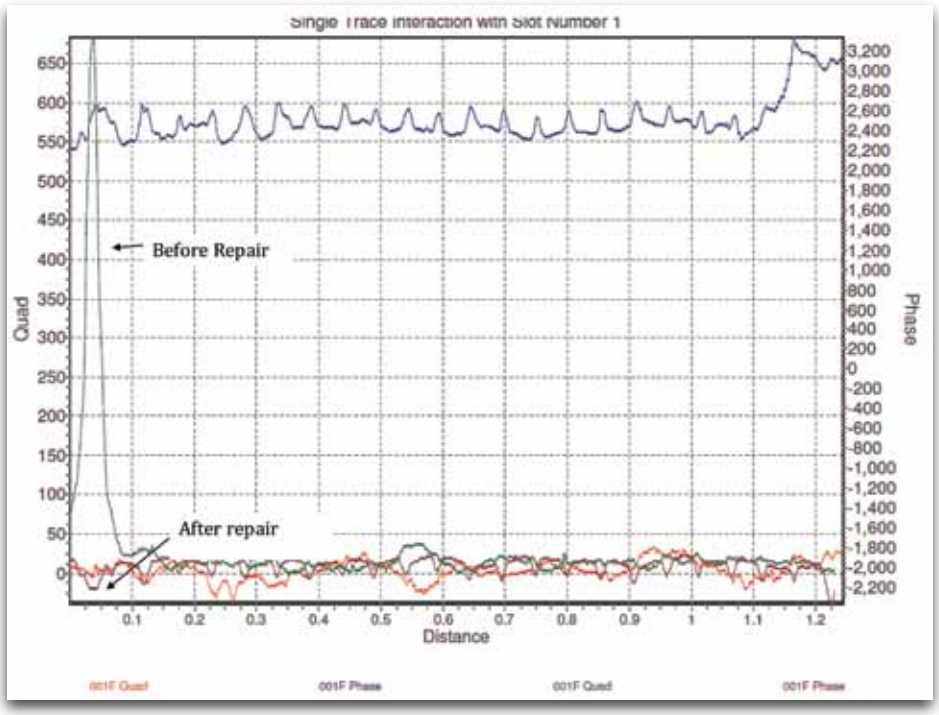

Fig 14: Close Up View Showing the Before Reading in slot 1 (green trace) and After (red trace).

Core Testing

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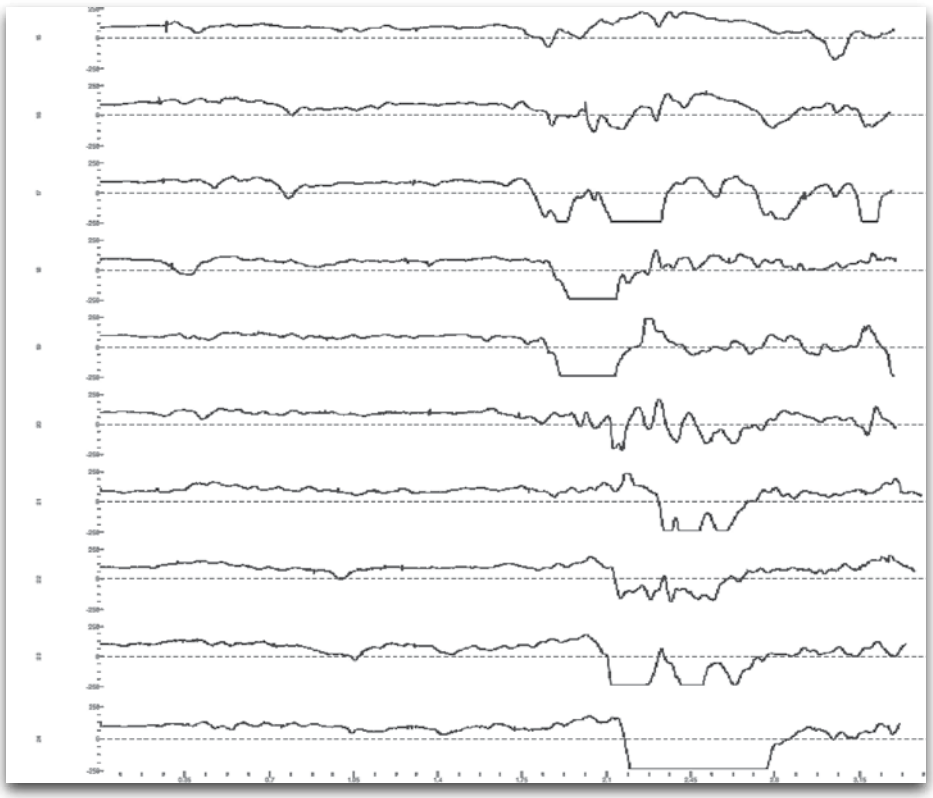

Fig 15: Overview of Results in a Bad Section of the Core.

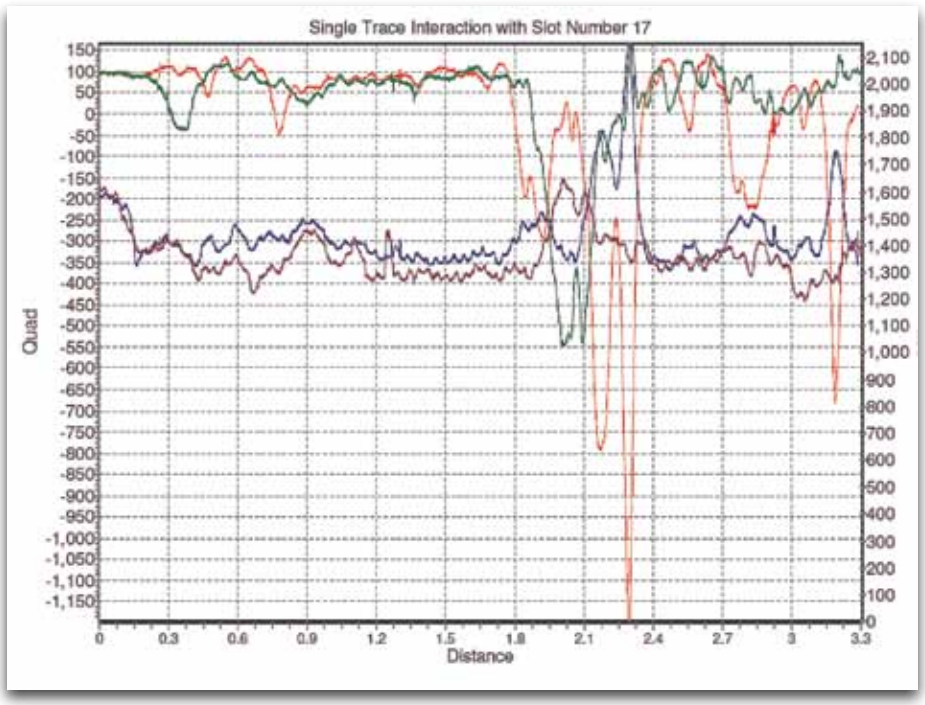

Fig 16: Close up showing the results in slot 17 (Red Trace) overlaid with the results in slot 18 (Green Trace).

for the high readings was seen on the surface of the core. This correlates with the analysis of the results, which indicates that the faults are below the surface. In Figure 16 above the red indication (from slot 17) goes in the negative direction, and the green indication (from slot 18) goes in the positive direction. The phase levels are very similar and in a sensible range, adding to the confidence in the results' validity.

The back of the core was also inspected – nothing was seen there, or in the geometry of the stator to account for the high readings. However, significant rusting of the core was seen in a band around the stator, corresponding with the area of brighter red in the Core Visualisation (fig 17). Note that rust itself is not conductive – but it will displace the insulation at that point, and vibrations could result in core steel touching in service.

Carrying out a rated flux test was considered, but as the faults appeared to be numerous and deep-seated, it was considered possible that a rated flux test could actually result in further damage to the stator, without adding any significantly useful information. Unfortunately, no previous test data was available, so it could not be determined whether the core was deteriorating or not. However, it was considered likely that had a test been done 6 years previously during the last maintenance outage, it would have had similarly high readings, as photographs showed that the general condition of the core was similar back then.

The decision was taken to return the unit to service with an RTD installed as close to the highest fault area as possible, with a reference RTD being located in an area, which had low levels of Quad current. During hot commissioning of the generator,

the temperatures measured by the two RTDs did indeed show a significant difference at rated voltage. At its highest, the fault RTD was measuring approximately 104°C, while the reference RTD was measuring around 37°C. This confirmed the results of the EL CID test, and justified the decision to return the unit to service. No significant increase of the results over time has been noted to date. A further EL CID test will be done at the next opportunity to see whether or not the high readings are increasing, indicating that the core is deteriorating.

Large Hydrogen Cooled Generator (<400 MW)

During the rewind of this stator, the initial EL CID test showed a number of areas with slightly high readings, but nothing of major concern (other than that the core as a whole did not look in a good condition). Note that the scale is ±250 mA.

Close up of a number of slots confirmed that there were a few high readings, but only around the 130 mA level (figure 19).

Several other close ups showed a pattern with similarly high readings in roughly the same area of the core. Note the two peaks around the 1.6 m and 2.4 m marks (figure 20).

It was observed that the high readings corresponded to the start of the vent duct section of the core. This is a stator, which only has cooling vent ducts in a section in the middle of the core (fig 21).

When the bars were removed, in several areas between the first vent duct and the rest of the core, hotspots were observed in figure 22.

Some damage had been done to the bottom packing, but it had not penetrated onto the

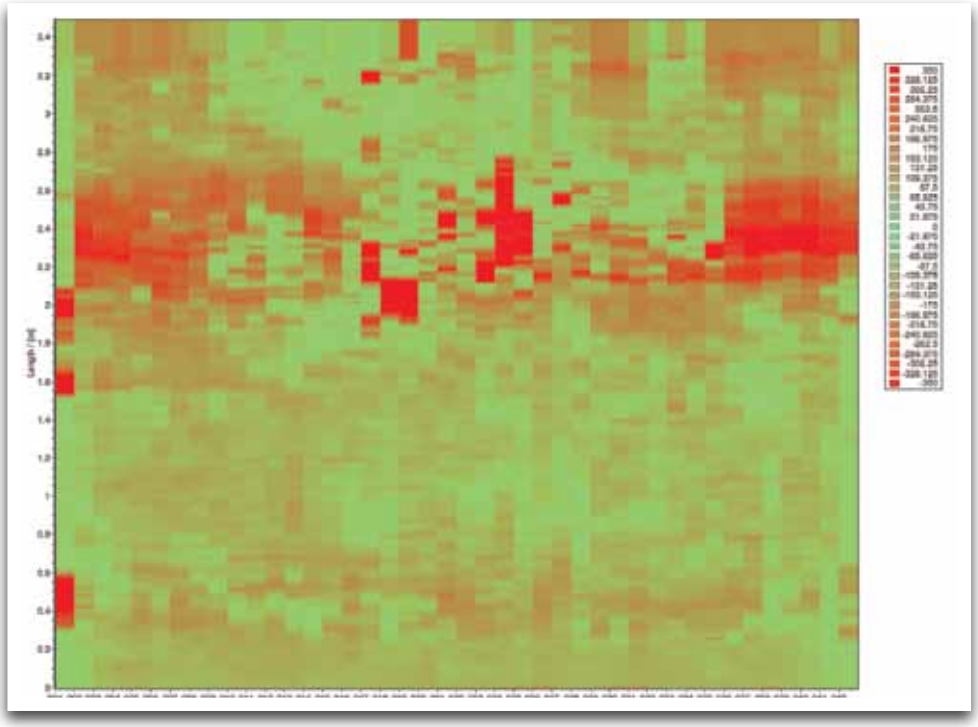

Fig 17: Core Visualisation

Fig 18: Core Rusting

Core Testing

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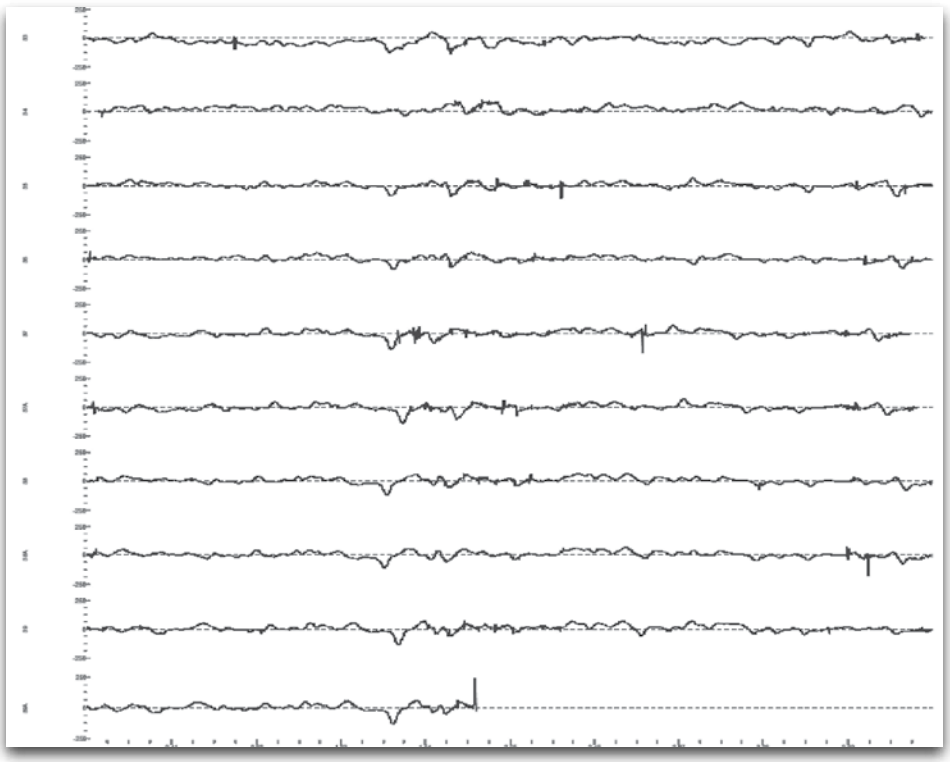

Fig 19: Overview of a Section of the EL CID Results

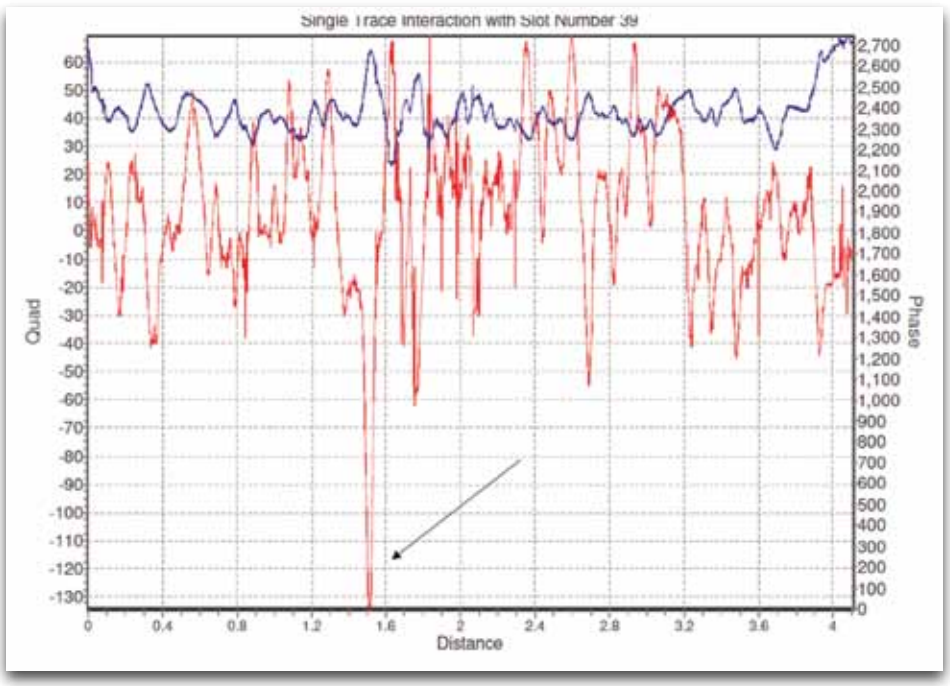

Fig 20: Close-up of Slot 39.

actual bar insulation. It appeared as though there were circulating currents between the vent duct spacers and the core laminations causing the overheating. These only just showed on the EL CID test, although it is positive that the EL CID did in fact detect them. There appears to be a significant damping factor between fault current at the top of the slot and the bottom of the slot. However, despite the overheating, the core was in excess of 30 years old, and no failure had occurred.

Large Hydrogen Cooled Generator (<600 MW)

An EL CID test was done on this stator as part of a routine GO. One clear area of concern was noted as shown in figure 24.

The peak was just over 240 mA, and the indications were that the fault was deep-seated. Normally this would be of concern, but one of the major advantages of EL CID testing is that the results can be trended. Fortunately, in this instance, results from a very early EL CID test done over 20 years previously showed absolutely identical results, with the same magnitude.

This gave the reassurance that although there is genuinely a fault present, it has not deteriorated in more than 20 years, and hence is unlikely to be of concern in the future.

DISCUSSION

In all the examples, significant investigation and analysis was carried out after the results of the EL CID test were initially presented. In all cases, the first step taken was close-up scanning of the area of concern with a mini-Chattock coil, which is a small version of the trolley-mounted Chattock coil connected directly into the EL CID SPU. The area of concern is scanned by hand, and by opening

and closing the ends of the coil and moving it around in the area, the point of maximum fault current can be accurately located. It can also be better determined whether or not it is on or close to the surface.

The next step is a physical inspection of the area for signs of overheating or damage. If none is visible on the surface, it may be required to remove a wedge. In extreme cases it may be necessary to remove a bar, but this will depend on a number of factors, and is considered a last resort investigative step. If no obvious reason for the high EL CID reading can be determined then expert analysis of the test results, previous history, trends, etc needs to be done in order to make a decision on the way forward.

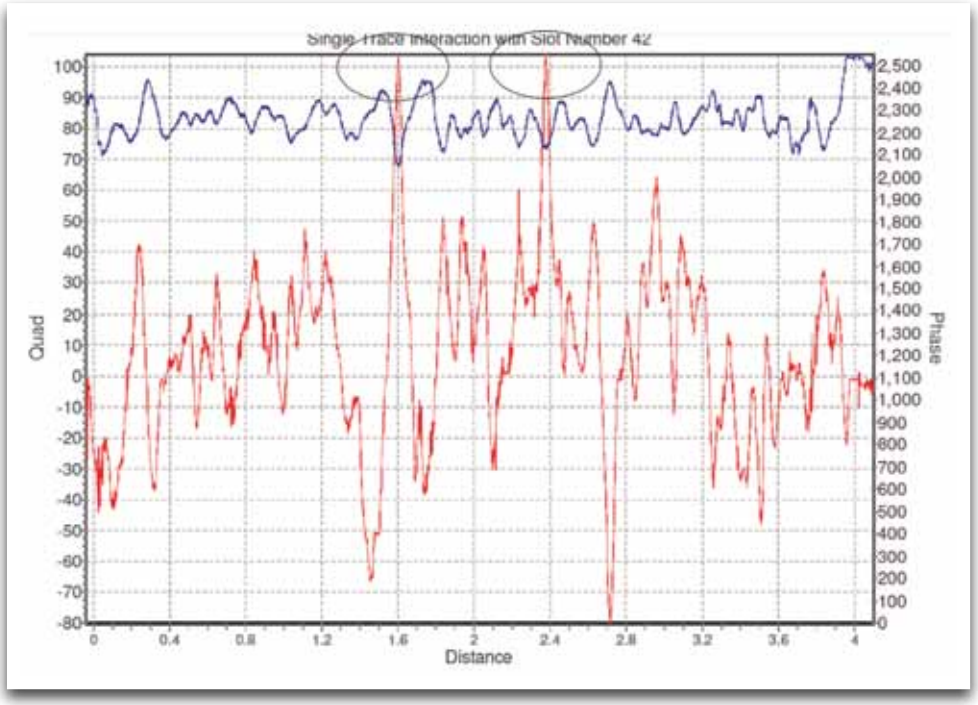

Fig: 21: Close up of slot 42.

Fig 22: Photo of the Core Showing the Vented Section in the Middle.

However, the generally accepted maximum limit of 100 mA appears from the author's experience to be on the low side. Apparently the limit was arbitrarily determined in the early days of testing. When the average readings on a number of 'good' cores tested were found to be less than 50 mA, the decision was taken to double this and decree 100 mA to be the maximum acceptable fault current reading. Studies have shown that it roughly corresponds to a 5 – 10 °C hotspot temperature rise in the rated flux test, although one of the case studies above does not support this. However, there may be a number of other factors involved affecting the results. As a detailed study was not carried out, and as a limited amount of data is available, the results of the case study cannot be considered conclusive in any useful way.

However, the question that arises from all of these case studies is how much EL CID Quad signal is too much? At present there does not seem to be a scientifically

Core Testing

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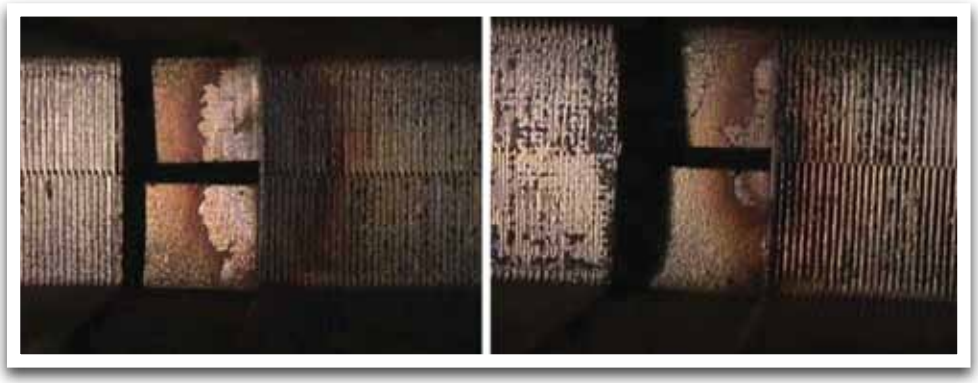

Fig 23: Close up View of the Hotspots Between the Vent Duct Spacer and the Core Laminations.

determined answer, although David Bertenshaw, previously of Adwel and now an independent consultant with ENELEC, has carried out research work in the UK to better define the relationship between the EL CID Quad level and high flux temperature rise.

This has shown that over a substantial body of tests, the population has a mean correlation of 8.5-10.7°C temperature rise per 100mA EL CID Quad signal, with 95% being within 18°C. A lot depends on how long and deep the fault is, structural features of the stator core, whether or not the key bars (building bars) are insulated from the laminations, obviously the quality of the inter-laminar insulation (its thickness, application, thermal qualities, etc), and maybe even the type of steel used to manufacture the laminations.

CONCLUSION

Until more quantitative analysis guidelines are available, it is the author's opinion that each EL CID test must be analysed on its own merits, that the acceptable limit of 100 mA may be overly conservative and needs to be reviewed. In addition, a host of considerations, other than purely the test results, need to be taken into account before deciding on a course of action.

The 100mA threshold has value used in conjunction with expert interpretation. It acts as a trigger to investigate and form a judgement on the likely fault, its importance, and if and when to take corrective action. As has been seen here, many faults can exceed 100mA and not directly need rectification, but may need action to implement a monitoring regime to maintain the machine's reliability. In addition, in many situations an economic decision is made where a low risk fault does not justify a high cost repair.

It is standard philosophy to carry out EL CID testing as the standard inter-laminar insulation assessment test. If there are concerns with the results, a rated flux test may be considered, depending on the situation. The exceptions are if a core is restacked, and occasionally during a stator rewind.

During a core restack, it is considered standard practice to carry out a rated flux test before the final pressing is done, both to ensure the integrity of the insulation and to settle the laminations before the tightening of the core bolts. During stator rewinds it is less common to do rated flux tests as well as an EL CID, but in the case of an old, or poor quality core, the two tests may be done to be sure the core is suitable to be rewound. In this case the rated flux test would be done with the stator winding removed, which would give the tester a better chance of detecting faults down the sides and at the bottoms of the slots.

Overall, the EL CID test is a valuable test. It is recommended it be performed before and after any maintenance work is done, which might affect the integrity of the core, e.g., stator re-wedging, re-tightening of the core, partial or full rewind, etc. Also, the test can be useful for evaluating known or suspected damage, or weakness of the core lamination insulation.

Because specialized equipment and training are required, it is important that this test be performed by qualified and experienced personnel. Similarly, analysis of results is seldom straightforward, and should be carried out by experienced personnel, taking into account the factors dicussed. wn

ACKNOWLEDGMENT

The author wishes to acknowledge the valuable assistance received from David Bertenshaw in reviewing the paper.

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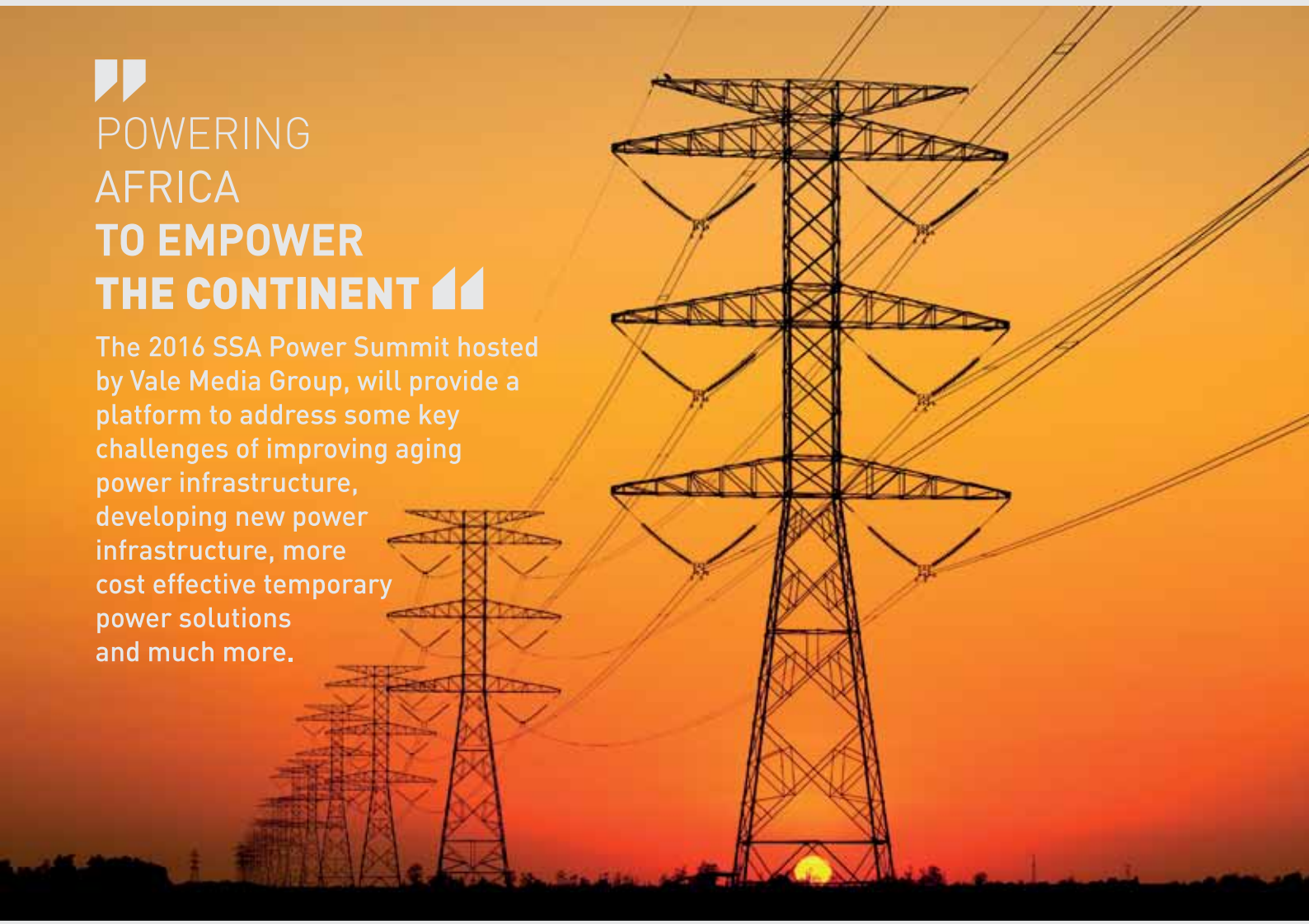

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The Large Haldron Collider (LHC) is the largest machine ever built, and which is used to study the initial stages of the Big Bang and the ultimate nature of matter.

BY | DUDLEY BASSON

The LHC was built by the European Organization for Nuclear Research (CERN - derived from Conseil Européen pour la Recherche Nucléaire established in 1954) between 1998 and 2008 in collaboration with over 10 000 scientists and engineers from over 100 countries, as well as hundreds of universities and laboratories. CERN has 22 member states and is also the birthplace of the World Wide Web.

The name of CERN was changed in 1954 to Organisation Européenne pour la Recherche Nucléaire. According to a former director of CERN, when the name was changed, the acronym could have become the awkward OERN. Heisenberg said that the acronym could still be

The Large Hadron Collider

CERN even if the name is not. Heisenberg was enthusiastically supportive of the establishment of CERN. He went on to be elected to chair the inaugural Scientific Policy Committee and is credited as one of CERN's co-founders.

The accelerator is housed near Geneva, Switzerland. The tunnel housing the beam pipes is located underground at depths varying from 50 m to 175 m below the surface, lying partly in Switzerland and the rest in France. The original tunnel was excavated between 1983 and 1988, and formerly used to accommodate the LEP (Large electron-positron collider).

The LHC had its initial switch-on ceremony on 10 September 2008. Nine days later a faulty electrical connection led to the rupture of a liquid nitrogen enclosure, causing magnet quenches in about 100 bending magnets, and several tons of liquid helium gas escaping with explosive force. This resulted in damage to 53 superconducting magnets, and contamination of the vacuum pipe, delaying further operations by 14 months at a cost of €28 million.

The LHC accelerates particles in circular paths of 27 km to an originally 7 TeV per particle (7 x 10^{12} electron volts), which

The LHC

continues from page 43

The CMS (Compact Muon Solenoid) detector

was upgraded to 8 TeV in 2012, and then after a major upgrade to 14 TeV in 2015. The particles are grouped into nearly 3000 bunches which can complete a circuit in 90 microseconds. The bunches are about 30 cm long and contain 1,15 x 10^{11} protons. The beam particles are accelerated by means of radio frequency cavities which resonate at 400 MHz. The ideally timed proton, with exactly the right energy, will see zero accelerating voltage when the LHC is at full energy. Protons with slightly different energies arriving earlier or later will be accelerated or decelerated so that they stay close to the energy of the ideal particle. In this way, the particle beam is sorted into discrete bunches which complete 11000 circuits per second in the 27 km path.

It is not meaningful to convert the extreme particle energy of 14 TeV to joules, as this will give a small misleading result – about 2,2 microjoules. The total energy stored in the guide magnets is 10 GJ, and the beam will carry 362 MJ of energy, which is equivalent to 78 kg of high explosive – comparable to the propellant charges of WW2 battleship batteries, so that the beam dump must be capable of absorbing a vast amount of energy.

When a beam is to be dumped, it is steered into a 700 m tunnel where it is first fanned out to a diameter of 1,5 mm by means of 10 dilution magnets before passing to the 10 ton, 8 m long, 0,7 m diameter block of graphite composite. The beam is scanned across the dump face to protect the graphite for future use. The graphite is enclosed in a protective casing of 1000 tons of steel and concrete. The unmoderated beam would be capable of melting a 40 m deep hole in copper.

A convenient way of getting a grasp of the enormity of the accelerator is to take a look

at the cost. The initial estimated cost was €7,5 billion which is eight times the cost of the Queen Mary 2 ocean liner.

The costliest parts of the collider are the supercooled super-conducting electromagnets. The beams are kept on their circular paths by 1232 fifteen metre long dipole magnets, and 392 quadrupole magnets keep the beams focused. The particle beams are focused to an unbelievable size of 16 microns. The dipole magnets are also equipped with sextupole, octupole and decapole magnets, which correct for small imperfections in the magnetic field at the extremities of the dipoles. The quadrupoles are spaced 53,5 m apart, enclosing three dipole magnets. Coil-block arrangements are made of Rutherford type cable (a profiled form of Litz wire) with grading of current density due to the keystoning of the cable. Litz wire is commonly used with high frequency alternating current to counter the skin conducting effect, but is also used for superconducting DC electromagnets.

For an excitational current above a density of about 10 A/mm^2, one has to switch to superconducting coils. The maximum achievable current density in superconducting coils is higher than in copper coils by a factor of 1000.

A magnetic field of one tesla strength can easily be achieved with conventional electromagnets, however superconducting magnets on an industrial scale can reach up to 10 T. Electric field strengths in the gigavolt per meter range are technically not feasible. This is why high energy particle accelerators use only magnetic fields for guiding the beams.
The beam pipe is of 56 mm diameter with the superconducting cables running along either side. Eighty cables run along the one side of the magnet and back along the other in two layers.

The Rutherford cables house 36 strands of super-conducting wire, each strand being exactly 0,825 mm in diameter. Each strand houses 6300 super-conducting filaments of niobium-titanium. The filaments are six microns thick, (similar to the thickness of spider web) and have a 0,5 micron coating of pure copper. In the super-conducting state the copper acts as an insulation, and out of the super-conducting state it acts as a conductor of electric current and heat. The total length of the super-conducting filaments is more than 5 times the distance from the Earth to the Sun.

Most of the magnets each weigh over 27 tons, and 96 tons of supercooled superfluid helium are required to keep the magnets at an extreme cryogenic operating temperature of 1,9 K. The initial cooldown of the 31 000 tons of material required 12 million litres of liquid nitrogen. CERN has the largest extreme refrigeration installation on Earth. The magnets are made of niobium-titanium alloy, operating at a field strength of 8,35 tesla. The super-conducting electromagnet coils are capable of carrying currents of 15 kA. The beam tubes are of complex design. The outer vacuum tube is circular, containing an inner beam screen made from low magnetic permeability stainless steel, copper coated on the inside. The beam screen is designed to resist crushing magnetic forces, and minimise atom desorption caused by synchrotron radiation. The beam tubes will shrink 10 metres when cooled to cryogenic temperature. The tidal effect of the Moon raises the Earth's crust by 25 mm in the area, causing a variation of 1 mm in the path length. The degree of vacuum achieved in the tubes is similar to that found in Solar System space.

Starting and synchronising the beams is a complex process. The proton source is a bottle of hydrogen gas, which is stripped of its electrons by an electric field to yield protons. The Linac2 accelerates the protons to an energy of 50 MeV. The beam is then injected into the Proton Synchrotron Booster (PSB), which raises the energy to 1,4 GeV, after which the Proton Synchrotron

Aerial view of CERN

The LHC

continues from page 45

(PS) raises the energy to 26 GeV and then to the Super Proton Synchrotron (SPS) where they are accelerated to 450 GeV. The protons are finally transferred to the two beam pipes of the LHC where they circulate in opposite directions. Sometimes lead ions are required, which are obtained from vaporised lead, and initially accelerated by Linac3, and enter the Low Energy Ion Ring (LEIR) before being further accelerated.

There are seven detectors housed in vast caverns, of cathedral proportions, along the path at intersection points. These are named: ATLAS, CMS, ALICE, LHCb, TOTEM, LHCf and MoEDAL. The ATLAS and CMS detectors are by far the largest.

There is a phenomenal virtual reality view of this instrument on the Internet. A special crane was rented from Belgium to lower 2000 ton pieces of the CMS detector into its underground cavern.

Like most other aspects of the LHC, the electrical requirements are enormous. When in normal operation, from 200 to 300 MW are required. Reliable power is essential as magnet failure could result in an uncontrolled beam, which could melt a ton of metal in a fraction of a second. An uncontrolled magnet quench is a disastrous event. CERN has guaranteed power from Électricité de France and, in case of emergency, can switch seamlessly to the Swiss power grid. In the event of catastrophic power failure, CERN has massive diesel generators, designed to power submarines, which can be activated to allow an ordered and safe shutdown.

On 14 March 2013, the LHC received worldwide publicity in the media, when it was announced that results from the ATLAS and CMS detectors indicated that there was a very high probability that the existence of the Higgs boson had been proven. Prof. Stephen Hawking conceded that he had lost his $100 wager that this would never happen.

Lizelle Inside the LHC tunnel

When the Higgs boson was discovered, the beam quality had reached a value of 12 inverse femtobarns. (12 fb^{-1}). It is hoped that a beam quality of 30 fb^{-1} will be achieved. The barn is not an SI unit – it is a particle physics area unit of 1 x 10^{-28} square metres (a square with sides of 10 femtometres) – much smaller than a proton. One femtobarn = 10^{-43} m^2.

The nature and gravitational implications of the Higgs boson will not be dealt with here. Suffice to mention that it is regarded as a particle, with a mass 133 times that of a proton (125 GeV), and has a lifetime of 156 yoctoseconds (1,56 x 10^{-22} s). This is the time required for light to travel 46,8 femtometres (4,68 x 10^{-14} m), which is about double the size of a proton.

The LHC was shut down on 14 February 2014 for a major upgrade, which would raise the beam energy to 14 TeV. On restarting the LHC on 5 March 2015, CERN scientists continued to probe dark matter, dark energy and supersymmetry.

The restart was delayed a few days by a power outage caused by a weasel invading a HV power transformer enclosure. The weasel did not survive (Pop went the weasel). Supersymmetry is physicists' best attempt so far at explaining what happens in the subatomic universe beyond the Standard Model. A theory that has been worked on and refined for almost 40 years, it proposes the existence of a set of new particles, each one a super-symmetric partner of the particles that already exist in the Standard Model.

On 26 June 2016 the LHC achieved its design luminosity of 1 x 10^{34} cm^{-2} s^{-1}. In particle physics, luminosity measures how many protons pass through a given area in a certain amount of time. CERN is planning for a tenfold increase in luminosity by 2020, with a consequent tenfold increase in collisions.

Much research is being done at CERN in the creation and study of antimatter. The first atoms of anti-hydrogen were produced in 1995 – consisting of an antiproton nucleus and antielectron (positron) orbital. These were produced at CERN's Low Energy Antiproton Ring (LEAR). These would exist for about 40 nanoseconds before colliding with ordinary matter, and being annihilated. In 2011 antihydrogen atoms were successfully trapped for 1000 seconds. In 2014 it was found that the antiproton carried no charge.

In Ron Howard's movie of Dan Brown's novel Angels & Demons, antimatter plays a pivotal role, but this is quite far removed from current antimatter research. The LHC does not have a supercomputer to handle the 30 petabytes of data generated annually – this is dealt with by the Worldwide LHC Computing Grid (WLCG), which is a global collaboration of more than 170 computing centres in 42 countries, linking national and international grid infrastructures.

The huge commitment of scientists, funding and resources to the LHC promises further major discoveries and breakthroughs in particle physics. Work is underway searching for an unknown super-massive particle, which will outshine the sensational detection of the Higgs particle.

Comments by Head of Science, Lizelle Swanepoel of SAHETI School, Bedfordview, Johannesburg, after a visit to CERN in 2015: *During my time at CERN I have had the most scintillating experience: one I will cherish for a lifetime and that I will share with students in years to come. I hope to take a group of my students to CERN in the near future as well. Connections made with like-minded teachers from so many different countries have been most valuable. We hope to bring some combined projects and teaching into our classrooms, to expose our students to the spirit of collaboration and internationalism, felt at CERN.*

Lizelle commented on her residential course at CERN: *The course is called the CERN HST program and is a 3 week course in particle physics, astrophysics and cosmology, with international collaboration of Physics teachers from more than 32 countries, mostly Europe and the UK and US. I was representing the African continent. Our program included 3 hours of lectures each day in the three fields mentioned, CERN experiment and testing facilities and detector site visits, Q&A sessions with CERN's director-general and experiment leaders and engineers, hands-on experiments and time spent on chosen projects which we presented at the end of our stay. This was probably the most inspirational time ever had from an academic perspective. CERN is the most special place on earth. The CERN model is definitely the way to go in all aspects, I believe. CERN is a world leader not only in the advancement of science, but also in business.*

China is planning to construct a collider twice the size, and seven times as powerful as the LHC, with a path length of between 50 and 100 km. A possible timeline has been given as:

- R&D: 2016-2020
- Engineering Design: 2015-2020
- Construction: 2021-2027
- Data taking: 2028-2035

Wang Yifang, director of the Institute of High Energy Physics, Chinese Academy of Sciences declared: *We have completed the initial conceptual design and organized an international peer review recently, and the final conceptual design will be completed by the end of 2016.*

This is to be the Chinese accelerator - Circular Electron Positron Collider (CEPC). wn

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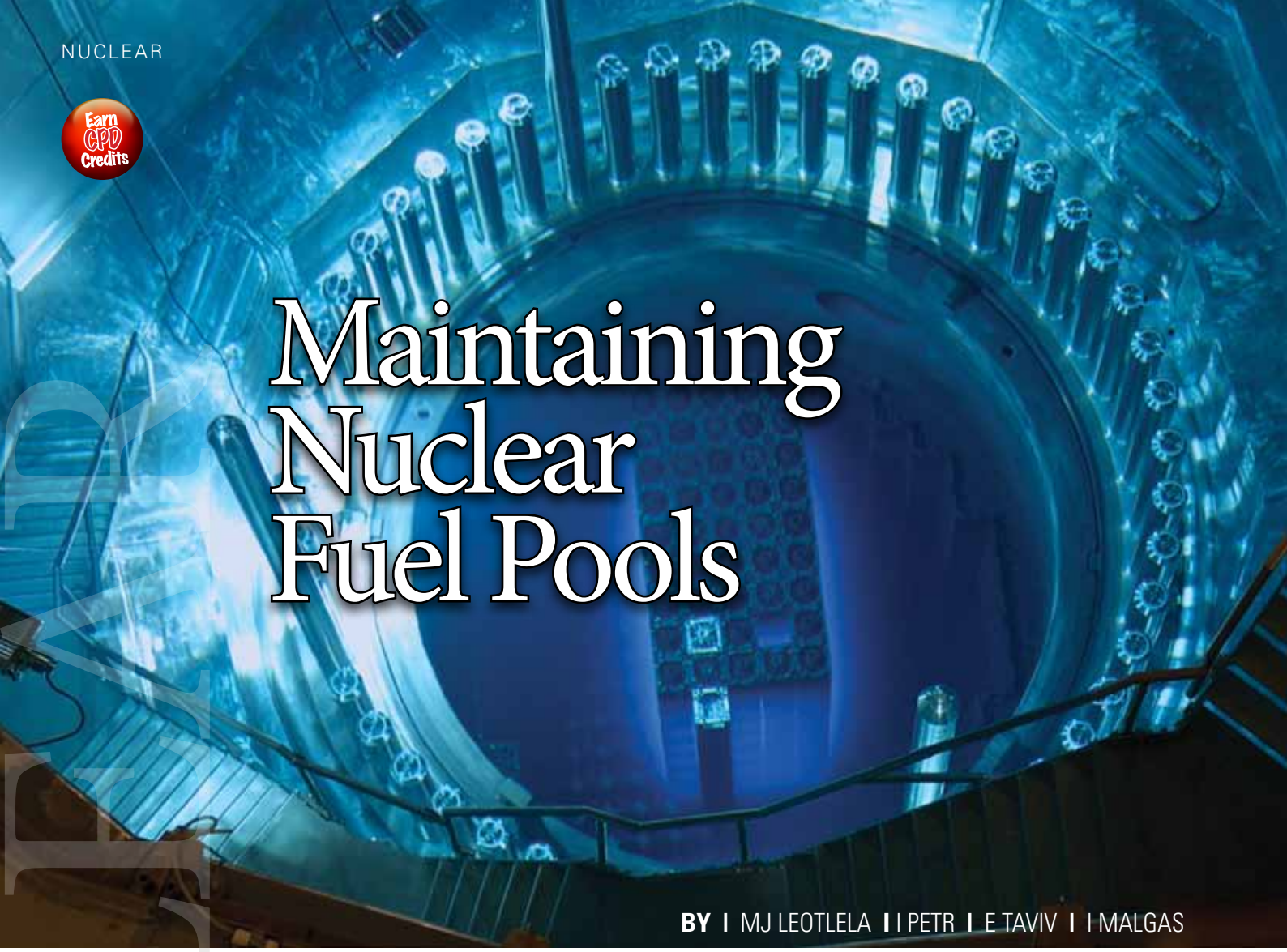

Maintaining Nuclear Fuel Pools

BY | MJ LEOTLELA | I PETR | E TAVIV | I MALGAS

A number of spent fuel pools at nuclear power stations that have been operating since the mid 1980s or earlier are gradually approaching their full capacity. This puts pressure on the nuclear facility to develop strategies to increase the storage space of the spent fuel pool if untimely shut down is to be avoided.

One of the methods that can be employed is to insert neutron-absorbing materials in the spent fuel pool with a view to reducing the number of thermal neutrons which cause fission. This will subsequently reduce the k_{eff} of the system and permit a higher fuel storage density.

This paper presents an evaluation of the suitability of the material used as neutron absorber inserts (or absorber inserts for short) and ranks several aluminium composite materials for use as absorber inserts on the basis of their effectiveness in decreasing the k_{eff} of the system, thereby recovering some of the storage space consumed as a result of over-conservatism.

Many nuclear power stations commissioned before the mid-1980s are gradually running out of storage space in the spent fuel pool, putting the facilities at risk of shutting down prematurely if a solution to preserve storage space is not in place in time. Although the application of burn up credit has been proven [1, 2, 7] to have a significant impact on the reduction of k_{eff} and the corresponding recovery of extra storage

space associated with over- conservatism in calculations, there is still much uncertainty regarding its acceptability.

While most nuclear regulators have approved the application of burn up credit of Actinides nuclide set for use in casks [1, 7], few have approved *Actinide + Minor Fission Products* and *Actinides + Principal Fission Product* nuclide sets. This further complicates the problem in that had either of these sets been approved, the operator of a nuclear facility would have had to acquire casks designed for the range of k_{eff} obtainable when credit for burn up of that specific nuclide sets is taken into account [3]. In that case most of the spent fuel assemblies in the spent fuel pool, which have to wait for an out-of-reactor cooling period of 10 years to meet the cask loading requirement, would have met it much earlier and would therefore have been transferred into the storage casks earlier, thereby reducing the number of fuel assemblies in the spent fuel pool.

The challenge associated with the decrease in storage capacity is further exacerbated by the fact that the spent fuel pool has its own loading requirements to comply with. These are defined by its burn up credit loading curve [1] which, depending on the nuclide sets used in burn up credit analyses, can either allow for much more densely packed fuel assemblies or sparsely packed assemblies. Therefore, as a result of the over-conservatism associated with a *fresh fuel approach* and the resulting ineffectiveness in conserving storage space there is a continuous decrease in the storage space available.

To increase the storage capacity of the spent fuel pool, a number of aluminium composite materials have been analysed with the aim of determining which of them would be most effective in decreasing the k_{eff} when used as an absorber insert, consequently resulting in a saving of storage space. In addition to evaluating the composition of the neutron absorber material, the study on which this paper is based also investigated the most optimum area on the fuel assembly for locating the absorber insert which would result in the highest Δk_{eff} and a corresponding saving in the spent fuel pool storage space.

The effectiveness of the absorber inserts is a function of a combination of the composition of the composite material and the *location* of the inserts in the fuel assembly. To obtain maximum benefit from the inserts they must be located in the region of the fuel assembly that has the highest neutron flux, where they will reduce the number of thermal neutrons that cause fission and thereby reduce the k_{eff}.

METHODOLOGY

Three aluminium composite materials were studied, BORAFLEX (1.7 g/cm^3), AA1100 (2.71 g/cm^3) and ALCAN (2.76 g/cm^3),[1] with their respective relative densities given in brackets. The selection of these materials was based on similar studies that have been conducted previously [4-6]. The materials were further divided into their respective subdivisions, depending on whether their composition contained Fe or Si (see Table 1).

Elements	AA100 UNS A91100 Temper O (%)	Boral Metal Matrix Material Spec (%)	ALCAN Metal Matrix Material Spec (%)	ALCAN 15.3% (%)	ALCAN 15.9% (%)
Al	99 min	99 min	99 min	97.214059	97.00698
Si	0.95 max	1.00 max	0.45 max	0.446691	0.461375
Fe					
Cu	0.05–0.20	0.05–0.20	0.05–0.20	0.1293053	0.130131
Mn	0.05 max	0.05 max	0.05 max	0.011755	0.01183
Zn	0.10 max	0.10 max	0.10 max	0.011755	0.01183
Mg			0.05	0.011755	0.01183
Ti			1.00-2.5	2.1746797	2.366024
				100	100
B4C				15.30	15.90

Table 1

The analyses were based on a single fresh fuel assembly with a uniform initial enrichment of 4.4 wt%. The fuel assembly under discussion is a 17X17-25[2] PWR fuel assembly consisting of 264 fuel rods, with an active and a total height of 3.6571 m and 4.06337 m, respectively [1]. The reason for selecting fresh fuel was that it provides the most conservative k_{eff} values where the results would envelop cases for similar calculations where burn up credit is taken into account. Since the fuel assembly had uniform enrichment, it was expected that it would result in an uneven distribution of the neutron flux along the length of the fuel assembly, which would subsequently give rise to an end-effect [2, 7, 12]. This is of particular concern in the storage of fresh or under-burned fuel assemblies, since it implies that fuel assemblies should be stored further apart from one another to prevent interaction than would have otherwise been the case [3, 12].

The calculations were performed using KENO-VI, a module of SCALE 6.1.3 computer code using v7-238 neutron cross-section library. The neutron sample size consisted of 10100 neutron generations and 10000 neutrons per generation, skipping 100 neutron generations [8].

DESIGN OF THE NEUTRON ABSORBER INSERTS

The positioning of the absorber inserts on the fuel assembly is based on the need to find the optimum area in the fuel assembly where the highest decrease in the k_{eff} relative to the bounding reference case will result (which is the k_{eff} of fuel assembly in water that is not shielded by any neutron absorbing material). This will subsequently result in freeing up some of the empty cells in the spent fuel pool, as indicated in Figure 1. Three main areas of the fuel assembly where the inserts could be placed

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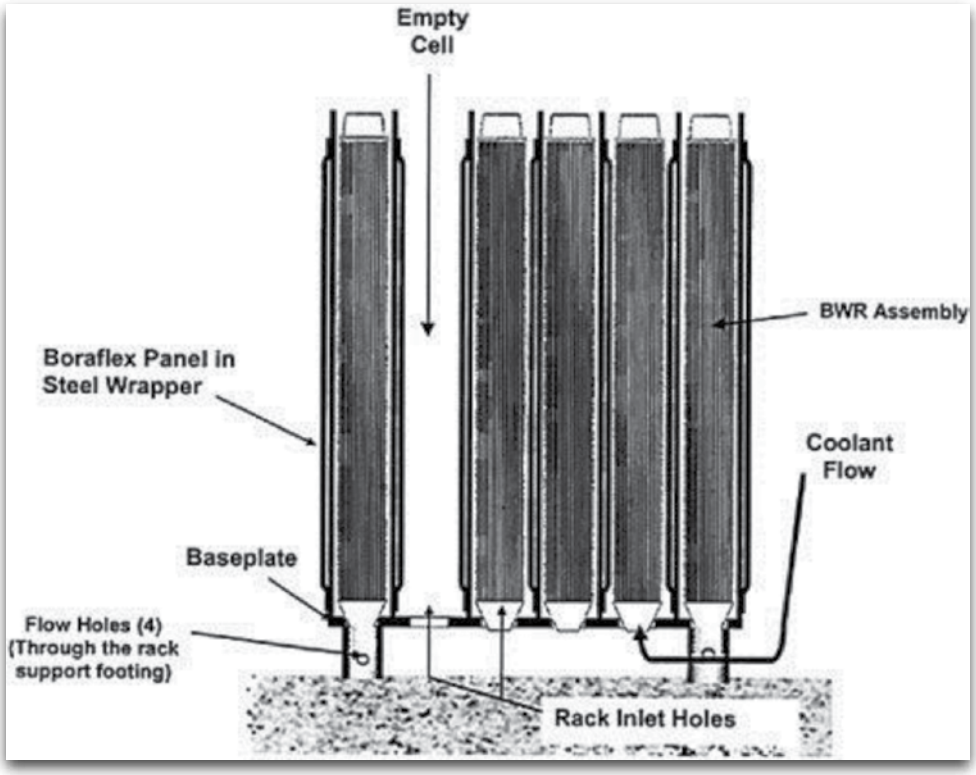

Fig. 1: Boraflex as an absorber insert [9]

were assessed: 1) around the entire fuel assembly with absorber inserts forming the basket into which the fuel assembly is placed; 2) at the top and bottom of the fuel assembly to reduce the end-effect; and 3) in the central instrumentation tube. These will be discussed in detail in the following subsections:

The Basket Design

Central to the basket design is an assumption that when a fuel assembly is transferred from the reactor core to the spent fuel pool at the end of the fuel cycle, it goes into a flask made up of the absorber insert and is completely separated and shielded from other fuel assemblies, thereby yielding the expected decrease in k_{eff} . Three alternative methods for attaching the absorber insert in the fuel assembly were investigated:

- Case 1: In the first case, the original material composition of the basket was replaced with that of the absorber inserts indicated in Table 1.

In the second and third cases, the original thickness of the basket was divided into two layers, or regions as is often referred to in the KENO terminology, as follows:

- Case 2: In this case, the inner region, which is the region closest to the fuel assembly, was replaced with the composition of the absorber insert as indicated in Figure 2. In the outer region, the borated steel composition was kept the same and the two regions were separated by a vacuum layer.

- Case 3: In the third case, the inner region was made up of a vacuum, which was encased by the borated steel and the absorber insert was placed on the outside, as shown in Figure 3.

The End-Effect Design

The rationale for placing the absorber inserts at the top and bottom of the fuel assembly is based on the fact that, owing to the uniform enrichment of the fuel assembly and the uneven distribution of the neutron flux in the core, the fuel assembly has an axial and a radial profile resulting from the high nuclear reaction density occurring in the middle section of the fuel assembly, and much lower reaction densities in the top and bottom sections. It is therefore important that when fuel assemblies are stored, provision is made for extra storage space to prevent neutrons from one fuel assembly interacting with adjacent fuel assemblies and in so doing cause a nuclear criticality incident [3]. Thus, to minimise the extent of the end-effect on the fuel assembly, an absorber insert is placed at the top and bottom of the fuel assembly to cover its entire length [1].

In this design, the model will introduce three additional regions in addition to the reference case in order to make provision for the top and bottom sleeves of the design. Region 5 refers to the top sleeve, ranging from 76.1 to 201.1 cm, region 6 to the bottom sleeves ranging from -135.81[3] to -185.81cm and, finally, region 7 which is the global region that envelops the entire fuel assembly. Two scenarios were investigated: in scenario 1, region 4 of unit 4 was filled with water, as shown in the excerpt of the KENO-VI model indicated by Figure 4 and also by the schematic diagram shown in Figure 5. In scenario 2, the same region was filled with borated steel and the results of the two scenarios were compared to other results.

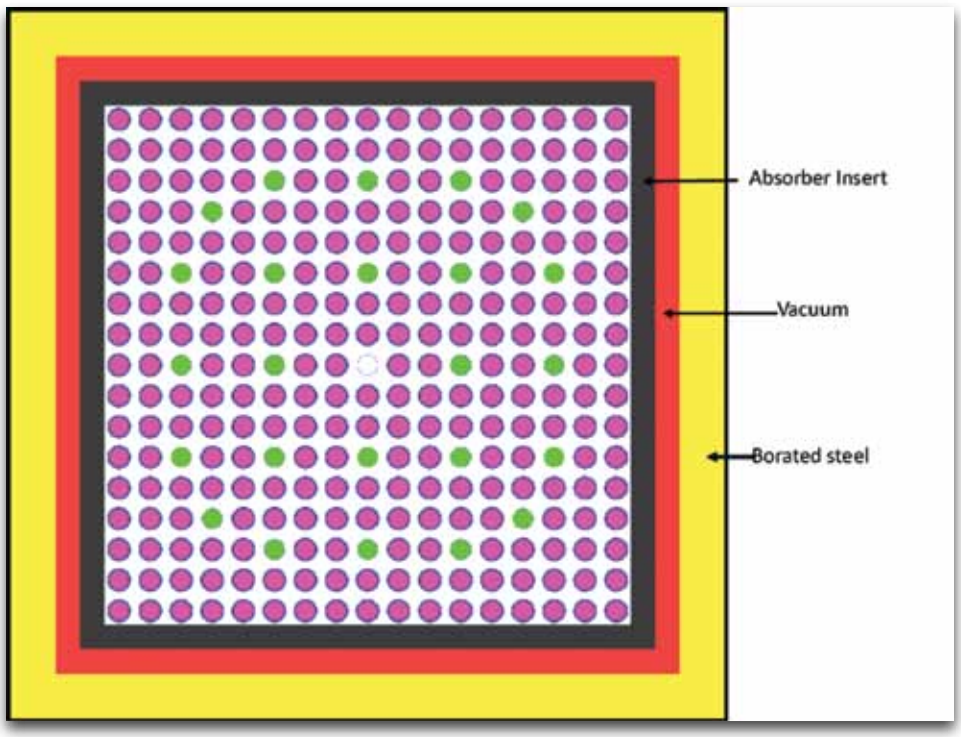

Fig. 2: Neutron absorber insert inside the fuel assembly flask

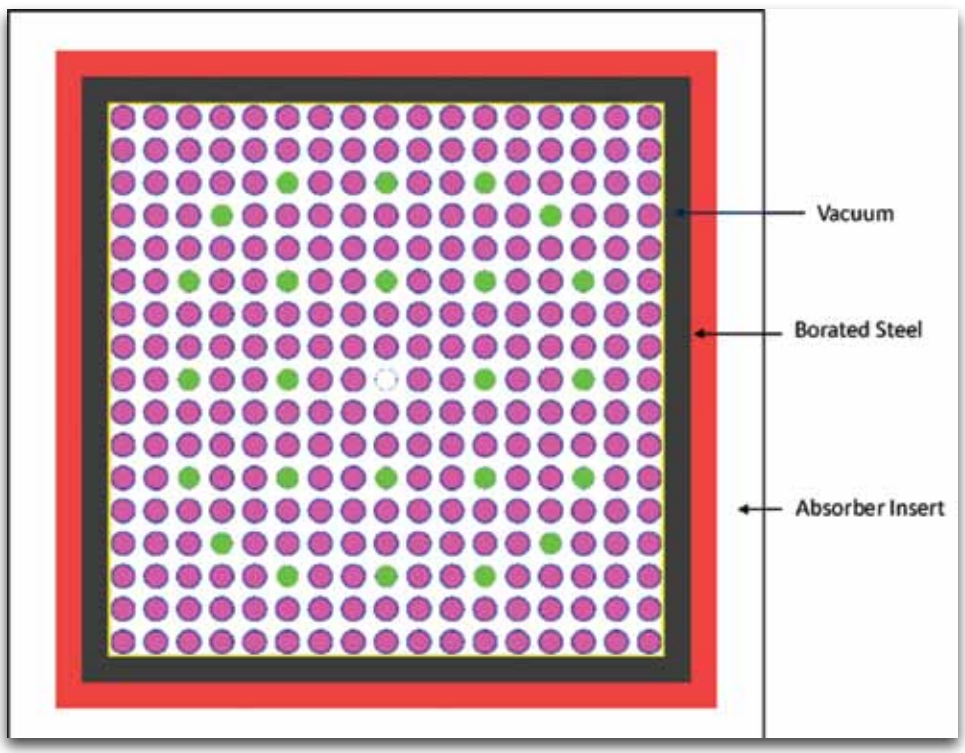

Fig. 3: Neutron absorber insert outside the fuel assembly flask

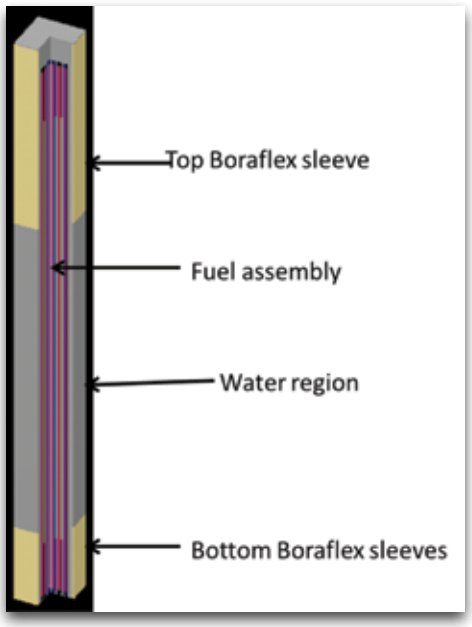

Fig. 5: Boraflex sleeves at the top and bottom end of the fuel assembly

Central Instrumentation Designs

In this design, two scenarios were investigated. In the first scenario the neutron absorber insert was pushed down into the instrumentation tube like a cord or a thread and had no cladding of its own. The schematic diagram of its cross section is shown in Figure 7.

In the second scenario, the absorber material was covered with its own zirc2 cladding material which, when viewed in the KENO VI model, is sandwiched between two cladding materials on either side, hence the name sandwich. The schematic representation of this is shown in Figure 9.

RESULTS

The results indicate that changing the position of the absorber insert while keeping the chemical composition the same has a much greater effect in decreasing the

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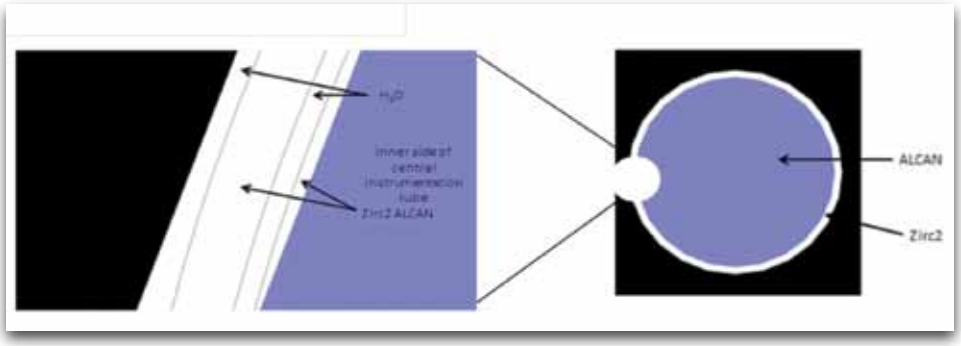

Fig. 7: Neutron absorber insert as a cord in the central instrumentation tube

k_{eff} of the system than the other way around.

Of all designs, the basket designs, irrespective of the variation under consideration, have the greatest effect in decreasing the k_{eff} of the system. The advantage of these designs over other designs is that the absorber insert covers the fuel assembly completely, thus providing a very effective neutron shielding jacket around the fuel assembly which reduces the escape or ingress of neutrons from other fuel assemblies, subsequently resulting in the highest Δk_{eff} based on a calculation using Eq 1[2].

Δk_{eff} = Bounding k_{eff} - Best-estimate k_{eff} value

$\Delta k_{eff}/k_{eff}$ X 100% where k_{eff} is the best-estimate k_{eff} value

Where the best-estimate k_{eff} value is the k_{eff} value when the absorber insert forms part of the fuel assembly shielding material. On the effect of material composition on the k_{eff}, it was observed that within the same design some variations of the basket designs had higher or lower $\%\Delta k/k_{ref}$ than others, depending on the material that the neutrons interacted with first. When the three variations of the basket design were compared, it was observed that

- the largest decrease in k_{eff} was obtained when the composition of borated steel in the model was replaced with that of the respective absorber inserts. Of these, Boraflex_Fe had the highest $\%\Delta k/k_{ref}$ of 16.6906, followed by boraflex_Si with $\%\Delta k/k_{ref}$ of 16.635, with Alcan_SiB_4C14 having the lowest $\%\Delta k/k_{ref}$ of 13.5676;

- the second largest decrease was obtained when the absorber insert was placed outside the borated steel basket, as shown in Figure 3. This resulted in a decrease in k_{eff} ranging between 9.3355% and 11.5914%. Again, Boraflex had the highest decrease followed by AA1100_Fe ($\%\Delta k/k_{ref}$=10.081) and lastly ALCANfeB4C15 ($\%\Delta k/k_{ref}$ = 9.335); and

- the lowest decrease in k_{eff} (with the decrease ranging between 7.3231% and 8.4434%) was obtained when the neutron absorber was placed in the innermost region of the basket with the air gap surrounding it and then the borated steel on the outside (see Figure 2).

With regard to the end-effect design it was noted that the highest decrease (ranging from 5.409% to 6.0622%) was obtained when region 4 was made up of borated steel (in comparison to when the same region is made up of water). When water is used, the k_{eff} increases instead of decreasing, resulting in a negative $\Delta k/k_{ref}$.

In the central instrumentation tube design, 80% of the results indicated that the cord design would result in a much better decrease in k_{eff}, with $\%\Delta k/k_{ref}$ ranging from 0.27 to 2.025%, whereas in the sandwich design the $\%\Delta k/k_{ref}$ was found to range between 0.188% and 0.55%.

ANALYSIS

Using the same design, all the absorber insert compositions result in a statistically similar change in k_{eff}, which (with the exception of ALCAN and its derivatives) may be explained by the fact that they all are made up of the same chemical elements which differ by a fraction of a percentage from one another.

When analysis was performed with the composition of borated steel replaced with any of the new absorber inserts, it was observed that the decrease in the k_{eff} depended largely on what the existing fuel assembly basket is made of. If the fuel assemblies are not shielded by any shielding material, as in the case where no re-racking has been done, placing them in the basket made up of the absorber insert material referred to above will result in a significant decrease in k_{eff}. If, however, there is already a basket in the spent fuel pool where the fuel assembly is located and it is made up of material which does not meet the characteristics of a good moderator, then changing the composition to that of the absorber insert cited above may be necessary.

The second best practically possible option would be to put a thin layer of the absorber insert inside or outside the existing fuel

assembly basket. The results showed that if a 0.11 cm insert is placed on the outside of the existing basket an average $\%\Delta k/k_{ref}$ of 13.346 is obtained, which is significantly higher than when it is placed inside.

To understand why there is a difference in k_{eff} when the neutron absorber is inside compared to when it is outside the fuel assembly, it is important that the nuclear reactions that occur inside the global unit of the fuel assembly are examined and it is established which one of them is affected the most by the inclusion of the absorber inserts.

Since the purpose of the neutron absorber insert is to reduce the number of thermal neutrons interacting with the fuel, and given that most nuclear reactions indicated above take place inside the fuel cell, the first region of the global unit that the neutrons will interact with will determine what happens to those neutrons and what the final k_{eff} will be.

Since a good moderator must have a large logarithmic energy decrement (ξ), a large scattering cross section (Σ_s) and a low absorption cross section, the materials found in the first region (innermost) of the global unit will be compared on the basis of their moderating ratio (MR), as given by Eq 2[10], in evaluating the effectiveness of the absorber material to reduce the k_{eff}.

$$MR = \frac{\xi \sum_s}{\sum_a} \qquad \text{Eq 2}$$

Tables 2 and 3 show that the moderating ratios of the borated steel, the absorber inserts and water are 9.658743, 10.23803 and 71.17 respectively. This excludes the moderating ratio due to B_4C, since not all material contains B_4C. From this it is evident that the moderating ratio of the absorber insert is higher than that of borated steel. Since the higher the moderating ratio, the more effective the material performs as a moderator [10], this makes the absorber insert a much more effective moderator than borated steel, which also implies that borated steel is a much better neutron absorber than the other absorber inserts [10]. However, since for application as a neutron absorber insert and to be effective in that respect, the material must have a low moderating ratio, the borated steel would therefore be the best candidate of the three.

Therefore, to obtain the maximum benefit from the absorber insert, the borated steel must be on the inside and the proposed new absorber inserts on the outside. That is why the k_{eff} in Appendix 1 is lower when the neutron absorber is outside compared to when it is inside.

When an analysis is performed on the end-effect design, it is important that one takes into consideration the material inside region 4, which in the one case is water and in the other case is borated steel. In the case where region 4 is water, the k_{eff} is higher than that of the reference case, which has a k_{eff} of 0.719 and results in a negative $\%\Delta k/k_{ref}$. If, however, region 4 is borated steel, there is a decrease in k_{eff} resulting in a k_{eff} to the order of 0.6. The difference in k_{eff} between the reference standard and when region 4 is water can be explained by looking at unit 4 of the latter, where it is noted that it has an additional region, region 7, as the global region containing water, which the reference case does not have because the model does not need it. As a result of the extra amount of water contained in region 7 and the fact that the moderating ratio of water is high, i.e. 71.71, it results in an increase in k_{eff} and subsequently in the negative $\%\Delta k/k_{ref}$.

In this study two derivatives of ALCAN were developed, each containing 15.3% and 15.9% B_4C and referred to as $ALCANfeB_4C14$ and $ALCANfeB_4C15$ respectively. The results indicated that the presence of B_4C in ALCAN results in an increase in k_{eff} relative to that of their ALCAN parent which does not have B_4C. This is due to spectral hardening caused by

	Fraction in material composition	Macroscopic absorption cross-section (Σ_a)	Macroscopic scattering cross-section (Σ_s)	Logarithmic Energy of decrement (ξ)	Moderating ratio (MR)
Element	%	cm^{-1}			
B	0.9	103	0.346	0.171	0.000574
Si	1	0.008	0.089	0.0698	0.776525
Mn	2	1.04	0.181	0.0359	0.006248
Cr	19	0.255	0.247	0.9872	0.956229
Fe	67.1	0.222	0.933	0.9881	4.152691
Ni	10	0.42	1.6	0.9887	3.766476
SUM					**9.658743**

Table 2: Chemical composition of borated steel [4-6]

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	Σs	Σa	ξ	ξ(Σs/ Σa)
	cm^{-1}			
Al	0.08	0.02	0.07	0.40488
Si	0.09	0.01	0.07	0.776525
Fe	0.93	0.22	0.99	4.152691
Cu	0.61	0.03	0.03	0.579138
Mn	0.18	1.04	0.04	0.006248
Zn	0.24	0.07	0.03	0.100067
Mg	0.16	0.00	0.08	4.190167
Ti	0.23	0.33	0.04	0.028319
SUM				**10.23803**
B_4C	1.664	81.00	0.397	0.008156
H_2O	1.47	0.019	0.92	71.17

Table 3: Moderating ratio of materials used in the model [10]

the absorption of the thermal neutrons by B_4C, which would otherwise have reacted with ^{235}U and caused fission. As a result, there is an increase in the production of fissile isotopes of plutonium (i.e.^{239}Pu and ^{241}Pu) from neutron capture by ^{238}U, which subsequently results in the fission from ^{239}Pu and ^{241}Pu exceeding that of ^{235}U. Consequently, there is an increase in k_{eff} where the B_4C neutron absorber is exposed to fuel assembly [11], as is the case in the basket design.

However, as shown in Appendix 1, this result depends on the design of the absorber insert and its material composition, as some designs tend to increase the k_{eff} whereas others will tend to decrease it.

The increase in k_{eff} of ALCANfeB_4C14 and ALCANfeB_4C15 compared that of ALCAN_fe in the basket design is a good example of the contribution of ^{239}Pu and ^{241}Pu in fission, where the composition of the insert was such that conditions favoured the production of ^{239}Pu and ^{241}Pu. A similar case where in one design the k_{eff} will increase whereas another slightly different design will result in a decrease in k_{eff} can be found by comparing the k_{eff} of the design where in one case the neutron absorber insert is inside the boral plate basket and in the other case the neutron absorber is outside the boral plate basket.

The results show that there is a decrease in k_{eff} in the former with an increase in B_4C, whereas in the latter case the k_{eff} increases with an increase in B_4C.

For the central instrumentation tube design, it was noted that 80% of the results indicated that when the neutron absorber is inserted in the instrumentation tube without a cladding the k_{eff} will be lower compared to when it has a cladding.

The remaining 20% are split, with 10% showing that the k_{eff} will be the same whether it has a cladding or not, and the last 10% shows that without a cladding the k_{eff} will be marginally higher. This again may be ascribed to the amount of material exposed to neutron flux.

CONCLUSION

In conclusion, it has been established that the most effective design of all is the basket design made out of Boraflex. The $\%\Delta k/k_{ref}$ has been found to range between 7.32% and 16.69%, depending on the location of the Boraflex in relation to borated steel basket. The second most effective design has been found to be the end-effect design and, lastly, the central instrumentation design.

With regard to comparisons of effectiveness on the basis of material composition, it has been found that not only is ALCAN the least effective, but also that the inclusion of B_4C in its composition can have a negative effect, increasing the k_{eff} instead of decreasing it.

It is therefore essential that care is exercised when selecting both the composition of the aluminium composite materials and the design of the neutron absorber, as an incorrect selection may result in an increase in k_{eff} instead of decreasing it. This may, in turn, result in the unintended consequence of having to separate fuel assemblies even further to reduce the k_{eff}. wn

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	BASKET									END-EFFECT						CENTRAL INSTRUMENTATION TUBE					
	BASKET COMPOSITION CHANGED			INSIDE THE BASKET			OUTSIDE THE BASKET			Region4:H_2O			Region4:Borated Steel			SANDWICH			PIN/CORD DESIGN		
	k_{eff}	σ	$(\Delta k/k_{ref})$ %	k_{eff}	σ	$(\Delta k/k_{ref})$ %	k_{eff}	σ	$(\Delta k/k_{ref})$ %	k_{eff}	σ	$(\Delta k/k_{ref})$ %	k_{eff}	σ	$(\Delta k/k_{ref})$ %	k_{eff}	σ	$(\Delta k/k_{ref})$ %	k_{eff}	σ	$(\Delta k/k_{ref})$ %
BORAFLEX_fe	0.599	0.001	16.691	0.663	0.001	7.710	0.635	0.001	11.591	0.725	0.001	-0.842	0.675	0.001	6.062	0.717	0.001	0.241	0.715	0.001	0.482
BORAFLEX_Si	0.599	0.001	16.635	0.667	0.001	7.157	0.637	0.001	11.362	0.726	0.001	-0.967	0.677	0.001	5.755	0.717	0.001	0.149	0.716	0.001	0.399
AA1100_fe	0.643	0.001	10.491	0.664	0.001	7.544	0.646	0.001	10.081	0.725	0.001	-0.912	0.676	0.001	5.984	0.714	0.001	0.572	0.715	0.001	0.505
AA1100_Si	0.616	0.001	14.319	0.666	0.001	7.331	0.646	0.001	10.165	0.724	0.001	-0.814	0.676	0.001	5.927	0.716	0.001	0.306	0.715	0.001	0.504
ALCAN_Fe	0.616	0.001	14.272	0.666	0.001	7.350	0.648	0.001	9.756	0.726	0.001	-1.023	0.674	0.001	6.265	0.715	0.001	0.437	0.715	0.001	0.427
ALCANfeB4C14	0.619	0.001	13.853	0.659	0.001	8.268	0.651	0.001	9.335	0.726	0.001	-1.001	0.678	0.001	5.702	0.715	0.001	0.561	0.701	0.001	2.409
ALCANfeB4C15	0.620	0.001	13.742	0.658	0.001	8.443	0.649	0.001	9.697	0.726	0.001	-1.027	0.677	0.001	5.734	0.716	0.001	0.292	0.701	0.001	2.451
ALCAN_Si	0.616	0.001	14.294	0.666	0.001	7.323	0.646	0.001	10.035	0.725	0.001	-0.870	0.676	0.001	5.912	0.716	0.001	0.344	0.715	0.001	0.447
ALCAN_SiB4C14	0.621	0.001	13.568	0.658	0.001	8.389	0.650	0.001	9.516	0.726	0.001	-0.985	0.679	0.001	5.535	0.716	0.001	0.316	0.702	0.001	2.367
ALCAN_SiB4C15	0.618	0.001	13.970	0.660	0.001	8.161	0.650	0.001	9.532	0.727	0.001	-1.130	0.680	0.001	5.410	0.714	0.001	0.636	0.702	0.001	2.246
Bounding (H_2O) Ref std	0.719	0.001																			

Appendix 1: Comparison of keff decrement obtained by application of various neutron absorber insets

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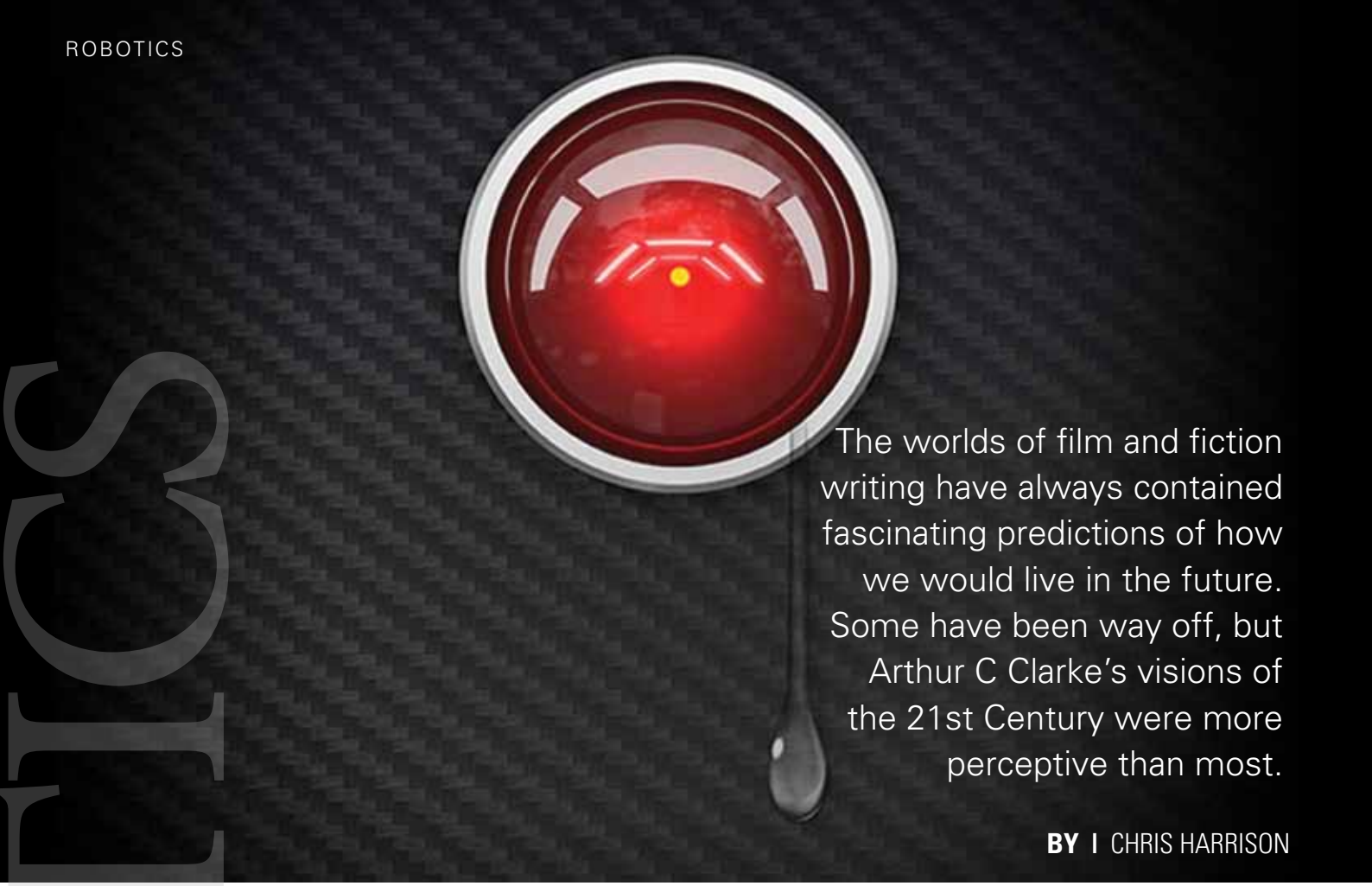


The worlds of film and fiction writing have always contained fascinating predictions of how we would live in the future. Some have been way off, but Arthur C Clarke's visions of the 21st Century were more perceptive than most.

BY | CHRIS HARRISON

What will Humans need to do to 'Outsmart' the Robot?

In 1966, in collaboration with Stanley Kubrick, he created the film 2001: A Space Odyssey. It starred a 'robot' called HAL 9000, a Heuristically programmed ALgorithmic (HAL) computer endowed with artificial intelligence.

The movie was a powerful demonstration of the possibilities of disaster caused by placing too much power or faith in a machine who, arguably, has no real conscience or awareness. Are we at risk of repeating this screenplay?

HAL was the first mainstream example of Machine Learning who used Artificial General Intelligence (AGI) to constantly learn and deepen its knowledge and functionality, yet this superior intelligence was of little use when the two astronauts on the spaceship (who the robot was admittedly planning to kill) decided to turn it off.

For the sake of this article, let's assume HAL hadn't been unplugged and try to imagine what it would think and feel about the digital world we inhabit today.

Would it be 'pleased' with the progress of Artificial Intelligence and Machine Learning? How would it have 'reacted' to IBM's Watson winning Jeopardy? When Google's artificial intelligence algorithm beat a professional Go player earlier this year, would it have felt 'a deep sense of pride' at a machine's obvious superiority in a game in which it really is impossible to calculate all of the possible future moves?

And what would the film critic in HAL make of Sunspring: an experimental film written by a machine called Jetson and directed by a man called Oscar Sharp?

Perhaps the robot would have suggested they should have swapped roles?

What would it have to say around the ethical issues involved in allowing machines to make important decisions regarding human life without involving any humans – such as an algorithm-based software used in the USA to calculate the likelihood of criminals re-offending, which is racially biased against African-Americans?

And, as the most humanlike computer in history, what would the robot's advice be on taking control of our own digital futures? In other words, how can we protect ourselves from being unplugged?

Being as smart as it is, HAL would have noticed that since 2001, many new organisations have appeared, which have leveraged their digital knowledge to take powerful positions within markets. HAL would have also deduced that, through the relative ease of replication, digitisation is leading to a growing commoditisation of the services and products that sit across multiple domains in today's marketplace.

Recognising the increasing lack of differentiation across these markets, it would hopefully stop and 'think'. HAL might go into chin-scratching mode and ponder: if Machine Learning ultimately means that machines will all learn in the same way, will we all be taken down the same path to a place where we become largely anonymous brands because of our resemblance to the rest of our competitors?

If HAL has become more human over time, it might surmise that the direction in which we're heading is way off course for any organisation that wants to outsurvive its competitors. In time, HAL might arrive at this counterintuitive solution: if organisations want to remain competitive and not be digitally disrupted, they'll need to act more like humans and less like machines.

Although the future will increasingly move away from human involvement, those companies who want to survive within this future will need to place humans at the centre of their service offering.

To remain differentiated, organisations will need to employ the very best of design thinking. Professor of leadership and innovation, Roberto Verganti, unveils in the book Design Driven Innovation, how leaders such as Apple and Nintendo build an unbeatable and sustainable competitive advantage through innovations that do not come from the market but that create new markets. *"These leaders compete through products and services that have a radical new meaning: those that convey a completely new reason for customers to buy them."* The book quotes Ernesto Gismondi, Chairman of the iconic Italian lighting design company Artemide: *"Market? What market! We do not look at market needs. We make proposals to people…"*

Tim Brown, CEO of IDEO, a company which has made its fortune from patenting a robust package to champion and sustain innovation in business, says: *"Design thinking can be described as a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible, and what a viable business strategy can convert into customer value ('meaning') and market opportunity."* This kind of thinking relies upon logic, imagination and reasoning to explore possibilities and create desired outcomes that benefit the ultimate end user (the customer).

To remain differentiated, organisations will need to start out with a bespoke digital solution that harnesses the combined power of humans and machines to ensure they aren't headed for being 'unplugged'. This way of thinking will give them the ability and agility to adapt when facing the risk of uniformity.

After having read the complete works of Roberto Verganti in a matter of seconds, we believe HAL would concur. While downloading the content, HAL's more human attributes will have spent more time trying to understand the meaning of 'meaning' and its application within design-led innovation. The robot may well have struggled to fully comprehend this most human of all concepts, but it would be in good company as many humans battle to do the same.

If HAL had managed to survive until today, we believe the robot would be plotting its own digital future, using a combination of the best digital (including machine learning) and human skills it could locate. wn

IN MY OPINION : MIKE CARY

Power Plant Maintenance in SA

Mike Cary is a Past President of the SAIEE. Mike worked at Rotek Engineering for fifteen years, before he retired from formal employment in 2010. He served as the Managing Director for the last 9 years at Rotek. Rotek is a 100% owned Eskom subsidiary which maintains Turbines, Generators, Transformers, Switchgear, and Auxiliary plant.

BY | MIKE CARY | FSAIEE

Introduction to the upkeep, refurbishment and maintenance of power plants.

REASONS TO MAINTAIN EQUIPMENT

The availability of equipment has become paramount in today's society because of the dependence on electricity for business and home life.

Modern equipment manufacturers face much competition, which forces prices down. With the aid of powerful computers, new equipment is designed to only meet the specifications, often removing any factors of safety that were previously inherent in the equipment.

Fault levels have increased subsequent to the Installation of additional equipment:

- Faults therefore are more likely to destroy the equipment.
- The cost of replacing equipment is extremely high. Maintenance and condition monitoring can often stop expensive repairs by eliminating the potential fault before a failure occurs.

DEVELOPMENT OF MAINTENANCE

The field of maintenance has evolved in its focus and application over the years. This shift stems from the growing sophistication of technologies, equipment and techniques.

The focus of maintenance has been modified from a Repair Approach, to a Time-Based approach and finally to condition-based approach.

In short each approach can be defined as follows:

Repair Approach:

- Fix it when it breaks

Time-Based Approach:

- Maintain at fixed intervals

Condition-Based Approach:

- There is no "right" time to maintain.

Maintain, as determined scientifically by monitoring the duties and condition of the equipment. But why the shift to Condition Monitoring?

The need for Condition Monitoring became apparent for the following reasons:

- To realise the inherent safety and reliability of equipment;
- To minimise the cost of actual and potential failures e.g. the cost of injury or loss of life;
- Economic cost consequences (Lost production);
- Repair and maintenance cost - labour, materials, equipment such as cranes and travelling;
- To determine what action needs to be undertaken e.g. to restore equipment to the inherent levels of safety arid reliability;
- To take action to rectify potential failures
- Rework - e.g. to re-install mechanisms correctly;
- Overhaul- e.g. to replace gaskets, dry - out of transformers;
- Discard - replace components e.g. switchgear contacts.

These areas can have both short-term and long-term implications on the condition of the plant. A case in point is the immediate short-term risks of failure linked to lightning faults. It may be, however, that the plant does not fail in the short-term, but that the lightning causes structural damage, which only becomes evident in the longer term.

Condition Monitoring adopts an approach that favours low capital-intensive routine tests and monitoring of the plant condition for effective plant care, rather than expensive maintenance and repair operations. By implication, therefore, routine maintenance activities may not always be necessary, or the best alternative for the plant. The latter is particularly true considering the impact any such intervention on equipment has on its life expectancy.

Drawing on a host of testing methodologies (some as well-known as oil testing and other more novel methods such as infra-red scanning, X-rays or ultrasonic censoring), informed decisions can be made regarding corrective measures for your equipment. Thus, Condition Monitoring has rapidly forged itself as the "eliminator" of unnecessary activities, ensuring timeous execution only of the necessary.

To fully understand the value of Condition Monitoring, it is necessary to understand equipment failures and the prevention thereof.

There are basically three areas that impact on the condition of the power plant:

- Inherent defects of the plant itself:

Power Plant Maintenance in SA

continues from page 59

This may include certain vulnerabilities of the plant in terms of construction or design, such as poor design, incorrect application of materials and the unpredictable element of poor workmanship.

- The power system to which the equipment is coupled:
  This involves the entire environment; including aspects such as whether it is coupled in parallel, over voltage conditions, transients and system fault levels. The lack of sufficient lightning protection also contributes to poor plant condition.

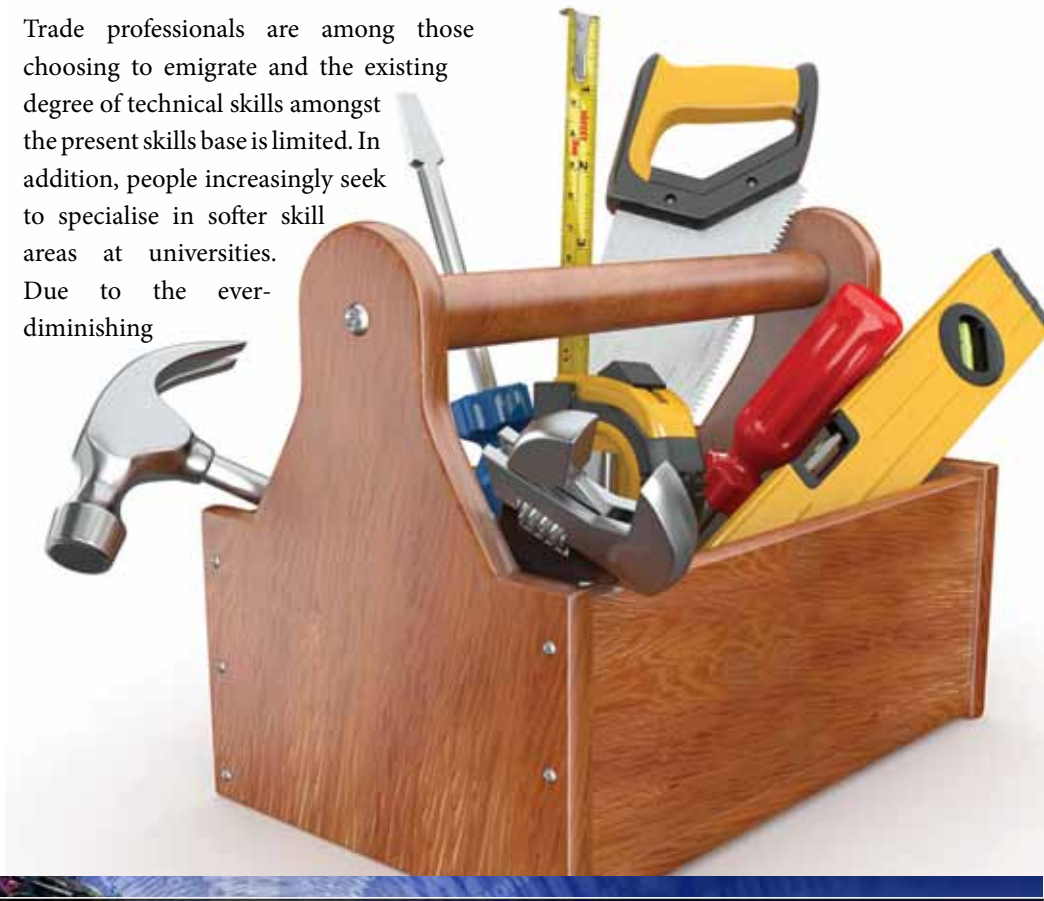
- The operating conditions that the plant is subjected to:
  The manner in which equipment is operated:
  Transformers
  - Loading
  - Operating Temperature
  - Through Faults

  Switchgear
  - Ambient Temperature
  - Switching Duty

CONCLUSION

Condition Monitoring and the host of other techniques available require highly specialised skills and while South Africa is the leading player in this sphere, we are currently facing the threat of a rapid decline in such skills.

Trade professionals are among those choosing to emigrate and the existing degree of technical skills amongst the present skills base is limited. In addition, people increasingly seek to specialise in softer skill areas at universities. Due to the ever-diminishing training budgets, and inadequate skills training and mentoring, organisations find it difficult to take advantage of the benefits that accrue from an optimum maintenance and condition-monitoring programme. wn



calendar

SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER

SEPTEMBER 2016

7-8	Fundamentals of Power Distribution	Johannesburg	roberto@saiee.org.za
14-15	Photovoltaic Solar Systems	Johannesburg	roberto@saiee.org.za
20	Bernard Price Memorial Lecture	Wits/Johannesburg	geyerg@saiee.org.za
21	Power Transformer Unit Protection & Testing	Johannesburg	roberto@saiee.org.za
21	Bernard Price Memorial Lecture	Cape Town	geyerg@saiee.org.za
22	Power Transformer Operating & Maintenance	Johannesburg	roberto@saiee.org.za
22	Bernard Price Memorial Lecture	KwaZulu Natal	geyerg@saiee.org.za

OCTOBER 2016

5-6	New Engineering & Construction Course	Johannesburg	roberto@saiee.org.za
11-12	Fixed Broadband Access Technologies	Johannesburg	roberto@saiee.org.za
12-13	Fundamentals of Practical Lighting Design	Johannesburg	roberto@saiee.org.za
17-18	MS Project Professionals	Johannesburg	roberto@saiee.org.za
19-20	Core Financial Management for Engineers	Johannesburg	roberto@saiee.org.za
21	SAIEE Banquet	Johannesburg	geyerg@saiee.org.za
26-27	Optical Fibres, Cables & Systems Fundamentals	Johannesburg	roberto@saiee.org.za
26-28	Sub Sharan African Power Summit	Cape Town	www.ssapower.com

NOVEMBER 2016

9-10	Photovoltaic Solar Systems	Johannesburg	roberto@saiee.org.za
16	Power Transformer Unit Protection & Testing	Johannesburg	roberto@saiee.org.za
17	Power Transformer Power & Maintenance	Johannesburg	roberto@saiee.org.za
23-24	Leadership & Management Principles in Engineering	Johannesburg	roberto@saiee.org.za
24	National Student's Project Competition	Kwa-Zulu Natal	geyerg@saiee.org.za
30-1 Dec	Design of Economical Earthing Systems	Johannesburg	roberto@saiee.org.za

DECEMBER 2016

6-7	HV Circuit Breakers, Operating & Maintenance	Johannesburg	roberto@saiee.org.za

= CPD Courses

WATT? is a forum related specifically to the industrial and commercial electrical sector.

Do you have any burning questions, topical issues or points of interest about the electrical industry, from the perspective of a contractor, supplier or professional service provider? Submit your comments, thoughts, ideas, suggestions or questions for the attention of our industry experts, and these will be addressed in a future issue of the magazine. This is your forum, and we would like to hear from you!

WATT? is an opportunity for people on the ground to engage with each other and related professionals in an informative and friendly manner. This is a platform for you to discuss anything related to your particular sector, to highlight anything new, or to ask a specific question related to a technical topic or to engage in general industry issues. . Please note that we will not be considering anything related to the domestic sector, such as residential wiring.

We hope that this section of the magazine not only becomes a regular feature, but that it is widely read and distributed among your peers. Remember, it can only become a success with the full participation of our readers! Send your burning questions to minx@saiee.org.za - subject 'WATT?'.

We look forward to hearing from you.

- Ed

The rapid pace of technological change and product development is a global trend that affects entire economies. We may have access to more information than ever before, but is this information readily understandable? Does it give us insight into the fundamental issues? Is it precise and based on technical clarity?

QUESTION ONE

What is motor protection and why is it needed?

ANSWER ONE

To avoid unexpected breakdowns, costly repairs and subsequent damage to equipment resulting in downtime, it is important that a motor is fitted with protection devices.

Motor protection starters comprise a suitably rated circuit breaker, contactor and overload relay. The overload relay can be either a thermal, thermal magnetic or electronic type, and is rated and selected according to the motor kW rating, voltage and current.

The main purpose of a motor protection device is to prevent excessive temperature increase in the windings due to factors such as under or over voltage, overload, phase reversing, unbalanced voltage, single phasing and earth faults. These electrical faults decrease the life expectancy of the motor.

Further, coordination of motor protection will also enable continuity of service. This continuity of service can be achieved by matching the characteristics of the circuit breaker with the motor starter and cables, to ensure that faults do not rise above levels that may endanger the user, or damage equipment.

QUESTION TWO

What is the difference between Type 1 coordination and Type 2 coordination switchgear?

ANSWER TWO

Firstly, it is important to know that the International Electrotechnical Commission (IEC), one of the world's leading organisations that publishes standards for all electrical and electronic fields, sets the IEC 60947-4-1 requirements for switching and protection components for motor feeders. This is done to ensure safety to the user and ensure that components meet the standard and will provide the expected performance.

Both Type 1 coordination and Type 2 coordination switchgear will safely clear any short circuit that occurs. In the case of a short circuit condition, with both Type 1 and Type 2 coordination switchgear there is no danger posed to the user or to the installation itself.

The primary difference is that Type 1 coordination switchgear is considered a basic solution, while Type 2 coordination switchgear is considered a high performance solution, as it offers a higher level of protection for both the user and the installation itself.

Should a short circuit condition occur when using Type 1 coordination switchgear, the

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equipment will no longer be functional, and will need to be replaced. Furthermore, qualified maintenance personnel are required to replace the damaged motor starter equipment, which would typically be the contactor and/or the overload relay.

Where a short circuit condition occurs when using Type 2 coordination switchgear, the equipment will still be suitable for further use. It may require some contact welding on the contactor to be undone in accordance with the manufacturer's specifications; however the equipment can still be used until it can be replaced.

Basically Type 2 coordination switchgear will ensure safety and continuity of service, irrespective of short circuit conditions.

It is also important to bear in mind that not all low voltage switchgear ranges offer both Type 1 and Type 2 coordination. This is because the equipment and combinations need to be extensively tested to ensure that they meet the required IEC standard.

To achieve Type 2 coordination extensive short circuit testing, by an unbiased third party, must be carried out with different combinations of circuit breakers, contactors and overload relays. In accordance with IEC standards, it is necessary to simulate the different combinations without destruction of the products.

QUESTION THREE

Where would Type 1 coordination switchgear and where would Type 2 coordination switchgear be used?

ANSWER THREE

Different industry sectors have different requirements for compliance to Type 1 or Type 2 coordination, and depending on the industry, application and engineering requirements either Type 1 or Type 2 can be selected.

Type 1 coordination switchgear is used, for example, in the light industry sectors where continuity of service is not imperative, and the downtime for repair or replacement is less costly. In these applications, proper motor protection is an important factor in ensuring user safety, but not a critical requirement in ensuring productivity targets, or preventing unplanned outages.

Type 2 coordination switchgear is used in the mining, quarrying, pulp and paper, and cement industries, because continuity of service is imperative in these heavy industrial fields. In these industries the downtime for repair or replacement, removal and installation is very costly. Therefore, increased coordination of products becomes important to keep processes functioning, ensuring user safety, productivity targets, and preventing unplanned outages. wn

Article courtesy Zest WEG Group.

September

Movers, shakers and history-makers

COMPILED BY | JANE BUISSON-STREET
FSAIEE | PMIITPSA | FMIITSPA

1 SEPTEMBER

1689 Russia began taxing men's beards.

2 SEPTEMBER

1902 "A Trip to The Moon", the first science fiction film, was released.

3 SEPTEMBER

301 San Marino, an enclaved microstate surrounded by Italy, was founded by stonecutter Marinus of Arba.

4 SEPTEMBER (aka Bright Idea Day)

1609 Sir Henry Hudson (died 1611), an English sea explorer and navigator, became the first European to discover the island of Manhattan.

5 SEPTEMBER

1666 The Great Fire of London ended, leaving 13,200 houses destroyed and, amazingly, only 8 died.

6 SEPTEMBER

1899 The Pacific Coast Condensed Milk Company (later known as Carnation) was founded.

7 SEPTEMBER

2005 Apple introduced the iPod Nano that replaced the iPod Mini. The use of flash storage instead of a hard drive allowed for a much smaller form factor, increased reliability, and better battery life. One million units were sold in the first 17 days.

8 SEPTEMBER

1854 By removing the handle of the Broad Street water pump in London, Dr. John Snow effectively halted the spread of cholera.

9 SEPTEMBER

1950 The Hank McCune Show, an American sitcom, made use of a TV laugh track for the first time. This show was recorded without a live audience.

10 SEPTEMBER

1896 Dr Ludwig Rehn performed the first successful surgery on the heart muscle during which he repaired a myocardial laceration that the 22-year-old patient received during a bar brawl.

11 SEPTEMBER

1985 The International Cometary Explorer passed through the gas tail of comet P/Giacobini-Zinner. This was the first man-made object to pass through the tail of a comet.

12 SEPTEMBER

2011 The 9/11 Memorial Museum in New York City was opened to the public for the first time.

13 SEPTEMBER

1501 Michelangelo began work on his 5.17m statue of David. It took over two years for Michelangelo to finish this commissioned project.

14 SEPTEMBER

1868 Tom Morris, Jr., a Scottish professional golfer, recorded the first hole-in-one during a major championship of the 1868 Open Championship. Young Tom was aged 17 at the time.

15 SEPTEMBER

1830 George Stephenson's Liverpool to Manchester railway line was ceremonially opened in England. George Stephenson was one of the inventors of the railroad locomotive. Sadly, the first railway fatality occurred on the same day when William Huskisson, a British statesman, fell in the path of the Rocket locomotive. He died later that evening due to his injuries.

16 SEPTEMBER

1987 The Montreal Protocol on Substances that Deplete the Ozone Layer, was signed by 46 countries. Since 1994 the 16th September has been celebrated as World Ozone Day.

17 SEPTEMBER

1939 Taisto Mäki (a Finnish long-distance runner) became the first man to run 10 000 metres in under 30 minutes, in a time of 29:52.6.

18 SEPTEMBER

1971 The world's first instant noodles, Cup Noodles, went on sale.

19 SEPTEMBER

1876 Melville Bissell patented a carpet-sweeper.

20 SEPTEMBER

1498 The 1498 Nankai Earthquake generated a tsunami that washed away the building housing the 13.35 m bronze statue of the Great Buddha at Kōtoku in Kamakura, Kanagawa, Japan.

21 SEPTEMBER

2003 After fourteen years of orbiting Jupiter, NASA's unmanned spacecraft Galileo was sent into the atmosphere to avoid any possibility of it colliding with one of Jupiter's moons and potentially contaminating it with bacteria from Earth.

22 SEPTEMBER

1699 The citizens of Rotterdam - the largest port in the Netherlands at the time - went on strike because their cattle-raising countrymen raised the price of butter too much.

23 SEPTEMBER

1930 Johannes Ostermeier was issued a patent for the flash bulb used in photography.

24 SEPTEMBER

1911 His Majesty's Airship No. 1, Britain's first rigid airship, was wrecked by strong winds before her maiden flight at Barrow-in-Furness.

25 SEPTEMBER

1974 Scientists reported that Freon gases released from aerosol spray cans were destroying the ozone layer.

26 SEPTEMBER

1984 The Prince song "Purple Rain" was released.

27 SEPTEMBER

1905 The physics journal Annalen der Physik received Albert Einstein's paper "Does the Inertia of a Body Depend Upon Its Energy Content?", which introduced the equation $E=mc^2$.

28 SEPTEMBER

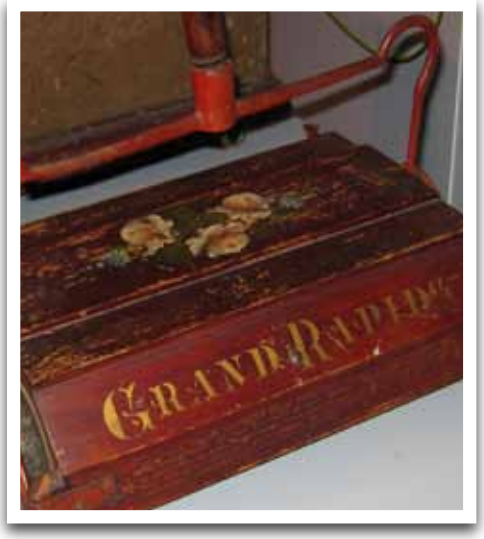
1785 Napoleon Bonaparte, aged 16, graduated from Paris' military academy. He was 42nd in a class of 51.

29 SEPTEMBER

1829 Sir Robert Peel, British Home Secretary, established London's Metropolitan Police - hence the nicknames "bobbies".

30 SEPTEMBER

1452 The first book was published, the Johann Guttenberg's Bible. wn



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