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SAIEE THE OFFICIAL PUBLICATION OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS | JUNE 2019

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This June issue features Power. Our first feature article takes a look at how we can mitigate the "Unsafe Broken Neutral conditions in 3-phase 4-wire Low Voltage Systems" written by Quentin Louw.

Read it on page 26.

The second feature article on page 36, discusses the economic benefits and challenges with utilizing increased enrichment and fuel burnup for light-water reactors. The Nuclear Energy Institute published this white paper in January 2019.

I'm happy to report that at the last Council meeting, SAIEE President George Debbo handed a cheque of R56 000 to YaBana Village for Children, which is the proceeds from the 2019 Charity Golf Day.

The SAIEE will be hosting its very own national conference from 27 - 29 November 2019 at the Sandton Convention Centre. Early registrations are now open.

Visit www.saiee-conference.co.za and book your spot now.

This event will include the SAIEE Annual Awards as well as the National Student's Project Competition.

The next issue of the **watt**now features "Water" - if you have any articles/ white papers you want to see in print, please send it to me by no later than 5 July.

Herewith the June issue - enjoy the read.

Visit www.saiee.org.za to answer the questions related to these articles to earn your CPD points.

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UNITED STATES VS HUAWEI

GEORGE DEBBO
2019 SAIEE PRESIDENT

Three years ago, China began implementing their "Made in China 2025" Industrial Policy, the plan to become the world leader in technology..

This policy also included a formal proposal to dominate artificial intelligence by 2030 by allocating billions of dollars towards research in this area. This scared the United States whose concern was that the US technology industry would be left behind; so the US Government started with a process to discourage the use of Chinese technology companies which has subsequently been intensified under the Trump Administration.

This started with the Trump Administration banning US telecom operators from deploying Huawei's 5G technology, the world leaders in this field currently. The reason given for implementing the ban is that allowing Huawei to use 5G in the US would significantly jeopardise security because this technology would, in the future, become the backbone of the modern economy.

5G, with its new wireless standards and significant improvement in performance from previous cellular technology standards, will in the future power a whole host of similar technologies and applications from self-driving cars to advanced medical procedures. The US Government has accused Huawei of implementing "back-door" access capabilities into their equipment, which would allow the Chinese Government to spy on the US. In the event of conflict this could be used to sabotage the domestic telecommunication networks, allegations which Huawei has denied and have even gone as far as indicating that they would be prepared to sign an international agreement, whereby they would not allow their technology to be used either by the Chinese Government or by any other foreign power for subversive activities.

The concept of providing "back door" access to telecommunications equipment is not new. Most telecommunication vendors do this to allow their equipment to be accessed remotely by their specialists if a telecommunications operator is unable to restore a unit after failure. Such access is also used to carry-out software upgrades where the operator has a support agreement with the vendor. It is true that such access can be used for subversive activities but strictly speaking the responsibility to prevent this should reside with the network operator and not with the vendor. The network operator needs to ensure that enough security safeguards are in place to prevent unauthorised access to their networks.

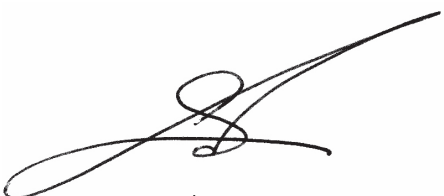
Notwithstanding the above argument, I have no problem if a government or a telecommunications operator within that country decides not to use a specific vendor because of security concerns. But I do have a problem when that country's Government tries to use its positional authority, as is the case with the Trump Administration, to instruct other countries to ban the use of Huawei in their networks — when this failed to take traction, imposing restrictions on their technology industries to supply the vendor with components and software. This, in my opinion, moves from being concerned

about security to becoming vindictive because your domestic technology innovation has fallen significantly behind that of the competitive country, in this case, China. I believe this is what is happening in the case of the Trump Administration's attack on Huawei and has nothing to do with security concerns. Trump has gone on record, indicating that he would never allow China to overtake the USA in technology.

So the question is: what effect will the US restrictions on its technology companies, such as Intel, Qualcomm, Google and so on, from supplying components and software to Huawei have on Huawei's short term business? Keep in mind that Huawei had a bumper year in terms of equipment and network sales last year, despite the US's attempt to discourage other countries from using Huawei technology. Information from analysts and other sources indicate that the effect will be minimal, and the consequences may well be more detrimental to the US industry than it is to China. The reason why the impact will be minimal on Huawei is that they have predicted that such a scenario may well occur and have taken precautions to minimise the consequences. Firstly, it is now common knowledge that over the past few months Huawei has been stockpiling critical components that they would generally receive from US companies, such as Intel and AMD, to provide them with at least 12-months reserve. They have also been working on creating their innate ability to manufacture the chipsets that they would require both for their network equipment and handsets, through a separate subsidiary called HiSilicon. The management of HiSilicon has already indicated that they have been preparing for some time for such a scenario whereby Huawei could be banned from buying US chips, and I believe the 12-month stockpile that Huawei currently has will give HiSilicon more than sufficient time to ramp up to full capacity.

A final issue to consider is the ban that Google has imposed on the use of the Android software operating system, which is a critical component in the Huawei Smartphone handsets, although there has been a 90-day reprieve given. Again, Huawei has predicted the possibility of this happening and have for some time been working on their version of Android using the opensource version as the basis. Within Huawei, this version is called HongMeng and is scheduled for release later in 2019, but I am sure that there is enough pressure being applied to have this release available at the time that the 90-day reprieve expires. The only problem that remains is that Google may ban operators from pre-loading several Google applications, like the Google Play Store, Chrome, Google Maps etc., from Smartphones that make use of the Huawei Android operating systems. But even here there is talk that such a move will be viewed as predatory and un-competitive by European Union Regulators, who are already concerned about Google's market dominance, and consequently outlawed.

Therefore, taking the above into account, it is my opinion that the move by the Trump Administration to ban the supply of US components and software to Huawei will, in the long run, be more damaging to the USA than it will be to Huawei and China.



G Debbo | SAIEE President 2019
Pr. Eng | FSAIEE

INDUSTRY AFFAIRS

2019 PRESIDENT'S INVITATION LECTURE

From left: Prof Chrisna du Plessis, George Debbo (SAIEE President), Sy Gourrah (SAIEE Deputy President) and Prince Moyo (Junior Vice President).

May 2019 saw the SAIEE President, George Debbo entertain Professor Chrisna du Plessis as his Invitational Lecturer, with her theme *"Smart Cities within a Developing Economy – the Promises and the Pitfalls"*. The SAIEE hosted this lecture at both the University of Johannesburg and the University of Pretoria, as well as using webinars for those members could not attend these two events.

Chrisna du Plessis is an Associate Professor, the Head of the Department of Architecture, and Chair of the School for the Built Environment, University of Pretoria, South Africa. Before joining the University of Pretoria in 2011, she was Principal Researcher at CSIR Built Environment. Prof du Plessis holds graduate and post-graduate degrees in architecture and sustainable development from the University of Pretoria, a PhD in urban sustainability from the University of Salford, from where she also received an Alumni Achievers Award, and an Honorary Doctorate from Chalmers University of Technology in Sweden. Prof du Plessis is the Leader of the Priority Theme: Sustainable Construction Chair, and Chair of the Programme Committee of the Board of the International Council for Research and Innovation in Building and Construction (CIB). She is also a member of the International Standards Organisation Working Group on the Resilience of Buildings and Civil Engineering Works and serves on the Editorial Boards of the journals Smart and Sustainable Built Environment and Sustainable Earth.

In her talk she explains the definition, as described by Townsend (2013:15): *"Smart cities are places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic and environmental problems."*

"These are all good things, and why the Smart Cities concept holds so much promise for cities in developing countries. Less is said of the negative aspects of smart cities, with critiques focusing on the potential for social polarization, the educational and financial demands made on citizens in order to participate in urban life, technocratic and autocratic governance, excessive surveillance, and an engineering approach focused on quantitative data analysis in pursuit of system optimization (Söderström et al. 2014)" she added.

Her paper explores both the promises and the pitfalls in developing economies which often come with challenges such as high levels of economic inequity, energy vulnerability, and questionable leadership, but also with the opportunities presented by the potential to leapfrog old systems and outdated solutions to city building. It further considers the possible implications of global systems disruptions such as climate change and a rise in fascism and social division, and how Smart Cities interventions can build resilience to these disruptors or make cities even more vulnerable.

The conclusion is that Smart Cities is a double-edged sword, and we would be wise to think carefully about how we wield it.

If you missed this talk and would like to see it, watch it on the SAIEE TV Channel – www.saiee.org.za.

IITPSA honours top Eastern Cape IT Achievers

From left: Belinda Samuels, EC IITPSA 2019 Woman in IT Award; Sonny Fisher, EC IITPSA 2019 IT Contributor of the Year; Anton van Kampen, EC IITPSA 2019 CAT Teacher of the Year; Lynne Thackray Smith, EC IITPSA 2019 CAT Teacher Lifetime Achievement Award; Katherine James, EC IITPSA 2019 IT Student of the Year; Hannelie Nell, EC IITPSA 2019 CAT Teacher of the Year (Special Commendation); Jean Greyling, EC IITPSA 2019 IT Personality of the Year; Ulandi Exner, President, IITPSA; Leanda Oosthuizen, EC IITPSA 2019 IT Teacher of the Year; Benjamin Roode, EC IITPSA 2019 IT Scholar of the Year; and Tony Parry, CEO, IITPSA.

The Institute of Information Technology Professionals South Africa (IITPSA) Eastern Cape chapter has recognised the province's leading IT achievers at its gala annual dinner and awards in Port Elizabeth.

With a strong focus on IT educators and students, as well as industry leaders, the awards named Jean Greyling, Associate Professor in the Department of Computing Sciences at the Nelson Mandela University, as the EC IITPSA 2019 IT Personality of the Year.

Professor Greyling was honoured for his outstanding contributions to school and university ICT education in the Eastern Cape and nationally. He has been promoting IT careers and specifically programming, through the use of the TANKS app, to school children with limited access to computers throughout South Africa.

Since the launch of the app in November 2017, coding boot camps have been presented to 3500 learners across South Africa, as well as in Zambia, Kenya and Norway. Corporate sponsors who have invested in the app include Standard Bank, BKB, Mandela Bay iHub, LexisNexis, Volkswagen, SITA, Entelect, S4 and Johannesburg Libraries. Schools such as Westering High, Victoria Park High, Pearson High, DF Malherbe High School, Harvest Christian School and Hudson Park Primary School have identified TANKS as an excellent tool to introduce learners to coding at a young age. Ms Kelly Bush from Hudson Park Primary School in East London has developed seven draft lesson plans, aimed at introducing learners to coding through TANKS.

Professor Greyling was invited to UNESCO's flagship Mobile Learning Week in Paris earlier this year, where TANKS was one of 60 innovations to be showcased. After Paris, he went to Germany as part of a DAAD-sponsored research project related to TANKS. He has also been invited to train trainers in Windhoek, for a roll out of TANKS in Namibia later this year.

In addition, Professor Greyling has played a very substantial role in organising millions of Rands in bursaries, enabling students in need to study Computing Sciences at Nelson Mandela University, mostly via BankSETA.

Prof Greyling will be nominated for the national IITPSA 2019 IT Personality of the Year award that will be awarded later this year.

Presenting the awards, IITPSA President Ulandi Exner and CEO Tony Parry, along with Dr Lester Cowley, Chairman of the Eastern Cape Chapter of the IITPSA, congratulated the winners and highlighted the importance of education in building the IT sector's capacity.

"Skills development and professional development are key focus areas for IITPSA, so it is encouraging to see nominees and winners of such a high calibre being recognised at these awards," said Cowley.

INDUSTRY AFFAIRS

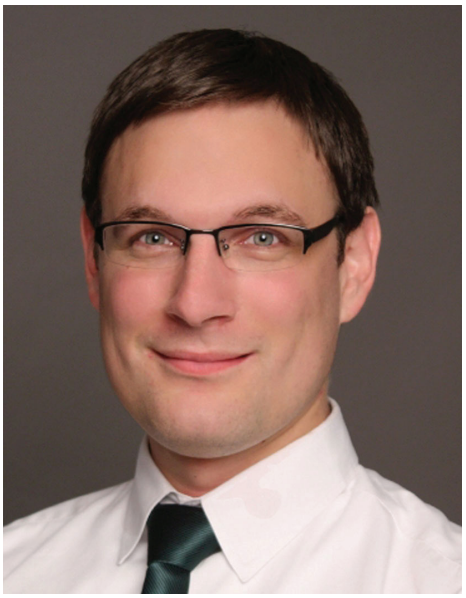
Intersolar Europe 2019: The trend is towards large projects

Schletter Group, the manufacturer of solar mounting solutions with activities around the world, gives a highly positive summary of the intersolar Europe 2019. At the fair, the company presented its tracking system, which has been optimized for bifacial modules, and a new genera-tion of roof hooks.

"Our talks with customers at the fair have confirmed what we have been observing for several months now in Europe, but also in our international markets: The trend is towards large projects," Schletter CEO Florian Roos said. Project developers and investors are increasingly focused on economies of scale and more interested than ever in achieving maximum yields. *"Given the right kind of planning, PV systems can already be competitive and profitable without any subsidies,"* Roos emphasized. *"We see now that our targeted development focus on yield optimization was the right approach."*

At this year's intersolar, the Schletter Group presented its 2018 tracking system which has been sold in Europe, Africa and Australia in a new version that is optimized for bifacial modules. Tracking sys-tems already create more yield than fixed mounting solutions. By using bifacial modules, the electrici-ty yield can be improved by another 10 percent compared to tracking systems with conventional modules. As the upper assembly group with the drive unit is delivered pre-assembled, the tracker can be installed almost as quickly as a fixed installation.

In the rooftop segment, Schletter likewise focuses on efficiency improvements – by saving material and installation time: With the new roof hook, presented at the fair, which is made from high-strength S700MC steel, systems mounted on tile-covered slanting roofs need fewer fastening points per kilo-watt output. On commercial buildings with flat roofs, pre-assembled systems with pre-fabricated mod-ules such as the FixGrid18 reduce planning and installation expenses.



Florian Roos
Schletter CEO

Trafo's quick transformer turnaround aids KZN mine

When a mining company in KwaZulu-Natal experienced a transformer failure recently, it was hoping for a quick solution. The mine got one from dry-type transformer specialist Trafo Power Solutions, who took just five weeks to design, build and deliver a non-standard cast-resin replacement. *"Once the situation with the old transformer was assessed, it was decided it would be more economical to replace the unit than to embark on major repairs,"* says David Claassen, Managing Director of Trafo Power Solutions.

"We were able to accommodate the customer's specifications in our replacement design, and have the unit manufactured by our European partners in just four weeks. After that, it took just a week to fly in the transformer and deliver it to the customer."

Claassen notes it is not uncommon for transformer replacements of this scale to take anything from 12 to 14 weeks, so the rapid turnaround time by Trafo Power Solutions was highly valued by the customer. The mine required a 1,600 kVA dry-type DYN11 transformer that stepped 33 kV down to 550 V, with a non-standard tap setting arrangement of seven tap settings instead of the normal five.

"We are always willing to step in when a user has an urgent requirement, and to propose innovative solutions that meet customers' priority needs," says Claassen.

Dry-type transformers – also called cast-resin transformers – are growing in popularity as users recognise their safety benefits, as well as their economy and flexibility of placement. To meet this demand, Trafo Power Solutions works in close collaboration with established and well-resourced manufacturing partners in Europe to source tailored designs that meet customers' exacting specifications. With its South Africa-based expertise and long experience all over Africa, Trafo Power Solutions provides users with peace of mind by ensuring ongoing after-sales service.

The TMC Transformers facility is Italy produces world class dry-type transformers.

Sydney Metro commences revenue service

Alstom congratulates Sydney Metro, Australia's biggest public transport project, on opening the North West Metro and the start of revenue service, delivering Australia's first fully automated, turn-up and go rail service.

The Metro North West Line is Stage 1 of Sydney Metro and includes 36km of track, 13 stations and a depot. The new network will provide a level of service never before seen in Australia with a train every four minutes in the peak in each direction. The project has been completed on time.

Under the contract awarded by Northwest Rapid Transit (NRT) in September 2014, Alstom has been responsible for the project management, design, supply, manufacturing, testing and commissioning of 22 x 6 car Metropolis trains and Urbalis 400 CBTC signalling systems. Alstom has also been awarded a 15 year maintenance contract for the trains, signalling, depot opera-tions and equipment. The maintenance contract also includes the application of Alstom's HealthHub state-of-the-art predictive maintenance tools. The HealthHub tools for the North-west Metro include Catenary Tracer, Track Tracer, Train Tracer, broken rail detection and point machine detection.

"Alstom is very proud to have partnered with the NRT consortium and Transport for New South Wales (TfNSW) to deliver our world leading metro solutions for Sydney's North West Metro. Sydney has now joined other great cities of the world (incl. Paris, Amsterdam, Barcelona and Singapore) that benefit every day from Alstom's metro solutions. The fully automated driver-less metro is a first for Australia and will provide a step-change for the commuters of Sydney" said Ling Fang, Senior Vice-President for Alstom in Asia-Pacific.

Designed uniquely for Sydney by Alstom in France and assembled at its centre of excellence in Sri City India, with contributions from Alstom's operations in Australia, Brazil, China and Belgium, the Metropolis trains demonstrate Alstom's leadership in urban mobility. Passengers have been placed at the heart of the development of this new train with the emphasis on on-board mobility and comfort.

The trains include 3 double-doors per car for improved access and passenger flows, large win-dows and ambient LED lighting. They will also have the highest levels of customer safety in-cluding constant CCTV monitoring, emergency intercoms and the latest way-finding aids for customer information and real time travel information. The system, equipped with Alstom's world leading computer based train control system, Urbalis 400, minimises the time stopping at stations and the times between each service – ensuring a comfortable and reliable journey for all passengers.

The Metro line is currently being extended from Chatswood to Bankstown via the City and by 2024 Sydney will have 31 metro stations and a 66 kilometre standalone metro railway in addi-tion to its extensive suburban rail network.

SAIEE hands over golf day proceeds to Ya Bana Village for Children

At the recent SAIEE Council meeting on 7 June 2019, the SAIEE President, George Debbo handed the proceeds from the Charity Golf Day, which took place on the 24th of April at the Pretoria Country Club to Carina Goosen, CEO of Ya Bana Village for Children. The cheque for R56 000 would not have been possible without our participants and our sponsors, who were Old Mutual Financial Services, MajorTeck, Sqwidnet, CMH Kempster Ford Hatfield and Dust-A-Side.

Dust extraction specialist set to exhibit at Advanced Materials Show 2019

Dustcontrol UK has announced it will be exhibiting a range of its highly effective extraction equipment at the UK's inaugural Advanced Materials Show 2019.

Taking place from 11 - 12 July at The Telford International Centre, Shropshire, the Dustcontrol team will be showcasing the firm's extensive range of both fixed and mobile cyclone-based dust extractors and air cleaners on stand 1220.

The DC 11-Module for example, which comes in several models, is an optimised stand-alone unit for source extraction and industrial cleaning. It has been designed to service up to six normal extraction points or several cleaning outlets at a time, and is modularly built, meaning it can be tailor-made to suit any manufacturing and production environment.

As with all of Dustcontrol UK's equipment, the DC 11-Module can be fitted with Hepa 13 filters, meaning exhaust air can be safely returned to the work environment.

James Miller, Managing Director of Dustcontrol UK, said: *"We're excited to be showcasing a range of our most efficient extraction equipment at the first ever Advanced Materials Show.*

"As well as showcasing centralised systems, we'll be exhibiting a range of H Class mobile air cleaners and cyclone-based vacuum units, with a selection of ATEX-approved models and accessories to complete the extensive range.

"In addition, all of our mobile machines are designed to be as ergonomic as possible, so they are easy to handle, move around and transport, as well as being simple to maintain."

James concluded: *"The Advanced Materials Show will provide us with a great platform to show trade users first-hand how our elite dust extracting equipment can help them stay healthy while on the job."*

For further information on Dustcontrol UK's products, please call 01327 858001, or email sales@dustcontrol.co.uk.

Support for SAIEE Bursary Fund

Every year Specifying Techniques facilitates charity driven corporate social responsibility initiatives aimed at the elevation of society's most vulnerable and needy. For over 22 years we have been dedicated to our communities with a focus on the elderly or young, the sick or displaced.

For 2019 we put our own industry at the centre of our initiative, recognising the need to help aspiring professionals realise their dreams.

Specifying Techniques offers project consultations to identify fit-for-purpose building products as part of a solution-driven project specification service, delivered to built environment professionals for free. As an organisation with roots firmly embedded in the success of the construction industry, we rely on highly skilled and educated Architects, Engineers, Quantity Surveyors and Project Managers to recognise the need for built environment product innovation and the use of Specifying Techniques' service as a channel of education on the latest innovations.

Through our partnerships with Impro Technologies, Eurolux, Major Tech, Decorduct, Etex, CED and Intellisec, we are able to consult on a wide array of electrical solutions in technical applications from access control, lighting systems, switches, sockets, power skirting, circuit breakers, security systems to photovoltaic roof tiles.

Eileen van Greunen of Specifying Techniques handing Dawie Barnard of DBA his Ticket

For 2019 we have secured 6 Quarter Final match day tickets to the 2019 Rugby World Cup in Japan, which will be raffled off in 3 raffles, entrants stand a chance to win a pair of tickets valued at R30 000 and a share of R115 000! The stakes couldn't be better, with only 150 tickets being sold for each raffle! The beneficiaries of all the raffle proceeds are the bursary funds of the South African Institute of Electrical Engineers, the South African Institute of Architectural Technologists for the 2 South African raffles, and the Namibian Institute of Architects alongside the Institute of Namibian Quantity Surveyors for the Namibian Raffle.

Helping the construction industry is at the heart of this years initiative, and we believe that the support received from all the product manufacturers and professional service firms who have purchased tickets will help Specifying Techniques advance the success of the industry alongside SAIEE, SAIAT, NIA and INQS.

This initiative has been made a success through sponsorships by Specifying Techniques, Safal Steel, Impro Technologies, Dulux, Eurolux, Cecil Nurse, Floorworld, NEO Paints. Limited tickets are still available, find more information at rwc.specte.ch

INDUSTRY AFFAIRS

Eastern Cape Centre visits the Mercedes Benz Plant in East London

The SAIEE Eastern Cape Centre visited the Mercedes Benz Plant in East London recently to expose our members to the automotive industry that is at our doorstep.

On arrival on site, the very hospitable Mercedes Benz staff welcomed us, offered beverages and snacks before being whisked to a boardroom. Firstly, we were informed of the safety evacuation procedures, and then we were presented with the following:

- the history of the plant and its evolution over the years;
- the pledge made by the workers after the release of Madiba, which meant that they work extra hours with no compensation, as a contribution to make the famous RED Madiba Car that was given to him after his release; and
- the paint shop process - we were not able to visit it due to the delicacy of the process and the fact that it has to be dust proof.

After the presentations, we embarked on a tour of the assembly line. The first area that was visited was the sheet press, where the vehicle sides were being shaped. The level of automation with the use of robotic arms shows how the transition from the 2nd Industrial revolution has evolved into the 3rd Industrial revolution. Henry Ford would not believe that the humble beginnings of automation have reached such levels.

Quality Management and Continuous Improvement are at the core of the operations as the plant has work charts and KPI measurement spreadsheets at every corner. The performance of the line is displayed on Human Machine Interfaces (HMIs), that show alarming and accuracy figures in real time. When it comes to the use of parts that are supplied by external stakeholders, they utilise the Just In Time (JIT) approach from the surrounding suppliers that are within the East London IDZ. Our members could not hold their excitement as we approached the end of the line to be welcomed by the roaring sounds of the C63 AMG machines, like a pride of lions showing off their manes and prowess. The plant makes both left-hand and right-hand drive vehicles as they export a large percentage of their cars to the west.

The Mercedes Plant runs three 8-hour shift per day and produces approximately 590 vehicles per day.

There is also a section of the plant where they construct trucks. This is mainly manual assembly due to the low demand, even though the market is inclusive of the SADEC countries. The daily output is between 35 and 40 trucks a day. After the truck session tour, we went back to the reception area to remove our protective gear.

We took pictures of the exhibition vehicles that are on display at the reception area, but the wooden Mercedes vehicle, one of the first, stood regal as a sign of humble beginnings.

Mercedes was the name of the daughter of the founder of the company.

There was also the beaded vehicle that represents the South African Ndebele heritage as all the beads were done by hand - an incredible feat!

One of the most outstanding information that was shared with us was that towards the end of the year, management conducts a lucky draw for an employee to walk away with a brand new C-Class Mercedes. The only catch is that only employees with zero absenteeism qualify. As a result, sick leave absenteeism is at a minimum, with high levels of performance being the result. Overall, it was a great day well spent and enjoyed by our members.

New Appointment Announcement

Ms Neda Taghadosi
Industry and Certification Director,
Bureau Veritas Southern Africa

Ms Neda Taghadosi has been appointed as the Industry and Certification Director for Bureau Veritas Southern Africa as of 1st April 2019. She was previously the Certification Director and joined Bureau Veritas in 2013. Before joining Bureau Veritas Neda was the Certification Manager in South Africa for the Technical Inspection Association. Neda holds a Bachelor degree in Electronics Engineering from Azad university of Tehran Central Branch and a Master of Business Administration from Faculty of Management, Blekinge Institute of Technology (BTH), Sweden.

ERROR

The caption to the picture published in the May 2019 **watt**now on page 37, in the article on the development of radio communications in underground mines, was incorrect and should have read;

"The 1961 underground radio base-station transmitter-receiver as displayed in the SAIEE Museum."

We apologise for the misprint.

Ericsson and Intellectual Ventures sign license agreement

License agreement ends all patent infringement lawsuits between the companies, including a lawsuit that went to trial earlier this year and resulted in a USD 43 million jury verdict for Intellectual Ventures.

As a consequence, Ericsson expects a negative impact on operating income within Segment Networks in Q2 2019.

Ericsson (NASDAQ: ERIC) and Intellectual Ventures have signed a license agreement ending all patent infringement lawsuits between the companies, including a lawsuit that went to trial earlier this year and resulted in a USD 43 million jury verdict for Intellectual Ventures. Since 2012, Intellectual Ventures has filed a number of patent infringement lawsuits against Ericsson and its customers in the U.S. and Europe seeking injunctions and monetary damages. While the terms of the agreement are confidential, Ericsson expects a negative impact on operating income within Segment Networks in Q2 2019.

Ericsson is a leading innovator in telecommunications and has a strong commitment to research and development. Ericsson has one of the industry's strongest intellectual property portfolios, which includes more than 49,000 granted patents worldwide. Ericsson is the largest holder of standard essential patents for mobile communication.

Gear up for Industry 4.0 at KITE 2019

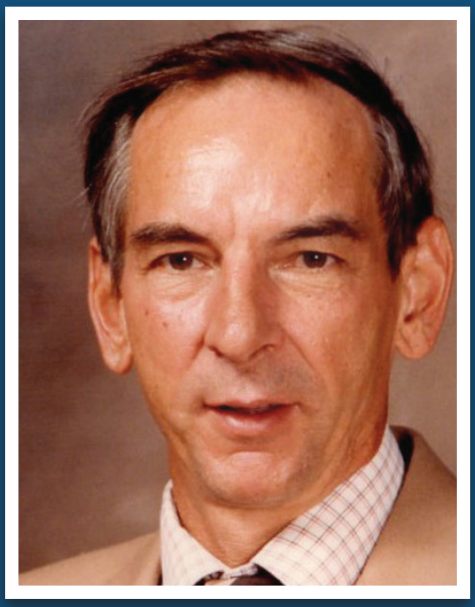
Industry 4.0 and the Fourth Industrial Revolution (4IR) were merely buzzwords back in 2014. Today, however, the traditional manufacturing industry is in the throes of a digital transformation that is accelerated by the exponential growth of smart technologies.

To remain competitive and sustainable organisations and industrial processes need to be fully committed to readily adapting to this rapid change and exponential growth. The current digital transformation is not simply synonymous with a greater level of production automation, but rather by the widespread adoption of information and communications technology by the manufacturing industry.

The KwaZulu-Natal Industrial Technology Exhibition (KITE), launched 38 years ago, has continued to embrace changing trends in industry, not least of which is the uptake of those in 4IR. "We recognise that in order to remain competitive on both the local and global stage, organisations need to gear up and retrain their teams to leverage the benefits that Industry 4.0 brings to the party. The exhibition, which is being held between 24 and 26 July 2019 at the Durban Exhibition Centre, attracts a diverse collection of leading industrial technology suppliers focused on increasing productivity and profitability for the market," says Nick Sarnadas, portfolio director at Specialised Exhibitions Montgomery.

KITE 2019 showcases a broad spectrum of industrial technology from local manufacturers, suppliers and service providers who understand the idiosyncrasies and specific needs of the local market.

To find out more information about the exhibition or to register online to attend the event for free, visit the website at www.kznindustrial.co.za.



DIRK J VERMEULEN
1930 - 2019

Thanks to the good offices of a mutual friend, it was my privilege to first meet Dirk Vermeulen in 1992. For the next 27 years, we worked together as members of the SAIEE Historical Section, who volunteer their services in the interests of the profession. In our particular case, this was mainly in all matters related to the history of Electrical Engineering.

BY | MAX CLARKE
CHAIRMAN
SAIEE HISTORICAL SECTION

OBITUARY - DIRK JAN VERMEULEN

Dirk Vermeulen joined the SAIEE as a Student member in 1951, moved up to Senior Engineer and later registered as a Pr.Eng. in 1969.

Dirk's knowledge of most things "historical"- and particularly those associated with his chosen profession - was terrific. And his enthusiasm for preserving the items and the stories behind them was just as impressive. Although his field of expertise was in electronic and telephony technology, his passion for preserving the history of electrical engineering covered the full spectrum of the industry and the profession.

He authored 12 papers on a wide variety of history-related subjects and produced two books. The first, "Living amongst the stars" records the history of the Johannesburg Observatory site on which the SAIEE has its headquarters, and was published in 2006. The second, "An Illustrated History of Electrical Engineering in South Africa, 1860 -1960" has only very recently been printed.

His talent for "building things" ranged from carpentry to electronics, and everything in between...
...we needed a convenient way of moving books and artefacts between places in our storage area…. he built a wheeled trolley;
... we needed a way to demonstrate various types of loudspeakers … he made an electronic unit to do the trick;
... we needed a way of displaying the evolution of the thermionic valve … he built a wall-mounting glass-fronted cabinet to do just that;
... the list is endless.

It is fitting that one of his hand-built prototype devices, developed while working for the Chamber of Mines Research organization - the foundation of wireless telephone transmissions in underground mines - should now be on display in the Innes House Museum.

And few will even know of, let alone remember, his efforts to turn the old Johannesburg Power Station building in President Street into a repository for electrical artefacts. While the efforts of the committee he chaired did not appear to yield fruit, no one will ever know what part his efforts indirectly played in the final establishment of the present-day Sci-Bona Center, in the very building he believed should be used for just that purpose.

He was a stalwart in the industry. Well done, Dirk and thank you.
My you rest in peace. wn

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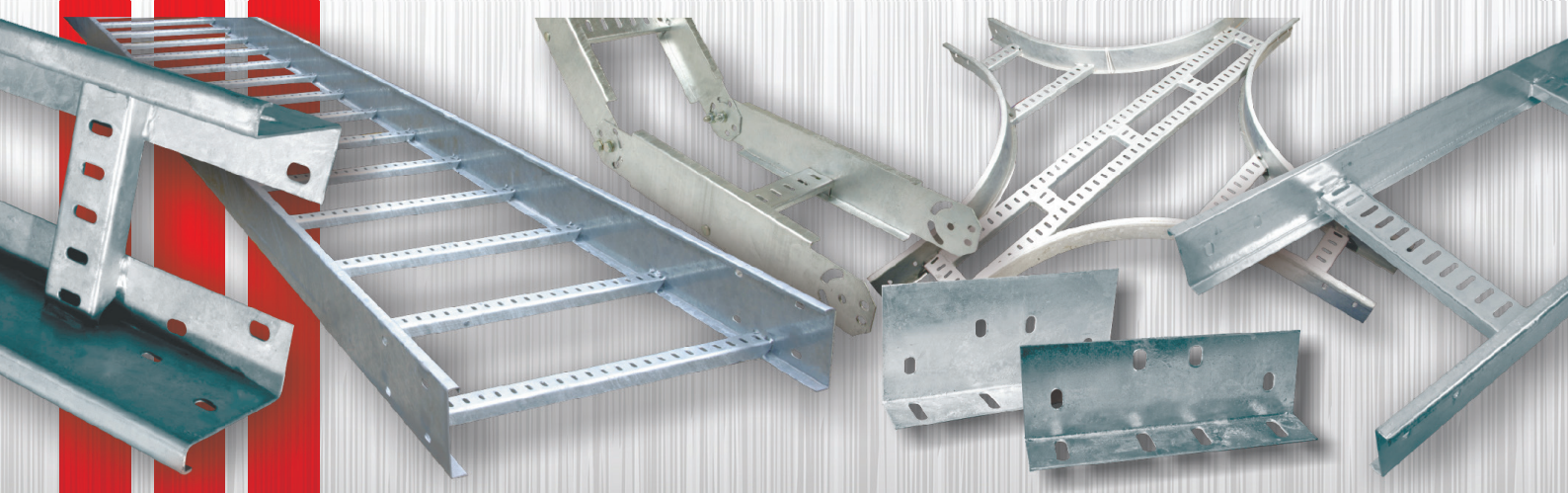

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Cummins Zambia grows its range

Cummins, a global power leader and corporation of complementary business units that design, manufacture, distribute and service diesel and natural gas engines and related technologies, has demonstrated its innovative range of state-of-the-art lubrication and filtration products at Zambia's premier and highly acclaimed Copperbelt Mining, Agricultural and Industrial Expo 2019 (CAMINEX) in Kitwe, Zambia in June.

CAMINEX offers essential value to the area's rich mining belts and is the only mining, agricultural and industrial trade expo in the Copperbelt region and has been in operation for some years now. Showcasing the latest in products, machinery, technologies and services that these and related industries can offer, CAMINEX brings together industry professionals, decision makers and purchasing influencers in a business environment that stimulates networking, exchanging of ideas and sharing of information to culminate in developing partnerships that enhances business growth in the region and promote environmental sustainability.

Cummins Zambia is proud to introduce its expanded Automotive and Agricultural product ranges to include the now-available innovative Cummins Premium Blue Valvoline Oil range. This product range provides superior technical performance and boasts advanced product technology to ensure a longer engine life, extended drain capability, reduced maintenance, keeping the engine operating at peak performance constantly, thus lowering the cost of ownership

The product has proved to be a high performing, reliable engine oil and has sustained the efficiency of its applications. Whilst the products are used extensively in Mining, they are highly compatible and aligned to applications in the Automotive and Agricultural markets.

The company has also introduced its extended superior Cummins Fleetguard Filtration product range at CAMINEX 2019. The range has been refined and developed over 50 years in close collaboration with an engine manufacturer to ensure world class excellence. The Fleetguard products are designed to meet and exceed Cummins, and many other OEMs, engine requirements. The full range comprises some 8000 Filtration products and are engineered to satisfy a wide range of applications in the Mining, Automotive and Agricultural markets

Cummins Zambia enjoys a strong presence in the Mining sector and is synonymous with Power Generation solutions from generators, engines, alternators to control systems. The products on display have been developed also for the Mining sector and continue to provide reliable and durable solutions to ensure the power solutions are always on.

Commenting at CAMINEX 2019, Aftermarket Leader for Cummins Zambia, Mr John Kambing'a, said: "*We are proud to be associated with CAMINEX 2019 and take pride in launching our Cummins*

recommended Valvoline Lubricant Oil and Fleetguard Filtration ranges to our customers and prospective customers in the Automotive, Agricultural and Mining markets. We are here to provide customer support excellence by providing products to suit their needs. We are enthusiastic about creating partnerships with our OEMs and other key stakeholders to empower and bring about business growth. We are here to add value to our customers - reduce down-time, locate difficult-to-find parts, provide engine specs, support events; we want to keep our customers Cummins. Our customers are King!"

Cummins serves customers in approximately 190 countries and territories through a network of approximately 600 company-owned and independent distributor locations and over 7,600 dealer locations. Backed up by a powerful global service network, Cummins stands behind the quality of its products by offering factory-backed Extended Warranty Programs. To get closer to customers, the company has fully equipped site service, field service and maintenance facilities in Zambia.

Cummins celebrated its centennial anniversary in February with a simple message: *"Challenge the Impossible,"* as it continues to innovate a wide range of technical solutions that break boundaries and power the future, pioneering a world that is Always On. The company enjoys decades of experience in power generation and is a world leader in the design and manufacture of generator sets and innovative energy solutions for the automotive, agricultural, marine, construction and power generation markets. The company has a strong sustainability focus and leads the industry in advanced emissions solutions, ensuring that its products meet the required emission standards. Enjoying a strong history of emission leadership has enabled Cummins to develop its own emission solutions which are packaged in accordance with regulations and requirements.

The headquarters for Cummins Zambia is in Kitwe, whilst the headquarters for Southern Africa and Cummins South Africa is in Waterfall City, Johannesburg, South Africa; with branches in Cape Town, Durban, Kathu and Middleburg in the country; as well as branches in Angola, Botswana, Mozambique, Zambia and Zimbabwe. The company also enjoys a wide range of dealer networks in support of its widespread Southern Africa footprint.

Commenting on the business environment in Zambia, the General Manager for Cummins Zambia, Mr Meshach Kwegyir-Aggrey said, *"Cummins offers extensive support to the mining sector and will continue to do so as it looks to strengthening and extending its product offering to other sectors of the market including Automotive and Agriculture. Cummins Power Systems is a global provider of power generation systems, components and services in standby power, distributed power generation, as well as auxiliary power in mobile applications, meeting the needs of a diversified customer base in the power generation industry."* wn

Mr Meshach Kwegyir-Aggrey
General Manager - Cummins Zambia

Artificial Intelligence Pilot results change the face of public healthcare

A pilot initiative implemented by Microsoft partner Mint Group and the Limpopo Department of Health (DoH) at the Rethabile Clinic, Polokwane, has proved the viability of intelligent healthcare at government clinics through the application of Artificial Intelligence.

With plans to transform 400 of Limpopo's clinics into intelligent healthcare facilities, the DoH will address some of the challenges plaguing the Limpopo citizens that are reliant on the public healthcare system.

The Rethabile pilot, which started in May 2018 and concluded in May 2019, comprised the use of predictive analytics, operational intelligence and remote monitoring to manage 25 000 patients a month, enabling access control and queue management, intelligent appointment scheduling, medication dispensing, and inventory control.

The technologies also enabled attendance and performance tracking of healthcare staff to improve service delivery and avoid ghost staff, and provided in-depth data on patient loads, waiting times and queues.

This data empowered the clinic to enhance staff allocation processes and digitise patient record keeping, with a holistic overview of patient care.

"The benefits realised at the Rethabile clinic were unlocked through the application of the Mint Vision App - a platform that extends organisations existing systems and processes with highly advanced computer vision as well as face-and-voice recognition functionality. The pilot has proved how Intelligent technology, coupled with the right vision, can transform public healthcare facilities in South Africa," stated Mint Group Head of Artificial Intelligence Peter Reid.

Reflecting on the Limpopo DoH's vision for transformative healthcare the Deputy Director-General of Health Care Services, Limpopo Department, Dr MY Dombo, stated: *"We are living in the 21st century, and public healthcare should be moving towards more efficient systems by embracing available technologies that can do just that.*

My vision is to have a clinic in the cloud with seamless and wireless processes across Limpopo. This entails automatic patient verification upon arrival via facial recognition, which will eliminate any uncertainty regarding patient identity. Clinic staff should also know which patients are coming before they arrive to ensure a

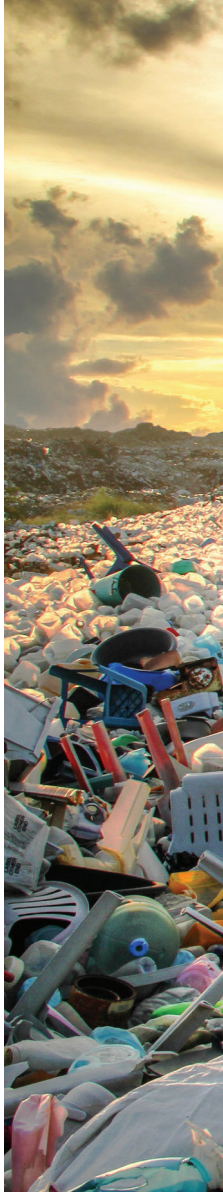
seamless treatment process. Lastly, all patient data should be stored in the cloud with all administrative processes digitised.

These initiatives will streamline patient care, ease the administrative burden of health workers, and enable better healthcare for all."

Praising the Limpopo DOH's forward-thinking initiatives and transformative vision, Mint Group CEO, Carel du Toit, stated that the Rethabile pilot proved the viability of intelligent healthcare in South Africa's public sector and established the Limpopo DOH as a revolutionary leader, paving the way for improved patient experiences and service delivery to the citizens of South Africa.

Following a visit to the Rethabile clinic on May 28, 2019, Limpopo Health MEC Dr Phophi Ramathuba tweeted *"We received an update on our electronic Q management system piloting from the team @Rethabile health centre. Watch the space. It's convincing this time around. There is light at the end of the tunnel. [The] Limpopo healthcare system will never be the same again once this project is done."* wn

$5 Million investment to tackle Plastic Pollution Across Africa



This World Environment Day, The Coca- Cola Company confirms it is on track to spend a third of its USD 38 million pledge before the end of this year.

In December 2018, the Company committed to invest USD 38 million over three years to stimulate polyethene terephthalate (PET) plastic collection and recycling in Southern and East Africa as part of its local effort to achieving a global "World Without Waste" vision. "World Without Waste" is an ambitious global Coca-Cola goal to help collect and recycle a bottle or can for every one it sells by 2030.

Since the beginning of this year, the Company, with its bottling partners, has invested USD 5.125 million to boost recycling industries across eight countries. PET collection and recycling rates are steadily increasing. As a percentage of the PET plastic it sells, the Coca-Cola system in Southern and Eastern Africa is forecasted to close 2019 with an average collection and recycling rate of 80%, led by South Africa at 114%.

"What makes Africa different when it comes to recycling is that every bottle we collect in Africa is recycled in Africa," says Bruno Pietracci, President of Coca-Cola Southern and East Africa. *"This approach brings together different producers along the value chain, creates jobs and stimulates a circular economy where PET packaging has value and life beyond its initial use."*

Vibrant PET recycling industries have been established in Kenya, Mozambique, Namibia, South Africa, Tanzania, Uganda, Zambia and Zimbabwe on the back of industry collaboration and funding kick-started by the Coca-Cola Company and its leading bottling partner across Africa, Coca-Cola Beverages Africa.

The majority of the investment to date has been allocated to setting up financial support models for recycling and collection infrastructure.

The recycling support is mainly channelled via PET Recycling Company (PETCO) in South Africa and Kenya and through recycling contracts for countries with no recycling infrastructure to collect and export their PET to South Africa to recycle.

In South Africa, for example, PETCO was set up in 2004 by Coca-Cola and other like-minded industries to promote and regulate the recycling of PET after initial use. In 2018, thanks to PETCO, 63% of all PET bottles in South Africa were collected and recycled into new products.

Through PETCO, The Coca-Cola Company has achieved its milestone of collecting and recycling more plastic than it put out in the market last year – collecting and recycling 113% of the plastic packaging it sold in 2018.

"The voluntary collection and recycling model in South Africa has proven so effective that we are looking at rolling it out in phases to other countries across the continent," says Pietracci.

"Of course, these types of initiatives take time, but they do result in sustainable solutions to the waste challenge, while at the same to creating jobs, boosting economic growth and helping to change consumer behaviour in each country."

Outside of South Africa, Coca-Cola's largest bottler in Africa, CCBA, has been instrumental in developing collection and recycling infrastructure. As of May 2019, across eight markets in Southern & East Africa, CCBA is helping collect and recycle on average of 79% of all the PET it puts out into the market.

"Food and beverage packaging is an important part of our modern lives, yet the world has a packaging problem. Like many companies that make products we all love, our packaging has contributed to this global challenge. We recognize our responsibility to help solve this challenge. We are confident about the progressive steps we are making to accelerate the achievement of the World Without Waste ambition," explains Pietracci.

World Without Waste is an ambitious global Coca-Cola goal to help collect and recycle a bottle or can for every one it sells by 2030. Additionally, the Coca-Cola Company will create packaging that contains at least 50% recycled material by 2030, meaning less virgin material will be used. The Company will also continue pursuing the goal to make all consumer packaging 100% recyclable by 2025. wn

These countries create most of the world's CO_2 emissions

Just two countries, China and the US, are responsible for more than 40% of the world's CO_2 emissions.

With CO_2 levels still on the rise, being able to track the global emissions hotspots are becoming more critical than ever. Before the industrial revolution, levels of atmospheric CO_2 were around 280 parts per million (ppm). By 2013, that level had breached the 400ppm mark for the first time.

On 3 June 2019, it stood at 414.40ppm.

BY | SEAN FLEMING

What's the World Economic Forum doing about the transition to clean energy?

Moving to clean energy is key to combatting climate change, yet in the past five years, the energy transition has stagnated. Energy consumption and production contribute to two-thirds of global emissions, and 81% of the global energy system is still based on fossil fuels, the same percentage as 30 years ago.

Effective policies, private-sector action and public-private cooperation, are needed to create a more inclusive, sustainable, affordable and secure global energy system.

Benchmarking progress is essential to a successful transition. The World Economic Forum's Energy Transition Index, which ranks 115 economies on how well they balance energy security and access with environmental sustainability and affordability, shows that the biggest challenge facing energy transition is the lack of readiness among the world's largest emitters, including the US, China, India and Russia. The ten countries that score the highest in terms of preparedness account for only 2.6% of global annual emissions.

To future-proof the global energy system, the Forum's Shaping the Future of Energy initiative is working with projects including the Partnering for Sustainable Energy Innovation, the Future of Electricity, the Global Battery Alliance and Scaling Renewable Energy to encourage and enable innovative energy investments, technologies and solutions.

Collectively, the top 15 generate 72% of CO_2 emissions. The rest of the world's 180 countries produce nearly 28% of the global total – close to the amount China produces on its own. Of course, aggregating emissions by country is just one way of assessing the problem and working out how to counter it. The per capita figures tell a different story.

Here, China doesn't even make the top 20. The per capita No one spot goes to Qatar, with the Gulf States making up 3 of the top 4. The US is ranked 8th, behind Australia at 7th. Looking at per capita figures rather than national-level totals could help bring the reality of the climate crisis closer to individuals. For example, a person may feel their decision to use less-polluting forms of transport is pointless in comparison to the colossal Chinese and American CO_2 figures.

But seeing how population size alters the rankings, and where their country appears, may encourage people to see a connection between their actions and the results they can help bring about. wn

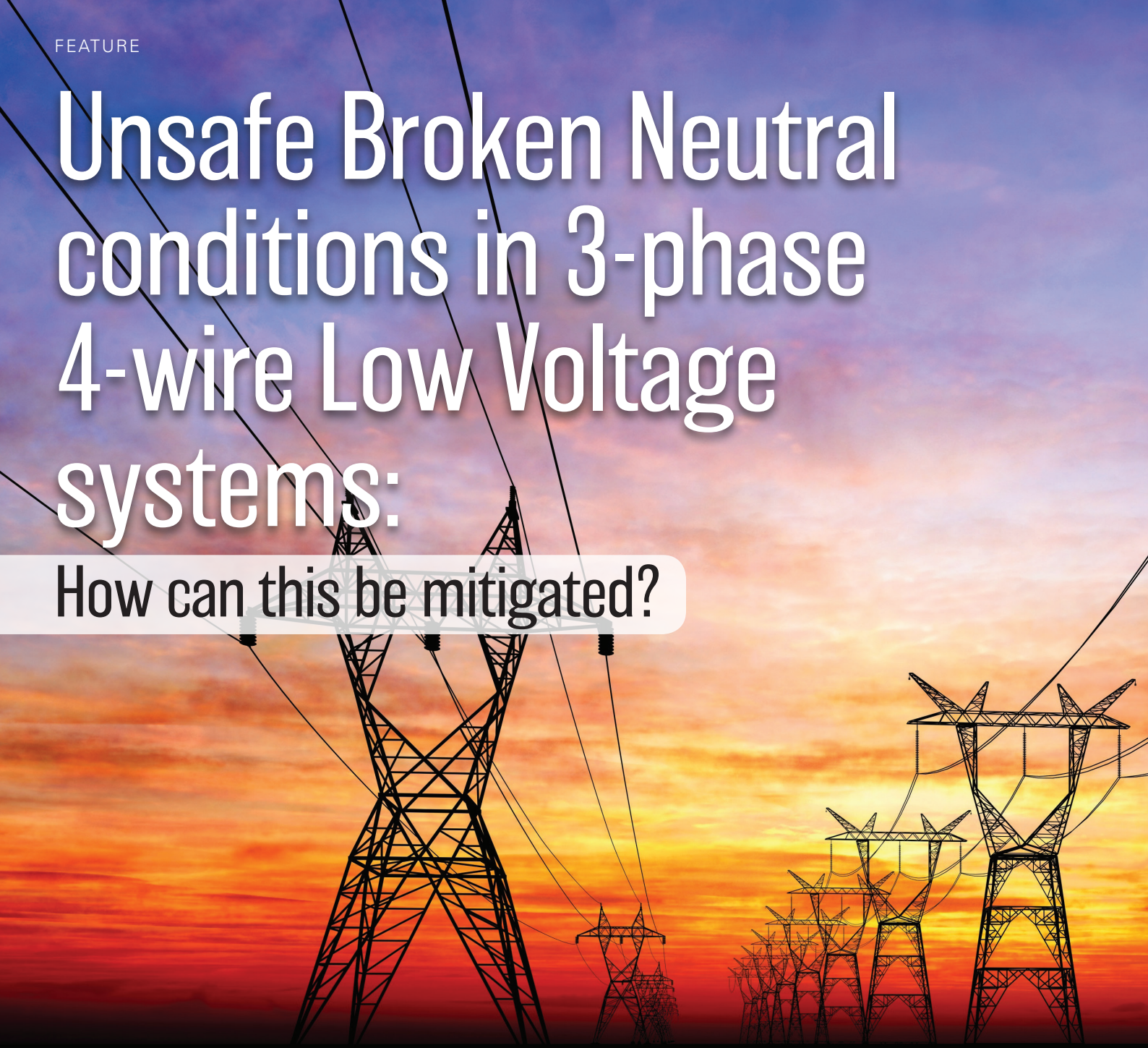
RANK	COUNTRY	EMISSION IN 2017 ($MTCO_2$)	% OF GLOBAL EMISSIONS
#1	China	9,839	27.2%
#2	United States	5,269	14.6%
#3	India	2,467	6.8%
#4	Russia	1,693	4.7%
#5	Japan	1,205	3,3%
#6	Germany	799	2.2%
#7	Iran	672	1.9%
#8	Saudi Arabia	635	1.8%
#9	South Korea	616	1.7%
#10	Canada	573	1.6%
#11	Mexico	490	1.4%
#12	Indonesia	487	1.3%
#13	Brazil	476	1.3%
#14	South Africa	456	1.3%
#15	Turkey	448	1.2%
	Top 15	26.125	72.2%
	Rest of the world	10,028	27.7%

Fifteen countries are responsible for more than two-thirds of global CO_2 emissions.

Per capita CO_2 emissions: the top 4

Unsafe Broken Neutral conditions in 3-phase 4-wire Low Voltage systems:

How can this be mitigated?



Keywords—Broken Neutral, Neutral to Earth voltage, Safety, Voltage dependent.

BY I QUENTIN LOUW PR. TECH ENG, SMSAIEE, MIEEE
(CEO NTAMO TECHNOLOGIES (PTY) LTD)

Broken neutral conditions on low voltage 3-phase 4-wire networks present a challenge not just in terms of appliance failures but more importantly exposes the possibility of life-threatening contact incidents. The Earth Leakage Circuit Breaker (ELCB), required under South Africa law, is purposely designed and installed in all household distribution boxes to mitigate for earth-fault conditions associated with these appliance failures and possible contact incidents. Due to limitations in the ELCB design, the unit fails to operate under broken neutral conditions and thus renders the system dangerous and unsafe. A new bespoke Broken Neutral Safety Device has been developed to ensure that the ELCB is tripped and that the incoming supply is isolated, in the event the domestic household experiences a supply authority broken neutral condition.

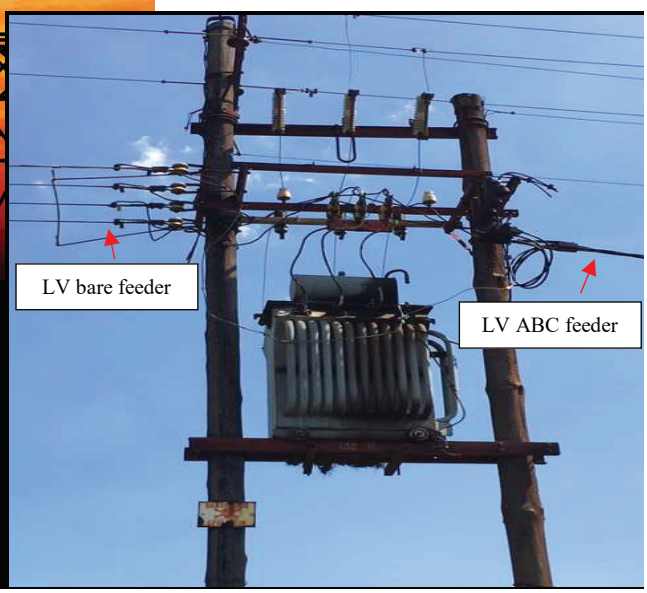


Figure 1: Typical 3-phase 4-wire overhead configuration

INTRODUCTION

The majority of domestic loads in South Africa are generally supplied from a low voltage 230V 3-phase 4-wire reticulation system, either via 4-wire bare-stranded conductor configuration or alternatively by aerial bundle concentric cables. The reticulation networks are derived from a 3-phase Delta-Star distribution transformer installed at a distribution pole as shown in figure 1, or alternatively from a ground level mini-substation to facilitate the electrification requirement.

A broken neutral condition occurs once the main supply authority neutral feeding from this transformer has been interrupted due to cable theft or as a result of ageing infrastructure. This condition contributes to domestic appliance failures as a result of excessive overvoltage's, and more importantly, can be classified as a

Unsafe Broken Neutral Conditions

continues from page 27

lethal condition to the safety of the occupants living within these domestic households, or people working in environments where the neutral has been interrupted unknowingly. Limited incidents due to broken neutral conditions have been recorded in literature as these incidents are usually attributed to power surges or equipment failure, however Electrical Construction and Maintenance magazine (EC&M) [1], reports in 2004 on an incident where a construction worker came into contact with a bare-stranded live neutral conductor while affecting repairs and suffered severe shock injuries as a result. A most recent case is recorded in Australia in 2018, where the publication highlights that an 11-year-old child was electrocuted and suffered brain damage whilst she was trying to turn off a tap in her household. The interim investigation found that the incident was attributed to a broken neutral condition [2]. It is therefore argued that broken neutral conditions do infact occur more regularly than recorded and almost always with significant implications. It is further suggested that the representation in literature is undervalued and more needs to be highlighted to acentiate this phenomenon.

All domestic households in South Africa are required, by law (Government Notice No:2286 gazette 10987 of 16 October 1987) [3], and SANS 10142-1:2006 [4], to have a Earth Leakage Circuit Breaker (ELCB) fitted within the main electrical distribution box to afford protection in the event of appliance failure, and more importantly, during an accidental contact incident.

What is of significance during the broken neutral condition is that the single-phase ELCB installed, fails to trip and isolate for earth-faults occurring, this as a result of design limitations within the ELCB. Most ELCB's are designed to detect a core flux-imbalance in the core of the current transformer during a fault to affect the tripping operation, but modern ELCB's have a limitation due to the electronic circuitry used for the algorithm in the tripping decision making criteria. This limitation is attributed to the voltage dependency of the incoming supply voltage necessary to provide power to the electronic circuitry of the ELCB, which is in the order of anything between 50 to 80V rms measured across the live and the neutral incoming terminations. Therefore, once a broken neutral condition occurs the live is transferred to the neutral supply side via the load impedance of the household as highlighted in figure 3 (below). Furthermore, as a result of the neutral being interrupted, no load current through the load impedance would be present, and it would seem that the domestic load has been disconnected from the supply during this condition. In fact, this condition could now present up to the full phase to neutral voltages of 230V rms between the neutral conductor and earth and should an earth-fault condition occur during this phenomenon the ELCB protection would now be rendered in-operable and not trip. With the load impedance considered the only fault current limiting factor under

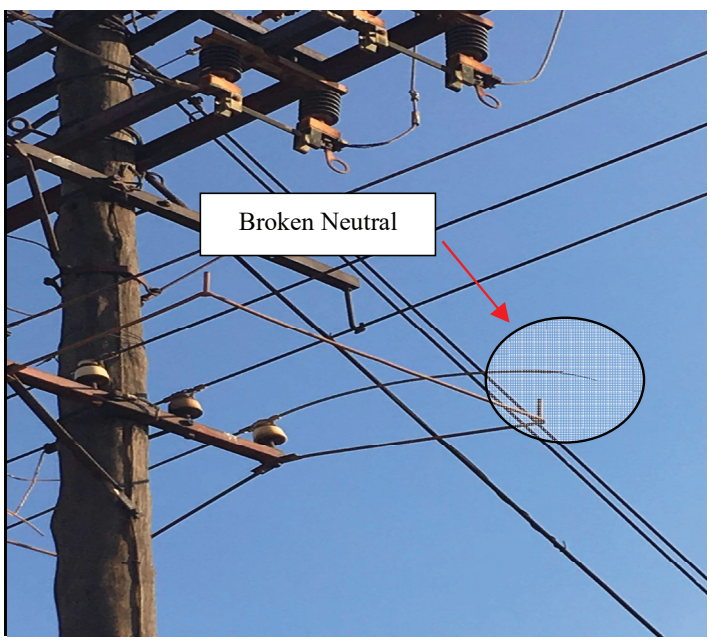


Figure 2: Broken Neutral

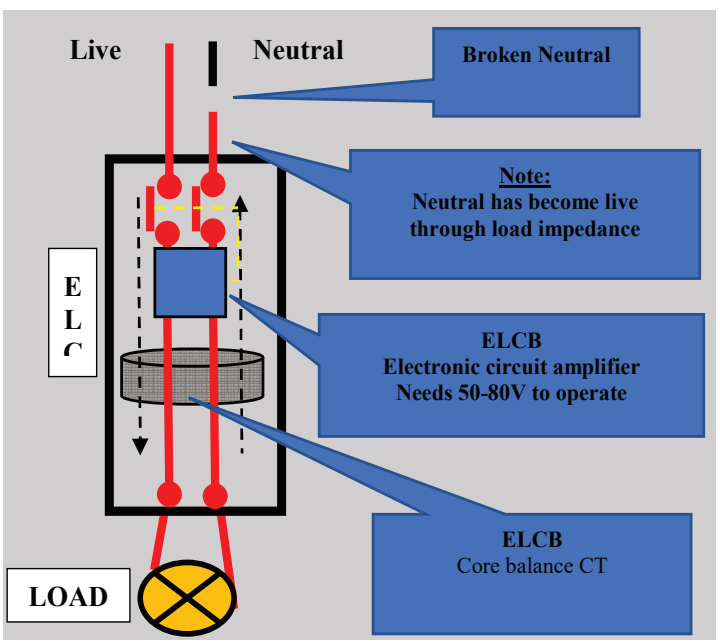


Figure 3: Neutral live during broken neutral and ELCB will fail to operate

ELCD failure, the fault current would still be large enough to electrocute a person coming into contact with the live circuit and earth.

This paper investigates this phenomenon and highlights a solution to mitigate for the broken neutral conditions in domestic households by using a bespoke *"Broken Neutral Safety Device"*.

BACKGROUND

Kirchhoff's current law states that the algebraic sum of all currents entering and leaving a node must summate to zero and equally so would the summated voltages be equal to zero i.e. no neutral voltage [5].

Equation 1 highlights the vectoral sum calculation of these voltages under system conditions, and in a perfectly balanced steady state system the vectoral summation of the voltage for the respective phases will be equal to zero as highlighted in figure 4 (below). Should the system have unbalanced loads as in figure 5 (below), Kirchhoff's law will still apply and the vectoral sum imbalance will now be reflected in the 4th wire i.e. the neutral wire.

$$Vn = VaSin(\omega + \theta) + VbSin(\omega + \theta) + VcSin(\omega + \theta) \quad (1)$$

Where:

Vn = Neutral voltage
Va = Phase A voltage
Vb = Phase B voltage
Vc = Phase C voltage
ω = Angular Frequency (2πF)
θ = Phase angle

This imbalance voltage in the neutral relative to earth should not exceed 50V rms as per SANS 10142-1 [4], as voltages above this value would be enough to inflict severe injuries or possible death due to the human body resistance characteristics, this in the event of a contact incident.

The typical network typography used in South Africa is configured as presented in figure 6. The low voltage supply is distributed from a secondary star vector group configuration; the star point is effectively earthed with no intentional impedance added in the star point circuit. Each phase is individually taken from the respective transformer terminals and the neutral is connected

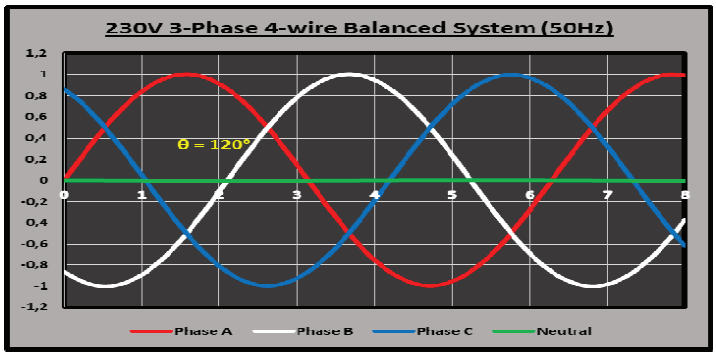


Figure 4: Balanced 3-phase 4-wire system

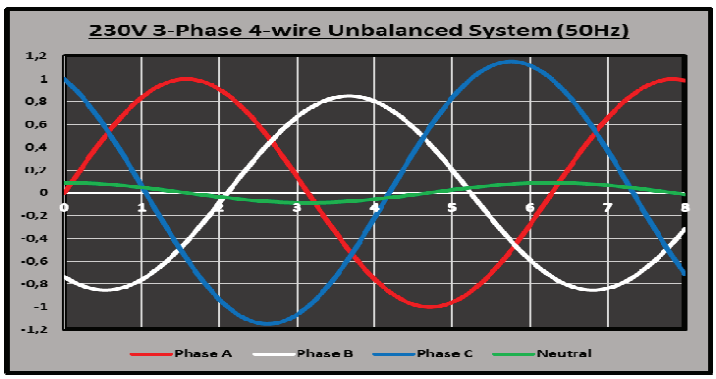


Figure 5: Unbalanced 3-phase 4-wire system

to the transformer star point. Figure 7 below, represents the electrical schematic in the event of a broken neutral condition. The instantaneous current flow under this condition is illustrated on the schematic and for graphical purposes the instantaneous red-phase current is used to illustrate. It is evident that a potential difference will be produced between phases as a result of the current flow through the load impedance circuit. The derived voltages are directly proportional to the load impedances of the system and the degree of load symmetry.

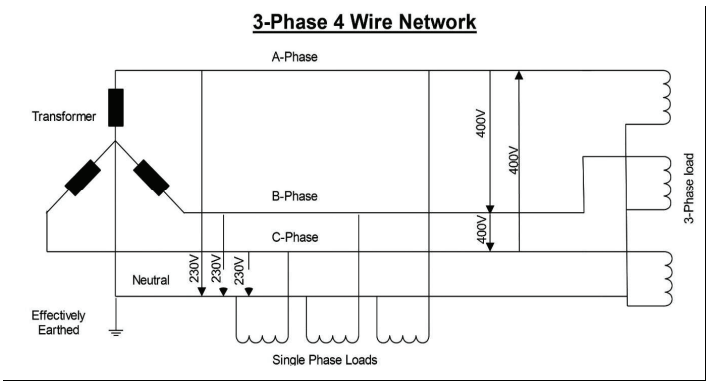


Figure 6: Electrical schematic of a 3-phase 4-wire system

Unsafe Broken Neutral Conditions

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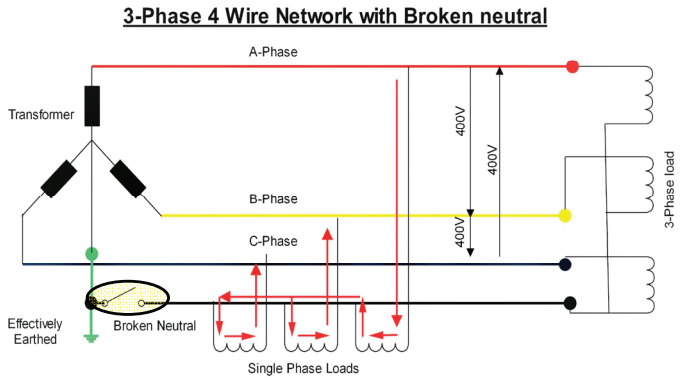

Figure 7: Electrical schematic of a broken neutral condition

Xivambu [6] and Cohen [7], highlight that in a 230V 3-phase 4-wire system the neutral voltage can float up to the line voltages depending on the load balancing in the event of a broken neutral condition (refer figure 7 above), and further elaborates that in a single-phase load scenario, should the neutral be lost, the impact would be minimal as power to the single phase customer would be interrupted. Although these authors highlight correctly the conditions pertaining to the phase-phase voltages, under a loss of supply neutral, the interpretation in terms of the single-phase scenario fails to identify the potentially hazardous condition associated with voltages present under these conditions.

Although the load seems to be interrupted, the full phase voltage of 230V rms is transferred to the neutral via the load impedance as a result of no current flow and thus now creates this potential difference between the *"neutral"* and earth. The argument might be presented that in a concentric cable system where the PEN (Protective Earth and Neutral) conductor (used in a TN-C-S earthing system) is lost, that no potential difference will be present between *"neutral"* and earth theoretically, as in this case the neutral and earth is lost simultaneously. However, should a person touch the live condition and be well grounded it is suspected that sufficient current will flow to cause an electrocution condition as a result of the soil resistance between the supply transformer and contact point. This condition is life threatening as the full power frequency voltage is available under this earth-fault condition (i.e. human body contact). To further exacerbate the problem, the ELCB will fail to operate should this potential difference between the incoming live and neutral of the ELCB be anything less than 50 to 80 volts rms, due to the voltage dependency design limitations of the ELCB used (refer figure 3).

This latter scenario is corroborated by Pillay [8], where experiments were conducted by simulating a broken neutral conductor situation under un-balanced load conditions. In the concluding statement, it is highlighted that unsafe conditions occur at single-phase installations as well as confirming that the ELCB under these conditions were unable to detect the unsafe situation.

Although most ELCB's operate on the core flux-imbalance principle in the event of an earth-fault current occurring, two main categories applicable to this paper have been identified and could be categorized as voltage independent and voltage dependent ELCB devices. Voltage independent ELCB's rely on the earth fault current to operate the tripping mechanism by virtue of the magnetic flux established during the fault. This flux operates a polarized relay which ensures a long enough duration to force the ELCB into operation, whilst in contrast the voltage dependent ELCB relies on the supply voltage between the incoming live and neutral terminations to derive power for an electronic amplifier to achieve a tripping result [9]. In South Africa, approval of ELCB use is granted based on the VC8035 specification as published in Government Gazette 10987 [3]. All suppliers of ELCB's must comply with this specification in order to sell these devices into the market, however the specification does not make a clear distinction between voltage dependent or voltage independent ELCB's. It does however refer to in clause 4.13 *"The test facility shall be so connected in the circuit as to ensure that the sensing device, the amplifier, and the circuit-breaker mechanism are all tested for failure or deterioration"*. As all ELCB's have sensing circuits (i.e. core CT), only voltage dependent devices have amplifiers, and the key word *"amplifiers"* in the specification affords the opportunity to assume that the majority of ELCB's supplied into the South African market are voltage dependent devices.

To further highlight this assumption one of the most commonly used ELCB's in the South African market was chosen for the laboratory simulation tests to confirm the veracity of this claim. The QA17C ELCB (voltage dependent) is VC8035 complaint and has no overload protection included in the design. This ELCB has a minimum 30mA core imbalance threshold for detecting earth fault conditions to ensure tripping and isolation. This unit is used pervasively throughout South Africa in electrification projects (i.e. ready boards) as well as in urban domestic households. These devices are freely available at retail outlets and are competitively priced in the market, making it very accessible for use.

MITIGATING SOLUTION

To mitigate the problem of the ELCB failing to operate under broken neutral conditions a bespoke *"Broken Neutral Safety Device"* (BNSD) was developed (figure 8 below). This device is considered a complimentary device to the ELCB and installed as a retrofit with the ELCB in the electrical distribution box. The functionality of this device relies on the potential difference between the *"neutral"* and earth and now provides for the ELCB to trip instantaneously in the event of a supply authority broken neutral condition occuring. The device is designed to take into account the voltage dependability of the ELCB and provides the necessary *"phantom"* power to the ELCB during broken neutral conditions in order to power up the amplifier circuit and to fascilitate the necessary tripping. During these conditions, the BNSD keeps the ELCB tripped untill such time as the neutral has been repaired and the system normalised. The unit also offers visible indication if a large voltage imbalance between the neutral and earth is presented, this prior to the ELCB tripping and beyond. Should the ELCB be reset under broken neutral conditions whilst using the BNSD, the ELCB will maintain tripping and isolation of the circuit with visual indication supplied by the BNSD. The BNSD will only become active in the circuit under broken supply neutral conditions and will not impede on any functionality under normal conditions.

Although the BNSD is designed to operate from a 50V rms threshold, the limitation in tripping is constrained by the ELCB amplifier voltage, which needs anything from 50 to 80V rms. Therefore tripping and isolation of the circuit is purely dependant on the limitations of tripping charateristics provided by the ELCB.

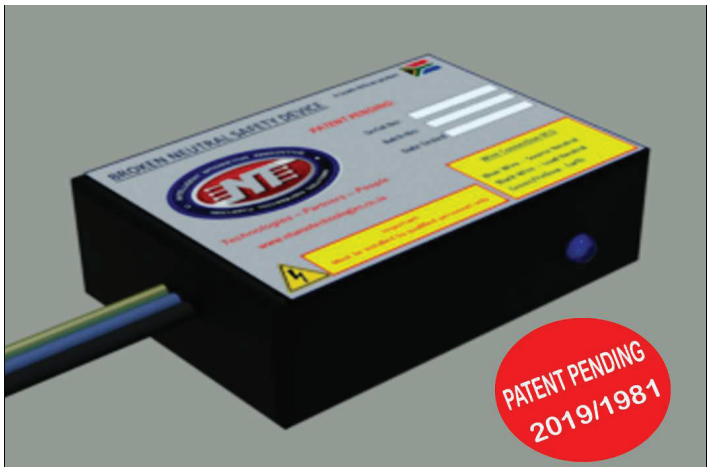

Figure 8: Broken Neutral Safety Device

LABORATORY SIMULATION

Figure 9 represents the wiring schematic of the simulator used to conduct the various broken neutral experiments. The simulator was supplied from the supply authority with a 400V 3-phase incomming supply. The simulator secondary provided for isolation of the test environment to that of the supply authority incomming end, this done through the use of a 415/415 V 5 kVA (Z1=4%) Delta-star transformer vector group configuration. Load impedances were simulated using incadescent and low energy compact fluorescent lamps (CFL) in various configurations in order to provide for the load balance symmetry requirements.

The simulator also provided for neutral interupting points in two positions, one at the transformer end and the other at the BNSD test circuit end. The BNSD test circuit was connected to the simulator and consited of using a QA17C ELCB for tripping and isolation of the single-phase load test circuit, a standard 10W CFL and finally the inclusion of the BNSD which could be switched in and out of the circuit for simulation purposes.

Test sequences were conducted by opening the various neutral links under the various load balance configurations and the *"neutral"* to earth voltages presented were recorded, this all done with the BNSD switched in and out of the circuit. Observations were also recorded in terms of ELCB operation during these conditions i.e. by noticing any tripping when the neutral was broken in addition to the functionality of the trip test push button of the ELCB.

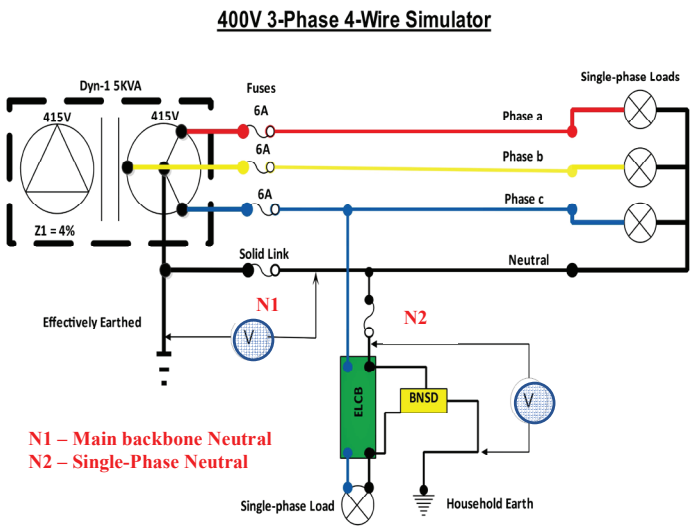

Figure 9: Laboratory simulator schematic

Unsafe Broken Neutral Conditions

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All results were recorded using voltmeters and visual indication (i.e. ELCB lever and blue LED on the BNSD) and these results were then tabulted for further discussion.

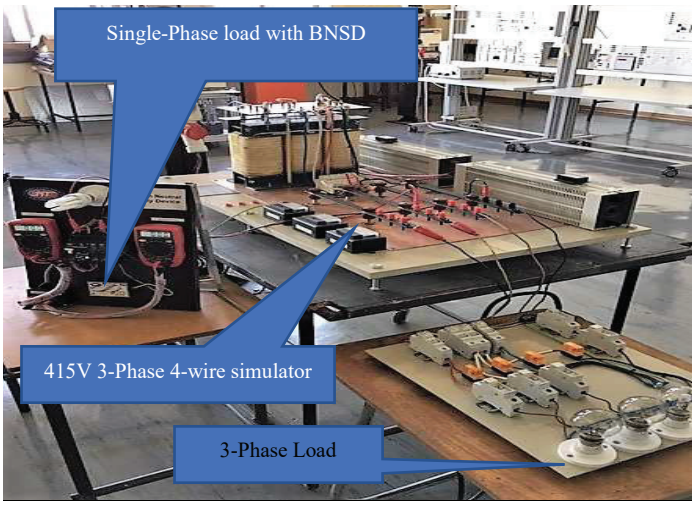

Figure 10: Laboratory test simulator

RESULTS

TEST 1 – ELCB MANUAL TESTING (TRIP TEST CIRCUIT WITH NO LOAD)

Under test 1 the ELCB manual trip test push button was pressed to simulated an earth-fault condition through the units internal trip test circuitry. Figure 11,12 and 13 represent the simulation and the following results were recorded:

From figures 11 to 12 above it is noted that at 50V and 70V rms the ELCB did not trip (green lever in tact) whilst pushing the trip test push button. Only at 80V rms (figure 13) did the ELCB manage to trip (green lever down). This test was conducted on the ELCB by applying a rms voltage from a single-phase 230V AC variac source to the incomming terminals of the ELCB with no load connected to the outgoing terminals. Measuring the AC rms voltages was achieved by using a UT33C multimeter. It was found that the the QA17C ELCB was a voltage dependant device and needed a minimum supply voltage of 80V rms to allow for tripping to occur, this before any core flux-imbalance was taken into consideration.

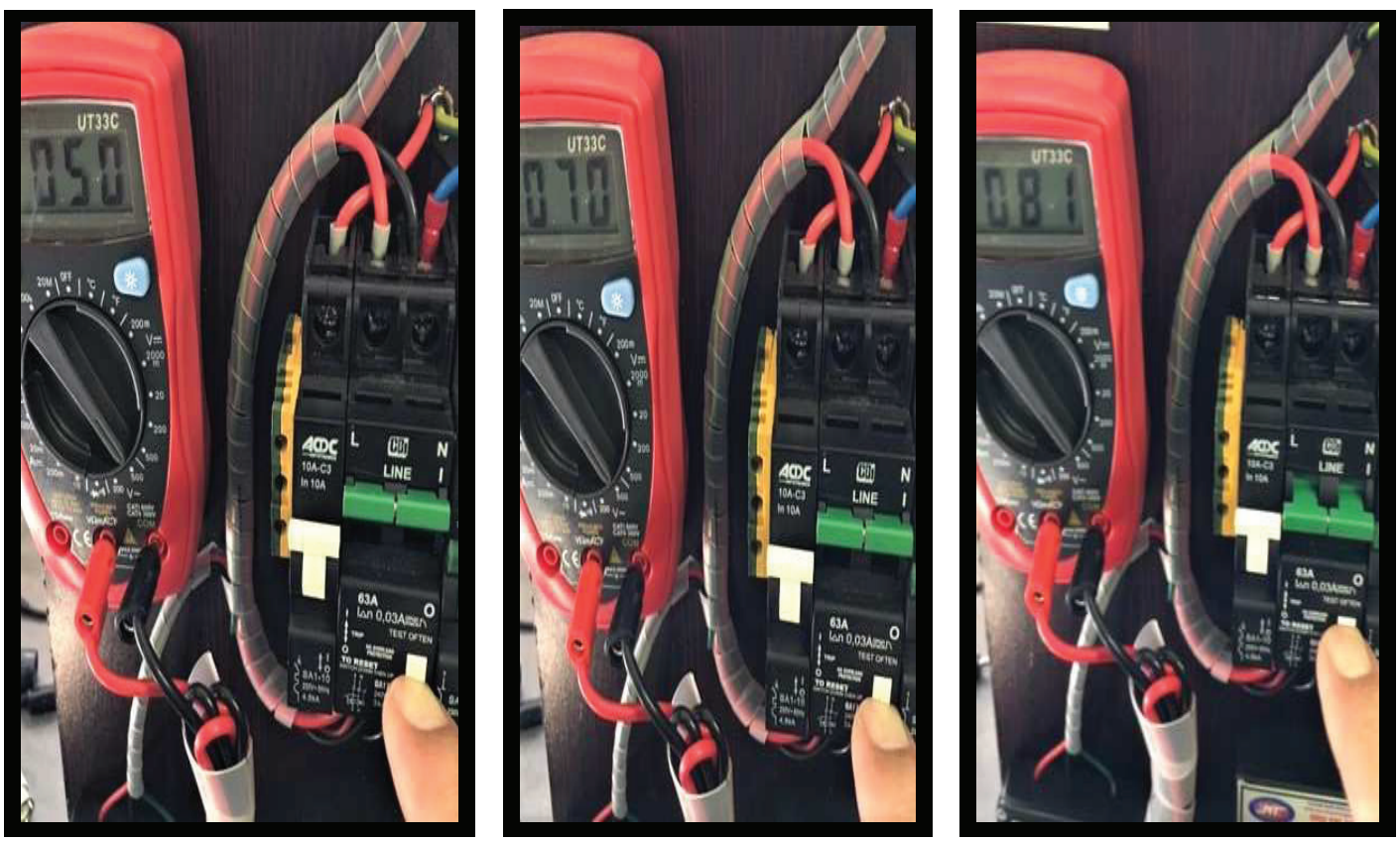

Figure 11,12 and 13 manual trip test function

TEST 2: TESTING BNSD WITH INCADESCENT BALANCED LOAD

TABLE I: 3-PHASE BALANCED LOAD (INCADESCENT LAMPS 60W EACH)						
N1 open	**N-E (V) Main Neutral**	**N2 open**	**N-E (V) S-Phase Neutral**	**BNSD In**	**ELCB Trip**	**Indi-cation LED**
No	0V	No	0V	No	N/A	No
Yes	47V	No	44V	No	No	No
No	0V	Yes	225V	No	No	No
Yes	45V	No	45V	Yes	No	Yes
No	0V	Yes	225V	Yes	Yes	Yes

TEST 3: TESTING BNSD WITH LOW ENERGY BALANCED LOAD

TABLE II: 3-PHASE BALANCED LOAD (LOW ENERGY LAMPS 11W EACH)						
N1 open	**N-E (V) Main Neutral**	**N2 open**	**N-E (V) S-Phase Neutral**	**BNSD In**	**ELCB Trip**	**Indi-cation LED**
No	0V	No	0V	No	N/A	No
Yes	161V	No	149V	No	No	No
No	0V	Yes	228V	No	No	No
Yes	60V	No	43V	Yes	No	Yes
No	0V	Yes	228V	Yes	Yes	Yes

TEST 4: TESTING BNSD WITH UN-BALANCED LOAD (1)

TABLE III: 3-PHASE UN-BALANCED LOAD (1 X INCADESCENT & 2 X LOW ENERGY LAMPS)						
N1 open	**N-E (V) Main Neutral**	**N2 open**	**N-E (V) S-Phase Neutral**	**BNSD In**	**ELCB Trip**	**Indi-cation LED**
No	0V	No	0V	No	N/A	No
Yes	114V	No	113V	No	No	No
No	0V	Yes	226V	No	No	No
Yes	162V	No	162V	Yes	Yes	Yes
No	0V	Yes	226V	Yes	Yes	Yes

TEST 5: TESTING BNSD WITH UN-BALANCED LOAD (2)

TABLE IV: 3-PHASE UN-BALANCED LOAD (2 X INCADESCENT & 1 X LOW ENERGY LAMPS)						
N1 open	**N-E (V) Main Neutral**	**N2 open**	**N-E (V) S-Phase Neutral**	**BNSD In**	**ELCB Trip**	**Indi-cation LED**
No	0V	No	0V	No	N/A	No
Yes	82V	No	80V	No	No	No
No	0V	Yes	226V	No	No	No
Yes	100V	No	100V	Yes	Yes	Yes
No	0V	Yes	226V	Yes	Yes	Yes

During these test the following was observed:

- The ELCB did not trip for rms values below 80V with BNSD in service.
- During the un-balanced tests, the voltage across the single-phase load reached a maximum of 365V rms whilst opening the main backbone neutral (N1).
- The BNSD displayed correct LED indication for voltages below 80V (where the ELCB could not trip).
- The BNSD indication LED worked correctly during ELCB tripping and interuption.
- With the BNSD configured in service on the single-phase load circuit the unit operated the ELCB correctly for the main backbone neutral (N1) interuption, however the loads connected to the remainder of the circuit without the BNSD fitted suffered catastrophic loss due to the overvoltage conditions related to broken neutral conditions.

DISCUSSION

From the experiments conducted, it was shown that when a single-phase domestic load neutral was broken, the full phase voltage was present between the neutral conductor and earth as the live voltage was reflected to the neutral via the load impedance under no load conditions. A further test in breaking the main backbone neutral revealed that the volatge measurements between the single-phase consumer neutral and earth was directly proportional to the network load balance arrangement.

Unsafe Broken Neutral Conditions

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From these test a concerning observation was noted that the QA17C ELCB only operated at approximately 80V beyond the critical point of 50V rms as determined by SANS 10142-1 [4]. This was attributed to the electronic ELCB design (voltage dependant) which needed approximately 80V rms between the live and neutral incomming terminals for the ELCB unit to operate correctly under all conditions.

By applying the *"Broken Neutral Safety Device"* to the ELCB circuit, it was observed that as soon as the neutral to earth voltages exceeded 80V rms the device would force the ELCB to trip and isolate the domestic load until such time as the supply neutral had been repaired, afterwhich the supply could be normalised.

Although the BNSD device indicates unbalanced neutral to earth voltages during in circuit operation, circuit tripping and isolation of the supply is limited by the ELCB voltage dependant operating limitation of 80V rms as a result of amplifier voltage demand requirement.

Finally, once the BNSD is installed as a retrofit, the unit acts in an quiescent *"out of circuit"* state during normal working conditions (i.e. with the neutral being intact) and does not impede on any functionality of the ELCB during earth-fault conditions under normal operational conditions.

CONCLUSION

Broken neutral conditions in low voltage 3-phase 4-wire networks should be considered very dangerous and unsafe. To date some research has been conducted into this phenomenon and historically various methods have been proposed in mitigation, of which none have conclusively come to fruition. The reason for this is that the perception of incidents are marginally low and therefore requires less attention. However, due attention should be given, as networks are subject to ageing infrastruture and the lack of maintenance (i.e where neutrals are subject enviromental conditions such as corrosion, etc) as well as the fact that more and more networks are subjected to cable theft, where the neutral is specifcally targetted.

The *"Broken Neutral Safety Device"* now offers that mitigation requirement and can be installed in domestic households to ensure correct operation of the ELCB under broken neutral conditions and not affect the normal functionality of the ELCB should an earth-fault condition occur through appliance failures and more importantly accidental human contact incidents. wn

ACKNOWLEDGEMENT

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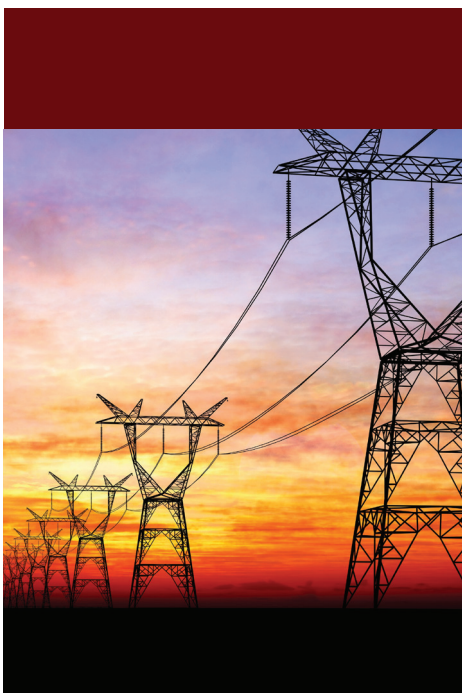

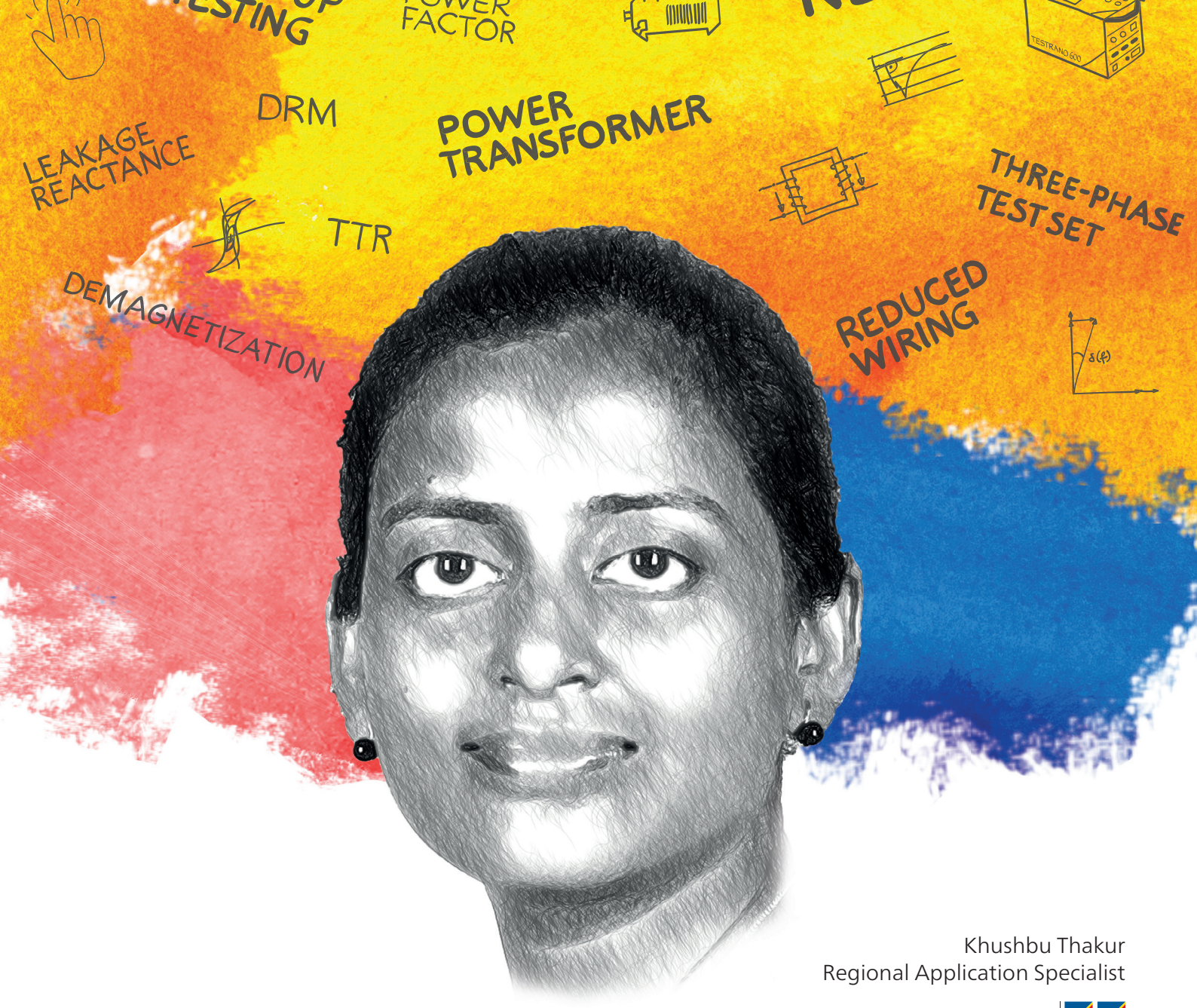

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The Economic Benefits and Challenges with Utilizing Increased Enrichment and Fuel Burnup for Light-Water Reactors

In the United States, commercial light water reactors generate electricity using low-enriched uranium (LEU) fuel. On average, fuel costs comprise approximately 20% of nuclear power plants' total generating costs. Few other individual cost components have such a significant impact on the economics of the nuclear fleet.[1] A site's fuel costs depend on two factors, the price of the fuel components (uranium feed, conversion, enrichment, and fabrication) and the efficiency of the core design. Fuel component costs are driven by supply and demand, and are largely outside the control of a utility. The effectiveness of a core design determines the quantity of nuclear material needed to meet a plant's energy objectives.

PREPARED BY THE NUCLEAR ENERGY INSTITUTE
FEBRUARY 2019

While a utility can improve the efficiency of the core design, this efficiency is ultimately limited by the specific design constraints of the core design. Two of several limitations that have been shown to impact the core design efficiency directly are the uranium enrichment level and discharge burnup achieved by the core and fuel design. A review of the current fuel management practices, based on equilibrium cycle designs, has shown that 99% of the variation in fuel cycle efficiency is attributable to changes in enrichment and burn up. Many sites are currently constrained by the existing regulatory limits on one or both of these parameters.

With the increased interest in higher burnup cores, it is likely that within the next decade, both operating and advanced reactors will see a demand for fuel enriched greater than five weight per cent (wt%) U-235. This white paper provides a study—including assumptions, economic projections, inflation and financial methodologies—that evaluates the technical, financial and regulatory issues associated with increasing the limits on uranium enrichment and fuel burnup for current uranium dioxide (UO_2) fuel types. Revising these limits impacts a large portion of the nuclear fuel cycle as well as the licensing bases for both plant operators and fuel suppliers. While there are economic advantages to making these changes, they also require long-term capital investment and regulatory changes. Revising these limits will provide savings through additional cycle length flexibility, reduced high-level waste storage and disposal requirements, and a positive benefit on the environmental impact of the fuel cycle. The final decision to pursue new limits must consider not only the expected benefits but the business risks associated with such an undertaking.

ECONOMIC ANALYSIS

2.1 TECHNICAL CHALLENGES

2.1.1 Burnup

Increasing the fuel burnup limit requires addressing many fuel mechanical design and reliability considerations. These include, but are not limited to, internal rod pressure, cladding corrosion, rod and assembly growth, and cladding strain. While demonstrating acceptable fuel performance that satisfies all these design criteria represents a significant effort, it does not present an insurmountable technical challenge. The fuel suppliers are developing, or have developed, advanced materials or design features to mitigate these considerations. Additionally, some

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of the features of new accident tolerant or advanced technology fuel (ATF) designs may provide additional safety performance margins in these areas.

However, issues related to fuel fragmentation, relocation and dispersal (FFRD) during postulated design basis accidents (DBAs) remains a challenge. FFRD has been observed in some test reactor experiments under simulated light water reactor (LWR) conditions. However, the Electric Power Research Institute (EPRI), with support from the U.S. Department of Energy (DOE), and in collaboration with the U.S. Nuclear Regulatory Commission, is conducting separate effect tests which may potentially result in a fully integrated test in 2022 using the restarted Transient Test Reactor (TREAT) at Idaho National Laboratory with the modifications for Loss of Coolant Accident LOCA testing. This integral test will be performed under prototypical LWR conditions, which combine realistic fuel temperature profiles, appropriate linear power densities, and fission gas distributions suitable to high burnup fuel and is expected to advance the understanding of FFRD to support potential extensions of existing burnup limits. Tests with next-generation cladding and fuel pellet designs may also provide some additional insights on the benefits of the proposed ATF concepts. These pellets typically have a larger fuel pellet grain size which has been shown in separate effects tests to reduce healthy and transient fission gas release behaviours during normal power operations and DBAs.

As an alternative approach limiting cladding swelling and, therefore, the associated ballooning and rod burst opening size will potentially reduce fuel material relocation and dispersal while ensuring adequate safety margin. Some international regulators have already licensed plants to higher burnup levels using this criterion. Crediting this phenomenon will likely require reductions in the linear power density as a function of burnup. EPRI and DOE are evaluating the practicality of this approach as a backup to the fuel fragmentation research strategy.

2.1.2 Generic Safety Analysis

In addition to the execution of standard core reload safety analysis methods, some generic analysis methods may be impacted by fuel burnup limit increases (e.g. revised accident source terms and decay heat). A full review of the existing industry database is needed to determine if sufficient margin exists in the current analysis limits to safely support higher burnup limits. Potentially, additional tests with higher burnup fuel might be required. Additionally, some sites will likely require revisions to their current licensing basis concerning fuel handling or other accident analyses that support higher accident source terms or the adoption of alternate source terms under 10 CFR 50.67 with appropriately revised regulatory guidance.

2.1.3 Dry Cask

Evaluations of dry cask fuel criticality, decay heat, and site boundary (both exclusion area and low population zone) dose limits will need to be performed to load higher burnup/enrichment fuel in dry casks. New certificates of compliance (COCs) are expected to be required to address the criticality requirements. Current decay heat limits are expected to be met with increased cooling times; however, methods will need to be developed to support extending the decay heat analysis for higher burnups and cooling times. While these changes to the design and licensing bases for dry cask systems will require effort, they do not pose a significant technical challenge. A substantial reduction in spent fuel discharge inventory is expected with higher burnup/enrichment. This reduction will allow longer cooling times for the same spent fuel pool storage capacity. This increase in cooling time will partially offset the increase in heat load due to higher burnup. Sites with minimal storage capacity will need to develop an appropriate strategy before committing to higher burnup fuel. These strategies could include revising their fuel selection, fuel loading configurations or using a cask design with higher heat load limits. Implementation of these strategies will not occur until after 2035.

2.1.4 Enrichment

The most substantial technical challenge to increasing the enrichment limit is related to the controls and analysis to maintain criticality safety margins for fuel enrichment and, fabrication facilities, as well as storage and transportation systems. The transportation of enriched UF6 from the fuel enricher to the fuel supplier is currently performed using Type 30B transportation packages. The current Type 30B design has sufficient margin to increase the allowable fuel enrichment limit to approximately 6 wt% U-235. However, this licensing basis is somewhat unique for transportation systems. It will be challenging to obtain the approvals to extend this analysis assumption to higher fuel enrichment. New transportation systems are being designed with fixed neutron absorbers to support an array of higher enrichment. These systems are expected to be licensed by 2022. Other fuel storage and transportation systems do not represent a significant technical barrier.

Fuel designed with higher enrichment will also include higher concentrations of fixed neutron absorbers to control in-reactor reactivity and power peaking. This is expected to offset the challenges for fuel storage and transportation. Additionally, higher enriched fuel will operate to higher burnups, which also tends to offset criticality issues. New criticality analysis assumptions must be consistent with the expected fuel designs. Both the fuel designs and storage system margins are site-specific. The strategy of using a higher concentration of fixed absorbers is generally likely to be effective; however, some sites have limited design or storage flexibility and will elect not to adopt higher enrichment fuel designs. While relicensing any fuel system to meet modern criticality analysis standards poses regulatory challenges, as discussed in Section 3.4, these are considered to be manageable with the current technology and regulatory guidance.

2.2 INDUSTRY DEMAND AND ECONOMIC EVALUATION

2.2.1 Fuel Management

Fuel management plans were developed based on current fuel designs and analysis methods. Separate EPRI-sponsored analyses for boiling water reactors (BWR) and pressurized water reactors (PWR) were performed[2,3] and are nearing publication in early 2019.

The BWR analysis[2] is based on a high power density BWR-6 reactor operating on a 24-month fuel cycle - the BWR-6s have a higher power density, more power per assembly, and therefore more restrictive design limits than BWR-4s. As such, the BWR-6 results are more conservative when extrapolated to BWR-4s. The fuel management plans produced equilibrium cycle designs using a 624 fuel bundle core, operating at 3299 MWt. Both the reference and high enrichment designs were developed based on models which maximized the economics within the available design margins. The differences in the fuel management results are, therefore, attributable to the higher fuel enrichment and burnup assumptions. The results are summarized in Table 1. Note that the high enrichment cases included in Table 1 use pellet enrichments as high as 5.9 wt% U-235 and achieved peak pellet burnups near the target limit of 80 GWd/MTU. The current fuel design case results in significantly more margin to this target burnup limit than the new fuel case.

PWR fuel management analyses[3] were performed for both high power and low power plants. Both sets are based on 18-month fuel cycles, the prevalent cycle length in the current PWR fleet. The high power design is based on a Westinghouse NSSS 4 loop, 193 fuel assembly core operating at 3469 MWt, based on the Westinghouse Robust Fuel Assembly (RFA) fuel design. The low power design

	Reload Batch Size	Batch Average Enrichment (%)	Peak Enrichment (%)	Batch Average Discharge Burnup (GWd/MTU)	Peak Pellet Burnup (GWd/MTU)	Fuel Utilization (gm-U-235/MW-Day)
Reference Case	256	4.18	4.9	48.19	62.9	0.8674
Higher Enrichment – Current Fuel Design	240	4.39	5.9	51.40	72.6	0.8540
Higher Enrichment – New Fuel Design$_1$	216	4.78	5.9	57.11	79.7	0.8369

$_1$ A new fuel type is required to optimize the fuel performance at higher enrichments

Table 1: Summary of BWR Fuel Management Results

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continues from page 39

is based on a Westinghouse NSSS 3 loop, 157 fuel assembly core operating at 2775 MWt, based on a Westinghouse Optimized Fuel Assembly (OFA) fuel design. The low power and high power cases were used to determine the fuel management efficiency's sensitivity to core power and core size. The efficiency was determined to be proportional to core size. The high enrichment cases are based on pellet enrichments as high as 5.95 wt% U-235. Both the reference and high enrichment designs were developed using a consistent set of aggressive design limits so that the differences in the design results reflect increases in enrichment and burn up, not increases in power peaking or other restrictions. The results show consistent power peaking and boron levels. The economics (Table 7 and 8) are based on the difference in the fuel management results between the reference and high enrichment cases (Table 2 and 3) and do not credit a significant increase in design limits. However, when higher enrichment and burnups are applied to individual sites, more aggressive design limits may be needed to obtain the full benefit of higher burnup and enrichment. Therefore, existing restrictions in the areas of peaking factors, moderator temperature coefficient (MTC), shutdown margin (SDM), crud induced power shift (CIPS) risk, etc. may be challenged and will need to be addressed on a plant-specific basis. Any revised limits will need to be developed within existing safety criteria. The fuel management results are summarized in Tables 2 and 3.

To apply these results to the entire fleet, fuel design data from the EPRI Fuel Reliability Database (FRED)[4] and a recently held EPRI-sponsored fuel management workshop were used to construct a database of site-specific reference fuel designs. The burnup and fuel utilization changes associated with the use of higher enrichments were applied to the reference designs. This produced a set of site-specific high enrichment/burnup fuel designs. This approach supports the analysis of various strategies, such as a moderate burnup increase of 67 GWd/MTU. The actual average burnup increase that is achievable may vary somewhat from this assumption based on the fuel design specific performance in regular operation and postulated accident scenarios. Fuel component requirements (feed, enrichment, conversion and fabrication) were determined for each site. The results for the reload fuel cases described in Tables 1-3 are presented in Figure 1 based on projected fuel component costs in 2030. For all cases, enrichment expenses increased. Most of the savings come from fabrication (e.g., reduced number of fabricated assemblies for new reload batches) with a modest contribution from feed U3O8 stock (e.g., reduced amount of feed uranium for new reload batches). Therefore, these results are not very sensitive to future feed or enrichment market prices.

Consistent with current industry practice, fuel leases and their corresponding carrying cost are not included in the determination of fuel costs. The approach is consistent with fuel cost reported on FERC Form 1, *"Electric Utility Annual Report"* and informal surveys of critical utilities. Currently, only one utility, representing approximately 5% of the fleet, continues to employ fuel leases. However, the use of higher burnup fuel will impact the amortization of fuel costs. Smaller batch

	Reload Batch Size	Batch Average Enrichment (%)	Peak Enrichment (%)	Batch Average Discharge Burnup (GWd/MTU)	Peak Pin Burnup (GWd/MTU)	Fuel Utilization (gm-U-235/MWd)
Reference Case – average of odd and even cycles	76.5	4.6147	4.8	52.15	59.5	0.9002
High Enrichment Case	60	5.6400	5.8	65.36	74.0	0.8629

Table 2: Summary of PWR Fuel Management Results for High Power Plant

ACTOM High Voltage Equipment completes R22-million generation transmission interface contract for ESKOM's Kusile Power Station

ACTOM High Voltage Equipment was awarded a R22-million contract for the generation transmission interface for all six generation units at Eskom's new Kusile power station currently under construction near Emalahleni in Mpumalanga.

The contract, involving the supply and erection of 400 kV transmission lines from each of the six generation units to the nearby transmission substation that will link the new power station to the national electricity grid, was awarded to the division in mid-2015.

The contract also included supplying and erecting galvanised steel cross-beams, which are to be installed between each of the generation units to support the transmission lines strung across to the transmission substation.

The contract follows the award to ACTOM High Voltage Equipment in mid-2012 of the generation transmission interface contract for Medupi, Eskom's other new coal-fired power station, near Lephalale, Limpopo Province.

ACTOM High Voltage Equipment has successfully completed erection of the transmission lines and associated equipment linking Kusile's Generation Units to the transmission substation. "It was completed as scheduled.

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	Reload Batch Size	Batch Average Enrichment (%)	Peak Enrichment (%)	Batch Average Discharge Burnup (GWd/MTU)	Peak Pin Burnup (GWd/MTU)	Fuel Utilization (gm-U-235/MWd)
Reference Case – average of odd and even cycles	62.5	4.8360	4.95	54.97	61.1	0.8797
High Enrichment Case	52	5.6154	5.8	66.07	74.7	0.8499

Table 3: Summary of PWR Fuel Management Results for Low Power Plant

sizes will tend to extend the depreciation while higher batch average power will tend to accelerate amortization. The net impact of these two opposing factors is core design specific. Also, if a site elects to adopt 24-month fuel cycles as part of selecting higher burnup designs, the amortization period is significantly reduced.

The sites are assumed to implement core designs using increased burnup/enrichment limits based on economic value to that site, over 8 years beginning in 2026. The fuel cost benefits continue until the expected retirement date of the plant. The current 60-year operating life and a possible 80-year working life are both evaluated. The economic analyses of the 80-year operating life cases terminate in 2067; however, these additional cycles have only a moderate impact on discounted cash flows and other project figures of merit.

2.2.2 Capital Costs

Capital costs were estimated based on results from previous studies,[6,7] input from fuel service supplier representatives, utility representatives, and engineering judgment. The price for the modified Type 30B UF_6 transportation systems was determined based on the assumption that NRC or international regulators will not approve an extension of the current moderator exclusion licensing basis to higher enrichment. A summary of the estimated capital costs is provided in Table 4. Note that capital costs vary somewhat for different scenarios. Table 4's results are representative of the expected typical costs. For example, utility costs vary depending on the number of sites expected to implement higher enrichment/burnups. The timing of the capital expenditures is based on the expected regulatory approval dates.

2.2.3 Fuel Component Unit Costs

The future fuel component costs (feed, enrichment, conversion and fabrication) are dependent on supply and demand for these components. A long term prediction of these costs was performed based on the

Category	Capital Costs($M)
Enrichment	20.0
UF_6 Transportation	21.3
Fabrication	136.0
Safety Analysis	10.0
Burnup Extension - DOE	7.5
Utility	79.5
Dry Storage	6.0
Total	280.3

Table 4: Summary of U.S. Fleet Required Capital Costs (estimated)

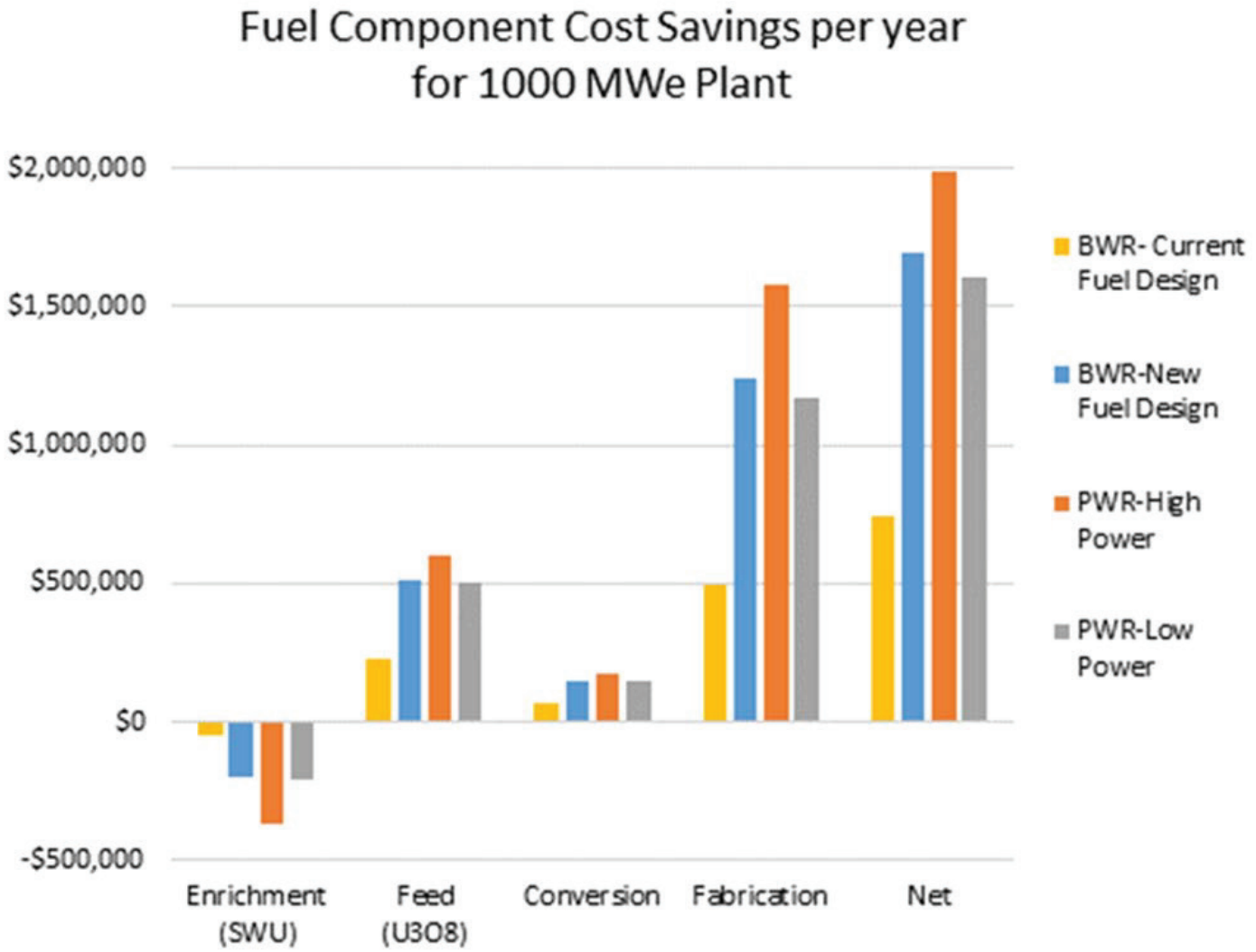

Figure 1: Annual Fuel Component Cost Savings[5]

projected global nuclear generation from several sources. These projections were provided to utility participants in the study and adjustments were made based on their feedback. Only the minimum unit costs were used in this evaluation. As noted previously, the fuel management savings are dominated by fuel fabrication costs. Fabrication costs are somewhat different from other components since they include significant technological and intellectual property barriers to entry (capital investment, design and manufacturing technology, regulatory approval). As such, fabrication prices are expected to increase as a result of investments necessary to manufacture higher enrichment fuel.

2.2.4 Discount Rate

The discount rate is used in capital allocation decisions to determine the current value of both costs and returns on investment, which occurs in the future. The sum of these discounted cash flows provides the Net Present Value (NPV) of a proposed project. Projects which produce returns over the required discount rate are expected to increase the value of the organization(s) sponsoring the project. The discount rate is also referred to as the hurdle rate. The appropriate discount rate is determined based on the weighted average cost capital (WACC). As shown in Table 5, the WACC is defined for three large nuclear utilities based on publicly available information. Utilities operating

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	WACC
Utility A	4.92%
Utility B	6.21%
Utility C	4.86%
Average	5.33%
Nuclear Risk Premium	2.60%
Project Specific Premium	2.00%
Total Discount Rate	9.93%

Table 5: Estimated WACC for Representative Utilities

in regulated and deregulated markets were selected. The resulting WACC reflects the required return for a typical capital project of nominal risk. Since a nuclear-related project generally involves higher risks, additional factors are needed to account for this additional risk. A nuclear risk premium was determined based on the accumulated interest payments for a large nuclear construction project. The regulatory and technical challenges necessary to modify the enrichment and burnup limits have a higher uncertainty than a construction project which is based on a sophisticated design. As such, an additional 2.0% risk premium was determined to be appropriate. This results in a 9.93% (rounded to 10%) discount rate for this project.

2.2.5 Escalation

All future cash flows were escalated to account for the expected impact of inflation. The escalation factors were determined based on published Department of Labour economic indices. These include indices for general and production employee compensation and the producer price index for industrial commodities. Applying different weighting functions result in escalation rates ranging from 1.92% to 2.62%, depending on the specific fuel cycle activity.

2.2.6 Economic Evaluation

Seven different scenarios were evaluated for both 60- and 80-year operating life assumptions. The scenarios are listed in Tables 7 and 8. These scenarios include individual BWR and PWR design results as well as various combinations of both designs. The PWR results consider two different burnups increase assumptions, a *"Moderate Burnup"* of 67 GWd/MTU and a *"High Burnup"* of 75 GWd/MTU. The *"Moderate Burnup"* case is estimated to correspond to a level that would be achieved if the LOCA no rod burst criteria are applied, as discussed previously in Section 2.1.1. The BWR results only consider one burnup increase scenario (*"High Burnup"*) since the BWR designs restrict the linear power density for high exposure fuel assemblies, so they are expected to demonstrate better FFRD performance. The BWR results include current designs and a future *"next-generation"* design, which is optimized for higher enrichment.

All of these scenarios assume that the initial reload begin operation in 2026 and the changes to the fuel cycle infrastructure occur in parallel to the testing and development of the increased burnup designs. An additional scenario was also evaluated, which delayed the most significant capital investments until after the high burnup design's testing and development (2025) were complete. This scenario reduces the risk associated with parallel activities but delays the initial reload date to 2029.

Fuel cost savings, capital costs, and dry cask savings were determined for each scenario. Escalation was applied to each area, and the results were used to determine the NPV based on the project-specific discount rate. Also, the internal rate of return and the average annual savings per reactor were determined. These results reflect the industry-wide performance that is available to compensate the stakeholders (e.g., fuel suppliers, DOE, utilities) of the project. The distribution among these groups is subject to commercial discussions that are beyond the scope of this study. However, to provide some perspective, estimates were made based on the following assumptions: -

1. All capital costs were recovered with a rate of return equal to the project-specific discount rate;
2. No dry cask cost saving flowed to utilities;
3. The fuel fabricator loss of revenue could result in significant fixed costs that are unrecovered. To account for this impact,

	Perturbation (%)	Resulting Impact of Perturbation on Estimated Annual Savings per Reactor Available to Utilities ($M)$_1$
Uranium Feed and Enrichment Price	15	0.02
Fabrication Price	10	0.14
Vendor Capital Cost	25	0.07
Utility Capital Cost	33	0.01
Total		0.16

Table 6: Uncertainty in Economic Evaluation

a portion of the fabrication savings was accrued to the fabricators and the balance to the utilities;

4. DOE provided no significant financial support; and
5. All feed savings and increases in enrichment cost are accrued to utilities.

The impact of these assumptions are illustrated in Tables 7 and 8. A discussion of these results is provided in the results section.

To estimate the uncertainty of these results, perturbations in crucial input variables were performed. The input perturbations and the corresponding impact on the estimated annual savings per reactor, available to utilities, are summarized in Table 6. The singular perturbations were combined as independent variables to provide an estimate of the overall uncertainty. Table 6's results correspond to 13% of Table 7's results for this parameter.

The impact of varying the number of participating plants was also evaluated. This evaluation determined the number of competing plants needed to recover the capital investment, including the minimum required rate of return. This evaluation assumed only PWR units participate in higher burnup/enrichment projects. Only plants which operate in a challenging economic environment with a high expected return were considered to participate. If fourteen (~25% of PWR fleet) of these high power units implement higher burnup/enrichment, then the minimum required rate of return is earned for the industry. The average annual saving for these fourteen units is $0.9M/reactor.

2.3 RESULTS

2.3.1 Economic Results

A summary of the economic analysis results is included in Tables 7 and 8 below. Table 7 contains results assuming all sites operate to the end of their 60-year license life. This excludes sites that have already publicly announced early shutdown dates. Table 8 includes results for all sites assuming an additional 20-year license extension is obtained to reach 80 years of operation. Each of the evaluated scenarios results in a net present value that exceeds the discount rate (negative NPV). Additionally, the resulting internal rate of return is provided to demonstrate the expected return on capital investment. This also exceeds the discount rate developed above (10%).

However, note that there is significant variation in these quantities as well as the expected average annual savings for each reactor core. For PWR units the maximum return is typically 25% higher than the average while for BWR the maximum is 10% higher. The expected average annual savings are strongly dependent on the discharge burnup assumed in the analysis. Results vary between approximately $3.83M/reactor and $1.93M/reactor for peak pin burnup limits of 75 GWd/MTU and 67 GWd/MTU, respectively [Table 7, Column 7]. Since this difference represents a significant uncertainty in the results, additional cases were evaluated, which show the impact of changing the timing of licensing the revised burnup limits. These alternative scenarios largely mitigate the risk of licensing the higher burnup limit with only a minor effect on the value of implementing higher enrichment limits.

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The results from delaying the capital investment until high burnup is proven to show slight increases in the average annual savings available to utilities. This is due to the elimination of initial, lower cost reloads, so the average value increases slightly. The net present value and internal rate of return are reduced since the number of reloads is reduced in this case.

The development of ATF design concepts has the potential to extend the value of increased enrichment and fuel burnup levels by optimizing fuel design thermal limits, improving corrosion-resistance of the fuel cladding and improving the fuel reliability over current designs. The specific performance of the various ATF designs has not been entirely determined at this time, and therefore, no quantifiable benefit regarding burnup and enrichment has been established.

2.3.2 High-Level Waste

In addition to the direct economic value provided to utilities, an increase in fuel enrichment and burnup will reduce the volume of high-level radiological waste generated and subject to long term storage and disposal. While the quantities vary between scenarios, reductions are projected for all the evaluated scenarios. For example, the 60-year operating life, moderate burnup PWR only scenario (*"PWR Moderate Burnup"* in Tables 7 and 8) is expected to reduce the dry cask storage requirements by approximately 200 dry casks while the high burnup PWR + New BWR fuel design is expected to reduce the number of dry casks by almost 500.

2.3.3 Impact on Cycle Length

While virtually all U.S. BWR reactors operate on a 24-month fuel cycle, only about 20% of the PWR plants can work economically on a 24-month fuel cycle with the current burnup and enrichment limits. With a modest increase in the burnup limit to 67 GWd/MTU, approximately 68% of the PWR fleet could operate on a 24-month cycle, and all PWR plants could do so if the limit were raised to 75 GWd/MTU along with an increase in enrichment. The capability to achieve 24-month cycles is based on each site's expected to reload batch fraction determined from the revised burnup limits. Sites with a batch fraction above 50% are not considered economically viable candidates for 24-month cycle operation. The decision to extend cycle lengths depends on the net economic value of the increase in fuel cost, reduction in replacement power cost and reduction in the number of outages over the remaining life of the plant. Some capital cost must also be considered to extend surveillance intervals and instrument drift calculations. While some plants might not elect to change their cycle length, multi-unit sites and fleets with single unit sites that share vital outage resources would realize additional operational benefits if they choose to transition to longer cycles.

As with previous industry increases in fuel enrichment and burn up, the plants would more efficiently use the available fuel. This results in a modest reduction in the demand for uranium ore and a corresponding decrease in uranium mining. While not quantified, some environmental benefits will be realized from this change in the fuel cycle.

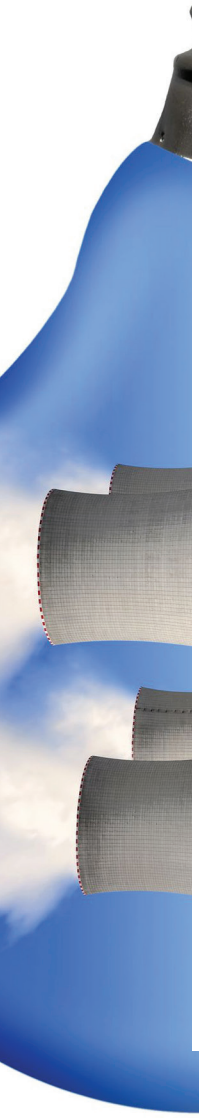
2.3.4 Summary of Results

As described above, the risk-adjusted discount rate was determined to address the unique features of a complex nuclear project. Each of the identified scenarios provides a return that exceeds the required discount rate, indicating the project will exceed the necessary standard of performance. However, this economic assessment is based solely on this specific project and does not evaluate its merits relative to other available options. Additionally, this project does require a commitment from many stakeholders and significant changes to fuel- related regulatory requirements. However, most PWRs would benefit from these changes, and higher power BWR units would also realize tangible benefits.

3 REGULATORY REVIEW

The degree to which existing regulations and guidance will need revision, or new regulatory requirements will have to be established, and new direction developed, depends on the level of departure from existing fuel designs. The figure below illustrates the current and potential future enrichment and burnup design limits.

The regulations in Appendix A, *"General Design Criteria for Nuclear Power Plants,"* to U.S. Title 10 of the Code of Federal Regulations (CFR) Part 50, *"Domestic Licensing of Production and Utilization Facilities,"* provide superior design and performance requirements. Rulemaking and other regulatory guidance changes will be needed to support the expansion of the existing regulatory framework. The safety performance protected by the general design criteria (GDC) related to fuel design and overall fuel performance under normal and accident conditions as required per 10 CFR 50.46 will be maintained. In addition to the regulatory guidance related to the GDC, the utilization of fuel designs with higher burnup and higher enrichment



60 Year Operating Life Cases	Fuel Cost Savings ($M)	Dry Cask Savings ($M)	Total Capital Expense ($M)	Interest Expense ($M)	Net Savings$_1$ ($M)	Average Annual Net Savings per Reactor$_1$ ($M)	Estimated Annual Savings per Reactor Available to Utilities$_2$ ($M)	Net Present Value ($M)	Internal Rate of Return (%)	Reactor-Years Using Higher Enrichment
New BWR Fuel Design	643	244	143	44	700	2.89	1.13	31.78	13.0%	242
PWR High Burnup + New BWR Fuel Design	2480	1034	321	93	3099	3.66	1.46	251	19.2%	846
PWR High Burnup + Existing BWR Design	2069	871	291	84	2565	3.19	1.23	195	18.2%	804
PWR High Burnup	1837	790	240	70	2316	3.83	1.45	179	18.7%	604
PWR Moderate Burnup	847	409	212	67	977	1.93	0.45	11	10.7%	507
PWR Moderate Burnup with transition to High Burnup	1647	712	240	70	2048	3.39	1.24	119	15.6%	604
PWR + BWR Delay Capital Investment Until High Burnup proven	2120	867	311	106	2571	3.62	1.38	160	17.6%	711

1 Fuel + Dry Cask - Capital - Interest
2 Fuel - Capital - Interest - Estimated Fabrication Cost Impact

Table 7: Summary of Results for the U.S. Fleet Based on an Assumed 60-Year Operating Life

80 Year Operating Life Cases$_3$	Fuel Cost Savings ($M)	Dry Cask Savings ($M)	Total Capital Expense ($M)	Interest Expense ($M)	Net Savings$_1$ ($M)	Average Annual Net Savings per Reactor$_1$ ($M)	Estimated Annual Savings per Reactor Available to Utilities$_2$ ($M)	Net Present Value ($M)	Internal Rate of Return (%)	Reactor-Years Using Higher Enrichment
New BWR Fuel Design	1734	966	157	47	2496	2.96	1.24	130	17.3%	844
PWR High Burnup + New BWR Fuel Design	9433	3540	342	98	12533	4.83	2.28	577	22.1%	2594
PWR High Burnup + Existing BWR Design	7882	2951	305	87	10441	4.05	1.89	461	21.2%	2578
PWR High Burnup	6687	2574	252	71	8938	5.11	2.31	384	21.2%	1750
PWR Moderate Burnup	2736	1365	230	70	3802	3.44	1.22	99	13.9%	1105
PWR Moderate Burnup with transition to High Burnup	7374	2824	254	71	9871	5.99	2.71	334	18.7%	1648
PWR + BWR Delay Capital Investment Until High Burnup proven	11890	3356	245	127	14875	6.29	3.60	650	24.3%	2366

1 Fuel + Dry Cask - Capital - Interest
2 Fuel - Capital - Interest - Estimated Fabrication Cost Impact

Table 8: Summary of Results for U.S. Fleet Based on an Assumed 80-Year Operating Life

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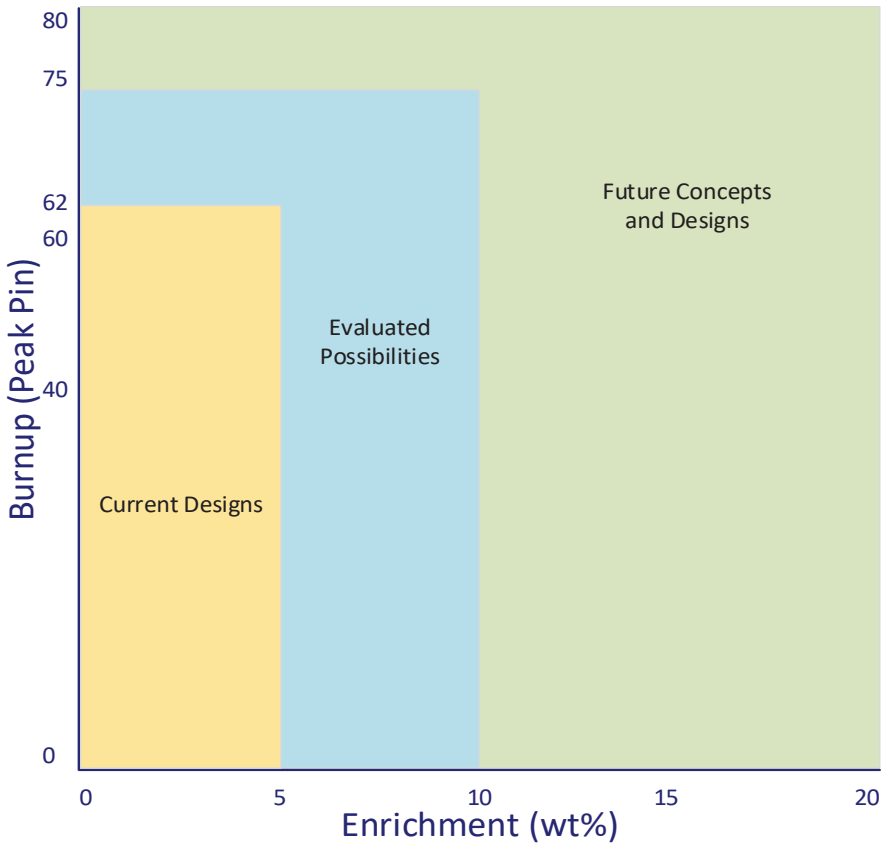

Figure 2: Comparison of Design Ranges

combinations may also affect regulations associated with nuclear fuel transportation, material control and accounting, and physical protection.

One of the purposes of this white paper is to highlight the regulatory issues that need to be addressed to allow the manufacture and use of current UO_2 fuel types with higher burnup and higher enrichment combinations. This review discusses enrichments up to 10 wt% U-235. Individual licensees may elect to license their facilities at somewhat lower levels. The following sections provide an initial review of the associated regulations and design criteria about each stage of the fuel cycle.

3.1 FUEL ENRICHMENT FACILITIES

U.S. fuel enrichment facilities are licensed under 10 CFR 70, *"Domestic Licensing of Special Nuclear Material."* A review of the applicable regulations, particularly all of 10 CFR 70, shows that there is no specific restriction on the level of enrichment of Special Nuclear Material (SNM) that a fuel enrichment facility is allowed to possess onsite. Precisely, a review of 10 CFR 70.24, *"Criticality Accident Requirements,"* does not include a limit on enrichment as is found in the corresponding regulation for nuclear power plants, i.e., 10 CFR 50.68, *"Criticality Accident Requirements."* The NRC has already issued a license to Centrus for a fuel enrichment facility, the American Centrifuge Plant, which permits enrichment up to 10%; however, this facility has not been constructed. The NRC has also issued a license to General Electric-Hitachi Global Laser Enrichment for a fuel enrichment facility, which permits enrichment up to 8%.

It is expected that currently licensed fuel enrichment facilities will request license amendments to modify existing facilities to accommodate enrichments higher than 5.0 wt% U-235. The only presently operating U.S. fuel enrichment facility has an operating license that allows it to enrich up to 5.5 wt% U- 235. For this facility to increase enrichment up to 10 wt%, the licensee would be required to apply to the NRC for an amendment to its license.

As part of this amendment process, the licensee, at a minimum, would need to revise its Nuclear Criticality Safety (NCS) and Integrated Safety Analysis (ISA) calculations and evaluations to reflect the effects of higher-enriched uranium in the facility and demonstrate compliance with NRC requirements. The licensee would also need to assess whether increasing the enrichment from the licensed limit of 5.5 wt% up to 10 wt% U-235 would necessitate a change to the conclusions in the NRC's Environmental Impact Statement issued as part of the licensing of the facility. As a result of these analyses, some modification of the facility may be necessary. According to statements from senior company officials, all this can be accomplished.

Getting approval to modify an existing license to enrich uranium up to 10 wt% U-235 is expected to take 12-18 months and require an environmental review.

This review concludes that there are no regulation or rulemaking changes, including criticality protection rules, needed to allow U.S. fuel enrichment facilities to enrich fuel up to 10 wt% U-235. Licensing U.S. fuel enrichment facilities for increased enrichments from 10 wt% U-235 would not require revisions or changes to the existing regulations. Although, NRC may still find a need to issue appropriate guidance for its staff review of licensee or applicant submittals.

3.2 FUEL FABRICATION FACILITIES

Fuel fabrication facilities are licensed under 10 CFR 70, *"Domestic Licensing of Special Nuclear Material."* A review of the applicable regulations, particularly all of 10 CFR 70, shows that there is no specific restriction on the level of enrichment of unique nuclear material that a fuel fabrication facility is allowed to possess on site. Precisely, a review of 10 CFR 70.24, *"Criticality Accident Requirements,"* does not include a limit on enrichment as is found in the corresponding regulation for nuclear power plants, i.e. 10 CFR 50.68, "*Criticality Accident Requirements.*"

The currently operating fuel fabrication facilities have operating licenses that allows them to produce fuel with enrichment of up to 5 wt% U-235. To fabricate fuel enriched up to 10 wt% U-235, the licensee would have to apply to the NRC for an amendment to its license. As part of this amendment process, the licensee, at a minimum, would need to revise its Nuclear Criticality Safety (NCS) and Integrated Safety Analysis (ISA) calculations and evaluations to reflect the effects of higher-enriched uranium in the facility. The licensee would also need to assess whether increasing the enrichment of 5 wt% up to 10 wt% U-235 would necessitate a change to the conclusions in the NRC's Environmental Impact Statement issued as part of the licensing of the facility. As a result of these analyses, some modification of the facility may be necessary. According to representatives of these facilities, the actions required to obtain an amendment from the NRC are achievable. Note, these facilities have relatively small throughput and may not be able to support the fleet-wide implementation of high enrichment without facility modifications.

Additionally, there are two U.S. facilities licensed to fabricate profoundly enriched fuel from existing HEU inventories, primarily for national defence use. The Nuclear Fuel Services facility (Erwin, TN) and BWXT Nuclear Operations Group plant (Lynchburg, VA) currently produced fuel for reactors requiring greater than 5.0 wt% U-235 (e.g., test, medical isotope and research reactors). These facilities provide fuel containing both high and low-enriched uranium, for use in the U.S. Naval Reactors program. They also blend down HEU to lower enrichment, which can be used for applications such as non-power reactors, as well as for LEU for use in existing LWRs. With their Category I fuel facility licenses; these facilities could produce fuel for High-Assay Low-Enriched Uranium HALEU reactors. Depending on the fuel manufacturing planned, these two sites might need only minor license amendments or none at all, to manufacture HALEU fuel.[8]

This review concludes that there are no regulation or rulemaking changes, including criticality rules, required to allow fuel fabrication facilities to make fuel with enrichments up to 10 wt% U-235. Licensing facilities for reactor fuel fabrication operations with enrichments up to 10 wt% U-235 would not require revisions or changes to the existing regulations. That being said, NRC might find a need to issue appropriate guidance for its staff review of licensee or applicant submittals.

3.3 FUEL TRANSPORTATION

The principal assurance of safety in the transport of nuclear materials is the packaging, which must mitigate against foreseeable accidents. Standard packaging of uranium hexafluoride (UF_6) consists of an inner steel cylinder that acts as a containment vessel, and an outer protective overpack. The overpack provides thermal protection to prevent overheating of the UF_6, which can cause the hydraulic failure of the cylinder. The overpack also protects the cylinder from impacts. Unenriched UF_6 may be transported in bare cylinders, without the protective overpack, as authorized in Department of Transport DOT regulations. Protective overpacks are typically required only for the transport of enriched (fissile) UF_6. Design and performance standards for fissile UF_6 packages are stated in 10 CFR 71, and design and performance standards for non-fissile UF_6 packages appear in DOT regulations. ANSI N14.1 and USEC-651 contain information regarding overpacks. Choice of specific design features (e.g. overpacks) to meet regulatory standards is left to designers.

Uranium hexafluoride feed can continue to be transported from the conversion facility to the enrichment facility using currently approved cylinders; however, transporting uranium hexafluoride enriched above 5.0 wt% from the enrichment facility to the

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fuel fabrication facility presents a regulatory challenge. There is no U.S. DOT-approved, commercially viable cylinder (i.e., 30-inch and greater inner diameter) or overpack for material that is enriched to greater than 5.0 wt% U-235. Currently, shipments of uranium hexafluoride are made in 30B cylinders and UX-30 overpacks that are certified for material up to 5.0 wt% enrichment according to Tables 2 and 3 of 49 CFR 173.417.

Cylinders designed to hold uranium hexafluoride are qualified under DOT regulations; see 49 CFR 173.420 uranium hexafluoride (fissile, fissile excepted and non-fissile). This regulation applies to the packaging and shipment of any quantities greater than 0.1 kg of fissile, fissile excluded, or non-fissile uranium hexafluoride. It also includes requirements on the design, fabrication, inspection, and the testing and marking of the packages as well as the applicable Codes and Standards for manufacturing the cylinder under ANSI N14.1. ANSI N14.1 specifies the design and fabrication of the UF6 cylinder. ANSI N14.1 - Table 1, *"Standard UF_6 Cylinder Data,"* provides details for the various UF_6 cylinder models and indicates the maximum enrichment allowed for each model. Additionally, NUREG-1609, Standard Review Plan for Transportation Packages for Radioactive Materials, discusses that for the 30-inch cylinder, the UF6 enhancement must not exceed 5.0 wt% U-235, along with NUREG 1617, *"Standard Review Plan for Transportation Packages for Spent Nuclear Fuel,"* that states the initial enrichment shall not exceed 5.0 wt% U-235 for the licensing basis limit.

In addition to the DOT rules, containers must also meet the NRC requirements in 10 CFR Part 71. Specifically, 10 CFR 71.55(g)(4) states that packages containing uranium hexafluoride only are excepted from the requirements of paragraph (b) of the section provided that the uranium is enriched to not more than 5 wt% uranium-235. These provisions provide the necessary regulatory requirements to preclude an inadvertent criticality in the package. For enrichments above 5 wt% U-235, the exception provided in 10 CFR 71.55(g) for uranium hexafluoride packages will no longer apply. Provisions are available to request approval of alternative package designs that could be used for the shipment of uranium hexafluoride with uranium enrichment higher than 5 wt% under §71.55(b) or §71.55(c). Merits of a new or modified design that included special design features would be reviewed and approved under the provisions of §71.55, including §71.55(c).

Therefore, if the industry moves to enrichments higher than 5 wt% U-235, fuel shippers would need to get approval for new packages that would meet the usual fissile material package standards in §71.55(b), or could include unique design features that would enhance nuclear criticality safety for transport for approval under the provisions of §71.55(c).

Daher-TLI has developed a replacement for the current 30B system, the DN-30. The DN-30 has been under development for the last 10 years. The EU regulatory authority (France) completed their review and issued an approval for the DN-30 in December 2018. The initial license allows fuel enriched to 5.0 wt% U-235. Daher-TLI has also had two pre-submittal meetings with the U.S. NRC and submitted the design for approval in August 2018 with expected support in mid-2019.

The company has also developed a modified version of the DN-30 capable of carrying fuel enrichments up to 20 wt% U-235. This design uses the same DN30 overpack with a modified UF6 cylinder. The DN-30-20 cylinder contains stainless steel tubes that will incorporate neutron absorbers to support the enrichment of 10 wt% U-235 or 20 wt% U-235. This configuration has a total capacity of 1600 kg, somewhat less than the current 30B (2267 kg). The arrangement has been analysed without credit for moderator exclusion, consistent with ANSI.N14.1.2001 and ISO 7195. Extending the license to this higher enrichment is not expected to require additional accident testing. The licensing would require a revised criticality safety analysis. A completed preliminary design demonstrated acceptable performance over a range of moderator configurations, including the presence of proper impurity levels (*"heels"*). Establishing the final configuration(s), and submitting and obtaining regulatory approval is expected to take 12-24 months. This design provides a viable option for addressing the transportation of UF_6, enriched over 5.0 wt% U-235, in a timeframe consistent with an initial reload in 2026.

Packaging designed to hold new fuel assemblies is approved under DOT and NRC regulations; see 49 CFR 173.417, *"Authorized Fissile Materials Packages"* and 10 CFR 71 *"Packaging and Transportation of Radioactive Material."* This packaging is designed to transport fissile material that does not meet the fissile material exemption standards in 10 CFR 71.55 and has total radioactivity less than an A1 or A2 quantity according to 49 CFR 173.435 (e.g. fresh, unirradiated nuclear reactor fuel). For new fuel assemblies, standard

packaging consists of a metal outer shell, closed with bolts and a weather-tight gasket. An internal steel strongback, shock-mounted to the outer shell, supports one or two fuel assemblies fixed in position on the strongback by clamps, separator blocks, and end support plates. Depending upon the type of fuel, neutron poisons are sometimes used to reduce reactivity. If the package is used to transport individual fuel rods, a separate inner container is often employed. The contents of the package are unirradiated uranium in fuel assemblies or individual fuel rods. Because the majority of these packages are for commercial reactor fuel, the uranium is typically in the form of Zircaloy-clad uranium dioxide pellets. The principal function of the package is to provide criticality control. The metal outer shell of the packaging retains the assemblies within a fixed geometry relative to other such containers in an array and provides impact and thermal protection. Shielding requirements are not significant because of the low radioactivity of unirradiated fuel.

This review concludes that the licensing basis of current UF6 package designs restricts enrichment to less than 5.0 wt% U-235. Also, new fuel shipping packages are currently designed to accept fuel enriched up to 5.0 wt% U-235. Container design modification and re-licensing would be required to ship uranium hexafluoride and fresh fuel over 5.0 wt% U-235.

3.4 CRITICALITY ISSUES

A significant factor in the licensing of any enrichment or fabrication facility is criticality. As licensees look for ways to optimize facilities and storage/transport packages, computer software methods and data used in establishing the criticality safety of systems with fissile material become more important.[9] For enrichments up to 11 wt% U-235, criticality benchmark data is described in NMSS-0007, an NRC guidance document. NMSS-0007 identified the need to develop and confirm the adequacy of methods, analytical tools, and guidance for criticality safety software to be used in licensing nuclear facilities.

"Computer codes used for criticality calculations must be benchmarked against critical experiments that represent the specific fissile materials, configurations, moderation, and neutron-poisoning conditions that represent the facility being licensed. However, it is well recognized that existing critical benchmark experiments will never precisely match these conditions. Besides, there are fewer benchmark experiments that are available at higher enrichment ranges [e.g. between 5 to 20 per cent and lower-moderation (i.e., H/X, where H is hydrogen and X is fissile media)] ranges, that could be of future interest to potential applicants. Methods are needed to extend the range of applicability of current benchmark experiments via sensitivity/ uncertainty (S/U) analysis techniques."

NMSS-0007 goes on to state that:
"NMSS has performed extensive work with Oak Ridge National Laboratory (ORNL) to develop criticality safety computer codes further [e.g. Standardized Computer Analyses for Licensing Evaluation (SCALE)] to address these challenges. The final reports for the S/U methods were published in November 1999 as Volumes 1 and 2 of NUREG/CR-6655. The reports cover the following subjects: (1) methodology for defining range of applicability including extensions of enrichments from 5 to 11 percent; (2) test applications and results of the method; (3) test application for higher enrichments using foreign experiments; (4) feasibility study for extending the method to multidimensional analyses, such as transport casks and reactor fuel."

NMSS-0007 concludes that the results of the test applications of the ORNL methods show: ".... for simple geometries with neutron spectra that are well moderated (high H/X), benchmark experiments at 5 per cent enrichment apply to calculations up to 11 per cent enrichment."

For enrichments above 11 wt% U-235, the Oak Ridge National Laboratory (ORNL) *"method provides sensitivity and uncertainty information, to help designers allow adequately large margins to cover the lack of benchmark validation."* Guidance to the NRC staff is provided in Fuel Cycle Safety and Safeguards-Interim Staff Guidance-10, Revision 0[10], which clarifies the minimum margin of sub-criticality for safety required for a license application or an amendment request under 10 CFR Part 70, Subpart H.

Criticality accident requirements for the spent fuel pool of a nuclear power plant are found in 10 CFR 50.68 or 10 CFR 70.24. These regulations specify requirements for licensees to maintain either a criticality monitoring system (10 CFR 70.24) or design margin to criticality accidents (10 CFR 50.68). 10 CFR 50.68 includes acceptance criteria which ensure that adequate safety margins are maintained and requires the maximum enrichment of fresh fuel to be limited to 5 wt% U-235. This additional limitation does not protect the criticality safety margins since many other independent parameters impact safety margins. These include, among others, the presence of integral neutron poisons in the fuel assembly, poison

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inserts in the storage rack and fuel storage configurations. The specific combinations of parameters which do protect criticality safety margins are described in each facility's licensing bases. With the potential need to increase enrichment levels for both existing commercial LWR reactors and advanced reactors, the appropriate action is to remove specific enrichment limits from 10 CFR 50.68. Retention of the necessary enrichment limits in the facility licensing bases, including Technical Specifications, provides adequate protection for criticality safety margins. Also, the use of exemption requests as a parallel path contingency to support the timeline for 10 CFR 50.68 rulemaking is an option.

In addition to the regulations and guidance documents described above, several guidance documents were identified wherein the use of enrichments up to 10% or the burnup assumptions would need to be addressed.

Section 7.5.2 of NUREG-1536[11] states, in part, *"Although the burnup of the fuel affects its reactivity, many criticality analyses have assumed the cask to be loaded with fresh fuel (the fresh fuel assumption). Alternatively, the NRC staff has provided guidance for limited burnup credit for intact fuel. This guidance is currently limited to burnup credit available from actinide compositions associated with UO_2 fuel of 5.0 wt% or less enrichment that has been irradiated in a PWR to an assembly-average burnup value not exceeding 50 GWd/MTU [increased to 60 GWd/MTU in draft NUREG-2215] and cooled out-of-reactor for a time period between 1 and 40 years."*

For criticality at the reactor sites, there is an opportunity to improve the analyses by relaxing much excessive conservatism. Based upon a review of the NRC sources and discussions with several subject matter experts, it is clear that numerous excessive conservatisms have crept into these criticality analyses which do not exist in other areas of design, analysis, and operation. This could potentially allow higher enrichments above 5.0 wt% U-235 to be utilized without a significant redesign of structures, systems, or components. These conservatisms could include, for example, additional credit for fission product poisons or credit for BWR burnup beyond peak reactivity. Additionally, the design of cores using higher enriched fuel would also require increased concentrations of neutron poisons to meet core limits, and fuel will achieve higher burnup, which also reduces reactivity. The additional poison concentrations and higher burnup are expected to offset the reactivity effects of higher enrichment. As is the current case, some assemblies will not meet the enrichment burnup requirements, so storage in profoundly poisoned racks or a checkerboard or other configurations will be required.

3.5 SAFETY ANALYSIS (HIGH BURNUP & HIGH ENRICHMENT)

This topic considers both an increase in pellet enrichment and an increase in fuel rod average burnup beyond currently approved limits. Many utilities need a combination of increased fuel burnup and increased enhancement to achieve their economic goals. The discussion below focuses on the issues identified during the regulatory review that would need to be addressed to support an enrichment increase up to 10 wt% U-235 and incremental growth in burnup to 75 GWd/MTU range.

Proposed rulemaking for 10 CFR 50.46c would limit fuel rod burnups due to NRC concerns with fuel fragmentation after cladding rupture. It is assumed that the fuel fragmentation question will be addressed by a licensee seeking higher fuel rod burnups even if rulemaking does not proceed. There are efforts currently underway to address this concern. EPRI is conducting research that is expected to result in a linear heat rate limit versus burnup to preclude fuel fragmentation. Additionally, fuel vendors are looking at how calculations can demonstrate that high burnup rods do not rupture following a LOCA. Reactivity insertion accidents will also need to be evaluated. It is expected that most sites will not exceed PCMI or temperature limits, so fuel fragmentation is not likely to be an issue. EPRI is also evaluating the industry needs in this area.

Utilities (except for those non-GDC plants who cite requirements specific to their licensing basis) and vendors typically use NUREG-0800[12] to demonstrate how they meet General Design Criteria 10. The software and methods used to illustrate the NRC approves compliance. For PWRs, the NRC limits the applicability of codes and techniques to no more than 62 GWd/MTU. Resolution of the fuel fragmentation issue is needed to permit higher burnups. There may also be an implied limitation of 5.0 wt% U-235 enrichment for codes and methods, if not specific limitations and conditions, which would require them to be relicensed for higher enhancement. Any necessary changes to the current fuel performance codes and methods should be able to support a modest burnup increase in the 67 - 68 GWd/MTU range with low regulatory risk. Burnups beyond 68 GWd/MTU may require additional fuel

performance data to validate the software models. At the EPRI sponsored workshop on Burnup and Enrichment in December 2018, the NRC was generally supportive of moderate burnup increases and open to a phased approach to higher burnup increases afterwards.

There are several Regulatory Guides (Reg Guide) that contain fission product data for dose analysis calculations. For example, Reg Guide 1.183 and Reg Guide 1.195 both state that the release fractions listed in the guides have been determined to be acceptable for use with currently approved LWR fuel with a peak rod burnup up to 62 GWd/MTU provided that the maximum linear heat generation rate does not exceed 6.3 kW/ft peak rod average power for burnups exceeding 54 GWd/MTU. Current regulations limit the use of these release fractions to enrichments below 5 wt% U-235. These regulatory guides will need to be revised to extend their applicability to support higher burnups and enrichments for implementation of higher lead rod burnup limits.

Addendum 1 to Volume 1 of NUREG–1437, *"Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants,"* (NRC 1999), states that the environmental impacts would be small for transporting spent fuel enriched with up to 5.0 wt% U-235 with an average burnup for the peak rod of up to 62 GWd/MTU. It also states that, if peak fuel burnup is projected to exceed 62 GWd/MTU and fuel is enriched to higher levels, license renewal applicants must submit an assessment of the implications for the environmental impact values reported in 10 CFR 51.52. Utilities would need to consider whether any licensing actions are needed for current operating licenses or renewed licenses for environmental impact statements for higher burnups and enrichment.

As discussed in 10 CFR 50.61 (Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events), calculations for vessel fluence include assumptions for core loading patterns. Vessel fluence only considers neutrons over 1 MeV, but it is not clear how the energy spectrum will shift due to the combination of higher burnup, increased enrichment, and more/different burnable absorbers. From a programmatic standpoint, even if the end of life fluence is increased only slightly, the plant's current pressure-temperature curves (which reside in either the plant's Technical Specifications or the Pressure Temperature Limits Report for ITS plants) will need to be re-analysed to determine if the valid Effective Full Power Year limit has decreased. This is primarily a concern for plants considering next license renewal (SLR).

In the Standard Technical Specifications (4.2.1, Fuel Assemblies), allowable fuel pellets are those with an initial composition of natural or slightly enriched uranium dioxide. Therefore, no changes to this Standard Technical Specification would be needed.

In conclusion, there are several areas, such as fission product inventories for dose analyses and the licensing of fuel performance codes, which will need to be addressed as change management items. While there are efforts currently underway to address fuel fragmentation, resolution of the NRC's fuel fragmentation concern is critical to moving forward with increased fuel rod burnups.

3.6 MATERIAL CONTROL AND ACCOUNTING (MC&A)

An MC&A program is the way a facility operator conducts a sustainable, sufficient graded safeguards program for the control and accounting of nuclear materials, to detect and deter theft and diversion of SNM. The MC&A program implements a defence-in-depth approach to ensure that all accountable atomic materials are in their authorized location and being used for their intended purposes, such that single component failures will not result in significant vulnerabilities. The goal of MC&A is to (1) maintain current knowledge of the location of SNM and resolve any discrepancies and (2) prevent undetected access resulting in unauthorized changes to quantities of SNM at a site that might ultimately result in the diversion of SNM. MC&A also complements international treaty obligations by accounting for SNM at facilities and reporting the quantity of SNM at those facilities, as appropriate, to the International Atomic Energy Agency (IAEA). As provided by 10 CFR Part 70.22(b), the rule applies to each applicant for a license to possess: -

- unique nuclear material;
- equipment capable of enriching uranium;
- to operate a uranium-enrichment facility; and
- to use at any one time and location unique nuclear material in quantity exceeding one effective kilogram (with exceptions for specific end users licensed under other regulations).

The entity seeking a license must provide an application which contains a full description of the applicant's program for control and accounting of such unique nuclear material or enrichment equipment

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that will be in the applicant's possession under license to show how compliance with the requirements of the applicable 10 CFR 74 requirements are accomplished.

NRC provides clear guidance on compliance with 10 CFR 74 (Material Control and Accounting of Special Nuclear Material) in the form of two documents prepared by the NRC, NUREG-1065 and NUREG-1280 for facilities involved with Category III and Category I SNM quantities defined in 10 CFR 70.4, respectively. These documents guide establishing a Fundamental Nuclear Control Plan (FNMCP) that describes how the requirements of 10 CFR 74.31 section (c) System Capabilities (1) through (8) are met. MC&A nuclear measurement non-destructive assay (NDA) is described in chapter 3 of NUREG-1065 and chapter 4 of NUREG-1280. NDA based on interrogation of U-238 (or total U) is not directly affected by enrichment changes of the type being contemplated. However, NDA systems based on an investigation of U-235 will be directly affected by an enrichment change, and therefore, those systems may need to be requalified.

In accordance with 10 CFR 74.31(b), each applicant for a license, and each licensee that, upon application for modification of its license, would become newly subject to the performance objectives of 10 CFR 74.31(a) of that section, shall submit an FNMC plan describing how the requirements of paragraph (c) of that section will be met. The FNMC plan shall be implemented when a license is issued or modified to authorize the activities being addressed in paragraph (a) of this section, or by the date specified in a license condition.

In conclusion, the regulations and associated guidance do not have assay-specific limits, and no rule changes in MC&A would be required to allow for an assay of up to 10 wt% U-235. However, a modification to the facility license may be needed, updating the FNMC plan, because NDA systems based on interrogation of U-235 will be affected when enrichment of U-235 is increased.

3.7 PHYSICAL PROTECTION OF HALEU PLANTS AND MATERIALS

10 CFR 70.22(k) requires license applicants seeking to possess SNM of 10kg or more of low strategic significance (except those who are licensed to operate a nuclear power reactor pursuant to 10 CFR 50) to include a physical security plan that demonstrates how the applicant will meet the requirements of 10 CFR 73.67(f). The program must address how and where the material is to be stored, how access is controlled, and provisions for a watchman or offsite response force to respond to all unauthorized penetrations or activities. Additionally, written response procedures dealing with threats of theft of these materials must be established and maintained.

The physical protection requirements are generally graded based on the risk of the material being used for evil purposes. The principal RGs used in licensing Category I, II and III facilities are: -

- Reg Guide 5.52, *"Standard Format and Content of a Licensee Physical Protection Plan for Strategic Special Nuclear Material at Fixed Sites (Other than Nuclear Power Plants)"* (NRC, Rev. 3, 1994);
- Reg Guide 5.55, *"Standard Format and Content for Safeguards Contingency Plans for Fuel Cycle Facilities"* (NRC, 1978b); and
- Reg Guide 5.59, *"Standard Format and Content for a Licensee Physical Security Plan for the Protection of Special Nuclear Material of Moderate or Low Strategic Significance"* (NRC, Rev. 1, 1983).

This review did not identify any regulatory obstacles for the current licenses for fuel enrichment or fuel fabrication facilities when enriching fuel up to 6 -7 wt% U-235. Current permissions of fabrication and enrichment facilities allow for possession of SNM of low strategic significance which, by definition, includes greater than or equal to 10,000 grams of SNM with enrichments up to 10 wt% U-235. Therefore, no modifications to the facilities' security plans and no revisions or changes to existing physical protection regulations would be required to support enrichment increases up to 10 wt% U-235.

3.7.1 HALEU in Transit

Performance objectives of the physical protection systems in transit are described in §73.67(g) for Category III materials. Category III SNM material, also referred to as SNM of low strategic significance, is defined as 10,000 grams or more of U-235 contained in uranium enriched above natural but less than 10 per cent U-235. In ways similar to the fixed facility physical protection requirements, physical protection requirements for material in transit are also graded based on risk. This review concludes that there are no regulatory obstacles for HALEU in transit when increasing enrichments up to 10 wt% U-235.

4 CONCLUSIONS

Many technical challenges will need to be addressed to demonstrate compliance with existing safety criteria before implementing

higher burnup and higher enrichment combinations with current fuel designs. One of the difficulties associated with the initial deployment of higher burnup/enriched fuels for the current LWR fleet is that neither the designers nor fuel producers can proceed past a certain point without the other.

Early in the process, developers of either cannot be guaranteed that the other is going to reach commercial deployment. The length of time it takes to gain commercial support for funding, address technical and regulatory issues and then construct the necessary fuel cycle infrastructure creates unique challenges for realizing these changes. To address these challenges, it becomes imperative that the federal government and the industry work together to achieve the benefits associated with the use of higher burnup/enriched fuels.

Each of the identified scenarios in the economic analysis discussed in Section 2.0 provides positive economic benefits for the U.S. nuclear fleet. The use of higher burnup fuel designs results in a reduction in high-level waste and the corresponding investment in dry cask storage systems. Additionally, most PWRs could increase their operating schedule flexibility, potentially resulting in fewer refuelling outages and increased energy production; however, these benefits are plant dependent and not credited in the economic analysis.

This project also requires a commitment from many stakeholders, including fuel suppliers, plant operators, and government agencies. Fuel fabrication savings dominate fuel management benefits for utilities. Estimated fuel fabrication price increases are included in the analysis; however, the actual gains are subject to commercial negotiations. Commitment by at least sixteen large PWR commercial reactors is estimated to provide the minimum required return for the project.

To support this initiative, changes to the regulatory framework will be needed to change or eliminate the maximum enrichment limit of 5.0 wt% U-235. With the potential need to increase enrichment levels for both existing commercial LWR reactors and advanced reactors, removal of specific enrichment limits from 10 CFR 50.68 is the most appropriate action. The particular combinations of parameters that protect criticality safety margins are described in the facilities' licensing basis documents.

These parameters include, among others, the presence of integral neutron poisons in the fuel assembly, poison inserts in the storage rack, borated water requirements, and fuel storage configurations. Retention of the necessary enrichment limits in the facility licensing basis, including Technical Specifications, provides adequate protection for criticality safety margins to support the removal of the specific enrichment limit from 10 CFR 50.68.

Federal government support of the development of Lead Use Assemblies (LUAs) to be used for testing will be needed. At present, the only U.S. source for uranium enriched to greater than 5.0 wt% U-235 would be uranium produced from down-blending government-owned high enriched uranium (HEU). Some test reactor fuel may be available to provide LUA quantities. While DOE could theoretically offer a limited source of greater than 5.0% enriched U-235 through down-blending, this option is constrained by the availability of HEU. Thus, this approach could be a stop-gap strategy but cannot be relied upon as a long-term fuel source.[13]

U.S. government assistance will also be needed to amend facility licenses and make necessary modifications to support an increase in enrichment for both fuel enrichment and fuel fabrication facilities in addition to license changes associated with transportation issues. Amending an existing license to enrich up to 10 wt% U-235 is expected to take 1-1.5 years and the estimated time to modify a facility to handle enrichments from 5-10 wt% U-235 is 1 year.

NRC staff has recognized through stakeholder interactions that requests for increased fuel burnups, beyond the current licensed limits, are very likely to occur. As such, it has begun assessing the existing knowledge and experimental data associated with high burnup fuels, starting with NUREG/CR-6744, *"Phenomenon Identification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel."*[14]

NRC staff has also indicated that it expects industry decisions on targeted maximum burnups will direct future plans in regards to an associated increase in enrichment to efficiently achieve the desired burnup. So, along with work associated with increased fuel burnups, the staff is beginning an assessment of what enhancement increase the current knowledge and database could also support concerning licensing accident tolerant fuels.15 Future work in this area will identify the next steps and implementation strategy. wn

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Issue	Potential Path Forward
Regulations limiting enrichment to 5 wt% U-235.	Initiate new rulemaking to eliminate the limit of 5.0 wt% U-235 from 10 CFR 50.68 based on retention of the necessary enrichment limits in the facility licensing bases, including Technical Specifications, providing adequate protection for criticality safety margins. Provisions are available to request approval of alternative package designs that could be used for the shipment of uranium hexafluoride with uranium enrichments greater than 5 wt% under §71.55(b) or §71.55(c). Merits of a new or modified design that included special design features would be reviewed and approved under the provisions of §71.55, including §71.55(c).
Resolution of fuel fragmentation issue	Ongoing research is expected to result in a linear heat rate limit versus burnup to preclude fuel fragmentation. Additionally, tests are planned to demonstrate that high burnup rods do not rupture following a LOCA. Reactivity insertion accidents will also need to be evaluated.
New fuel shipping packages are currently designed to accept fuel enriched up to 5.0 wt% U-235.	Container design modification and re-licensing would be required to ship fresh fuel in excess of 5.0 wt% U-235.

Table 9: Key Issues and Path Forward

5 LIST OF OTHER REFERENCES

1) ANSI N14.1-2001
2) 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities
3) 10 CFR Part 51, Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions
4) 10 CFR Part 70, Domestic Licensing of Special Nuclear Material
5) 10 CFR Part 71, Packaging and Transportation of Radioactive Material
6) 10 CFR Part 73, Physical Protection of Plants and Materials
7) 10 CFR Part 74, Material Control and Accounting of Special Nuclear Material
8) 10 CFR Part 75, Safeguards on Nuclear Material- Implementation of US/IAEA Agreement
9) 49 CFR Part 173.420, Uranium hexafluoride (fissile, fissile excepted and non-fissile
10) Argonne National Laboratory web site. Web.ead.anl.gov/uranium/guide/uf6/index.cfm
11) NRC Website, https://www.nrc.gov
12) Resolution of Generic Safety Issues: NMSS-0007. Criticality Benchmarks Greater than 5% Enrichment (Rev. 2) (Section 6 of NUREG-0933, Main Report with Supplements 1–34) December 2011
13) DOE-STD-1194-2011, Nuclear Materials Control and Accountability, June 2011
14) NUREG 1520, Rev. 2, *"Standard Review Plan for Fuel Cycle Facilities License Applications,"* June 2015
15) U.S. Nuclear Regulatory staff guidance, Fuel Cycle Safety and Safeguards-Interim Staff Guidance-10, Revision 0 (FCSS-ISG-10, Revision 0), ADAMS Accession No. ML 061650370
16) NUREG-1280, Rev. 1, *"Standard Format and Content Acceptance Criteria for the Material Control and Accounting (MC&A) Reform Amendment,"* 10 CFR Part 74, Subpart E," Issued April 1995 (for high enriched uranium facilities)
17) NUREG-1065 Rev. 2, *"Acceptable Standard Format and Content for the Fundamental Nuclear Material Control (FNMC) - Plan Required for Low-*

Enriched Uranium Facilities," Issued December 1995

18) NUREG-1748, *"Environmental Review Guidance for Licensing Actions associated with NMSS Programs,"* issued August 2003 (provides general procedures for the environmental review of licensing actions regulated by the Office of Nuclear Material Safety and Safeguards)
19) Draft NUREG 2215, *"Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities,"* draft report for comment November 2017
20) NUREG-1617, *"Standard Review Plan for Transportation Packages for Spent Nuclear Fuel,"* March 2000
21) NUREG- 1437, *"Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants,"* (NRC 1999)
22) Regulatory Guide 1.183, *"Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,"* July 2000
23) Regulatory Guide 1.195, *"Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors,"* May 2003
24) NUREG-0800, *"Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition"*
25) NUREG-1431, *"Standard Technical Specifications — Westinghouse Plants"*
26) USNRC, Fuel Cycle Safety and Safeguards-Interim Staff Guidance-10, Revision 0 (FCSS-ISG-10, Revision 0), ADAMS Accession No. ML061650370
27) ADAMSAccessionNo.ML013540584-NUREG/CR-6744, *"PhenomenonIdentification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel,"* December 2001.
28) ADAMS Accession No. ML18261A414 - Project Plan to Prepare the USNRC for Efficient and Effective Licensing of Accident Tolerant Fuels, September 2018.
29) *"Strategy for Deployment of Advanced Fuels,"* RPT-3005895-000, September 28, 2011.
30) NUREG-1609, *"Standard Review Plan for Transportation Packages for Radioactive Material,"* March 31, 1999.
31) 49 CFR Part 173.417, Authorized fissile materials packages.

CPD course calendar

VENUE: SAIEE HOUSE 18A GILL STREET OBSERVATORY

JULY 2019	
1-2	High Voltage Testing and Measurement
2	Road to Registration for Engineering Candidates
9-10	Fundamentals of Power Distribution
10-11	Financial Mangement for Engineering Professionals
16-17	Incident Investigation and Management (Incl. Root cause Analysis)
16-18	Eskom CIGRE SC B1 Tutorial Session - Cable System Reliability
18-19	Electrical Engineering Fundamentals for non-electrical engineers
18-19	Fundamentals of Developing Renewable Energy Plants
23-24	Fundamentals of Long Term Evoluton (LTE) Mobile Communication
25-26	Advanced Microsoft Excel: Practical Data Management Application for Engineers
26	Legal Liability Occupational Health and Safety Act (OHSA)
30-1/08	Power Systems Protection
AUGUST 2019	
5-6	Photovoltaic Solar Systems
13-14	SANS 10142-1. 2017 Edition 2 & OHS Act
13-14	Design Thinking and Innovation for Energy Engineering Professionals
15-16	Arc Flash Workshop
22-23	Earthing & Lightning Protection *(Blue Lagoon Hotel & Conference Centre, East London)*
27-28	SDN/NVF Standards and Application
28-29	Writing Good Technical Specifications
SEPTEMBER	
3-4	Network Frequency Controls
10-11	Practice of Management for Engineers
10-12	Substation Design and Equipment Selection
12-13	Fundamentals of Long Term Evoluton (LTE) Mobile Communication
17-18	Fundamentals of Developing Renewable Energy Plants
17-20	Advanced Microprocessor Based Power System Protection
19-20	Cable Jointing, Termination and Testing
26-27	High Voltage Testing and Measurement
27	Road to Registration for Engineering Candidates

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Our Expert Answers

Information provided by Zest WEG Group

QUESTION ONE

What are the benefits for an end-user who chooses an E-house over a conventional civil structure when designing an electrical substation?

ANSWER ONE

Awarding a single contract to design, manufacture, supply and test a complete E-House substation including all the electrical equipment at a unique facility is a massive time and cost benefit to an end-user. Project timelines are continuously reducing, and an E-House solution is a fast track solution for a project.

QUESTION TWO

What are the limits for transportation purposes?

ANSWER TWO

Unit sizes of up to 30 metres in length by 5 metres wide by 4 metres high with a mass up to 100 ton are easily transportable. This includes transportation to cross border destinations such as Botswana and Mozambique.

QUESTION THREE

What is the cost comparison between an E-House and a conventional civil structure?

ANSWER THREE

This question can only be answered if you can perform a complete analysis of all costs that constitute a conventional civil structure. This means you must include the costs to establish and manage multiple contractors on site. Management time for an end-user or design company is hugely reduced when an E-House is constructed. The supplier of the E-House takes on the responsibility of all subcontractor inputs in the manufacture of the E-House.

QUESTION FOUR

What is the typical manufacturing lead time of an E-House?

ANSWER FOUR

The typical lead time to manufacture the E-house structure alone could be between 16 to 20 weeks. A complete substation project consisting of multiple products within the E-House will, of course, depend on the lead time for the individual items of equipment required to be installed in the E-house.

QUESTION FIVE

Is it possible to combine multiple E-Houses to form a more substantial structure?

ANSWER FIVE

Yes, this is entirely possible. Multiple units can be joined together at ground level, and in space-constrained sites, many units can be assembled as multi-floor structures.

QUESTION SIX

Does the E-House manufacturer also supply the staircases and platforms required for an E-House substation?

ANSWER SIX

Often the E-House is elevated on columns to allow bottom cable entry, and this requires staircases and platforms to facilitate access for personnel and the loading of equipment. The E-House manufacturer can supply all the columns, stairways and platforms as part of the E-house supply contract.

QUESTION SEVEN

What type of electrical equipment can be supplied in an E-House?

ANSWER SEVEN

The sky is the limit here. All products in a conventional civil substation can be incorporated into an E-House. This includes dry-type or oil-filled transformers, medium voltage (MV) and/or low voltage (LV) Variable Speed Drives (VSD), MV and/or LV switchgear, PLC, ESD, motor control centres, UPS units and distribution boards to mention but a few.

QUESTION EIGHT

What are the typical HVAC designs that can be used for an E-House structure?

ANSWER EIGHT

Air conditioning is the primary consideration, and this can be achieved in several ways. The simplest is the use of mid-wall or ceiling-mount split air conditioning units. Very intricate HVAC designs will incorporate refrigeration package machines, and these are typically required when significant heat losses from VSDs and transformers are accommodated within the E-House.

QUESTION NINE

What testing is performed on a completed E-House at the manufacturer's works?

ANSWER NINE

Full mechanical and electrical testing and inspection is completed before despatch to site. An E-house is fully assembled structurally at the manufacturer, and this includes staircases and loading platforms.

This is so a full structural factory acceptance test (FAT) can be performed. All electrical systems and equipment are interconnected at the works to allow a complete electrical FAT to be performed.

QUESTION TEN

Are E-Houses ever used in underground mining operations?

ANSWER TEN

Yes, this opportunity has been recognised, and E-houses are used in many mining operations. Often these are built on skids to allow dragging of the unit to its final destination point. Dragging distances of up to 4 km are common practice.

QUESTION ELEVEN

How are fire risks accommodated within an E-House?

ANSWER ELEVEN

The fire rating of the structure should be tested to withstand a two-hour structural fire rating test. This is to ensure structural integrity in the case of a fire. Fire detection and suppression systems can be included in the scope of work. Again, all work is carried out at the manufacturer's facility. wn

June in History

June is the sixth month of the year in the Julian and Gregorian calendars, the second of four months to have a length of 30 days, and the third of five months to have a length of less than 31 days.

COMPILED BY |
JANE BUISSON-STREET
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1 JUNE

1995 Maxis, the company most famous for its SimCity video game, went public. Along with others in the series -- including SimEarth, SimAnt, and SimLife -- the SimCity simulator program which was based on Maxis co-founder Will Wright's childhood interest in model ships and airplanes. With Jeff Braun, he founded the company that allowed people to create virtual cities and protect them from various disasters on their home computers.

2 JUNE

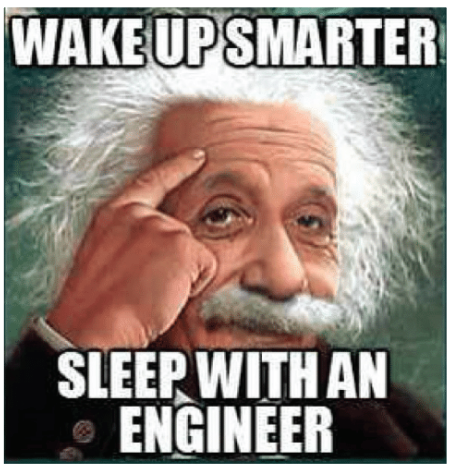
2014 India officially divided the state of Andhra Pradesh to create the nation's 29th state, Telangana. Hyderabad remains as the joint capital for both states for the next decade.

3 JUNE

1976 Queen's song *"Bohemian Rhapsody"* went gold, meaning over 1 million copies sold. This single stayed at the top of music charts all over the world for weeks. Especially in the U.K it stayed as #1 for nine weeks. It was written by Freddie Mercury and it was different than other songs because it had no specific chorus, but instead different sections. The song consisted of a ballad, opera section and a hard rock part which is what made it so unique and helped it attain such high success.

4 JUNE

1896 At approximately 4:00 a.m., in the shed behind his home on Bagley Avenue in Detroit, USA, Henry Ford unveiled the "Quadricycle," the first automobile he ever designed and drove.



Trust me, Im an engineer. #math #difficulty #civil #mechanical #mechatronic

5 JUNE

1975 The United Kingdom holds its first country-wide referendum on membership of the European Economic Community (EEC). The question on the ballot paper read *"Do you think the United Kingdom should stay in the European Community (the Common Market)?"* 67.23% voted yes and 32.77% no.

6 JUNE

1944 Supreme Allied Commander General Dwight D. Eisenhower gave the go-ahead for the largest amphibious military operation in history: Operation Overlord, code named D-Day, the Allied invasion of northern France.

7 JUNE

1989 23 year old Olympic barefoot South African runner Zola Budd retired.

8 JUNE

1937 A specimen of the world's largest flower, first bloomed in the USA's NY Botanical Garden. The giant Sumatran Titan Arum, Amorphophallus titanum, measured approximately 2.59 m high and 1.22 m diameter. Native in Sumatran jungles of Indonesia, it is known there as the *"corpse flower."*

9 JUNE

2016 Researchers in Iceland report on CarbFix, in the journal Science. This is a process whereby carbon dioxide emissions can be pumped into the earth and changed chemically to stone — significantly faster than expected.

10 JUNE

2015 Bidding for the 2026 FIFA World Cup was postponed due to the 2015 FIFA corruption case and the subsequent resignation of Sepp Blatter.

11 JUNE

1987 UK's Conservative Prime Minister, Margaret Thatcher, won an historic third term in office in 1987. She was the first British Prime Minister in 160 years to win third term.

12 JUNE

1942 Anne Frank received a diary for her thirteenth birthday. She was a German-born Jewish diarist. As one of the most discussed Jewish victims of the Holocaust, she gained fame posthumously with the publication of The Diary of a Young Girl in which she documented her life in hiding from 1942 to 1944, during the German occupation of the Netherlands in World War II.

13 JUNE

2010 After 7 years, 1 month and 4 days, a capsule of the Japanese spacecraft Hayabusa, containing particles of the asteroid 25143 Itokawa, returned to Earth. Hayabusa was the first spacecraft designed to deliberately land on an asteroid and then take off again.

14 JUNE

1699 Thomas Savery demonstrated to the Royal Society a small model of his invention - a steam-powered water pump. High fuel consumption and failures, due to construction materials unable to contain the pressure, meant the design was unsuccessful for use in mines.

15 JUNE

2011 The first lunar eclipse of the year occurred with it being the first central lunar eclipse since 1990. A central lunar eclipse is a lunar eclipse in which part of the Moon passes through the centre of Earth's shadow. This type of lunar eclipse typically appears darker than other lunar eclipses, and is relatively rare.

June in History

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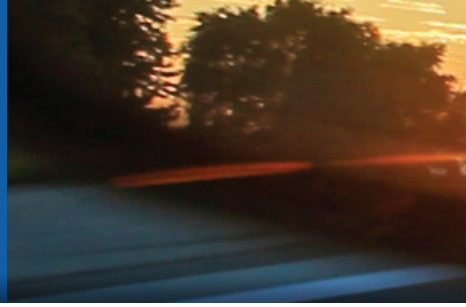


16 JUNE

1922 Henry A. Berliner demonstrated the first helicopter prototype for representatives of the U.S. Navy's Bureau of Aeronautics in College Park, Maryland. Earlier that year he bought a surplus Nieuport 23 fighter's fuselage, added a Bentley 220 hp engine on the front, and connected it by geared shafts to two horizontal rotors mounted on a truss extending sideways from the fuselage. A third horizontal rotor at the rear provided pitch control. This demonstration is often referred to (though disputed) as the debut of the helicopter.

17 JUNE

1936 Edwin H. Armstrong demonstrated his invention of FM radio in Washington D.C. His method modulated the frequency of a broadcast radio wave to carry the audio signal (FM). Armstrong's system used a higher frequency band and was clear of the hissing, buzzing and crackling static noises of AM.

18 JUNE

1983 NASA Astronaut Sally K. Ride became the first American woman in space, when she launched with her four crewmates aboard the Space Shuttle Challenger on mission STS-7.

19 JUNE

1963 After nearly three days and 48 orbits around earth Soviet cosmonaut Valentina Tereshkova returned to Earth. She was the first woman in space. Valentina had been interested in parachute jumping when she was young, and that expertise was one of the reasons she was picked for the cosmonaut program. She became the first person to be recruited without test pilot experience.

20 JUNE

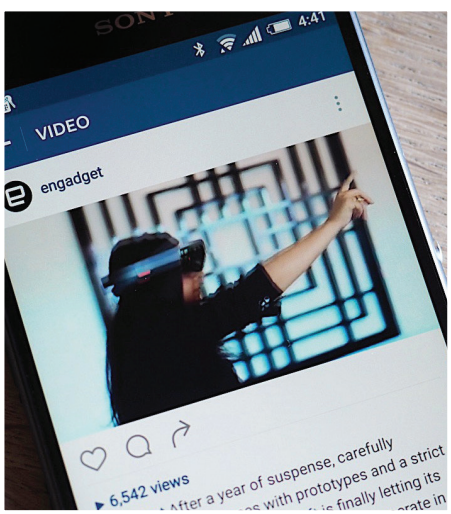
2013 Instagram introduced a 15-second video sharing service for the first time.

21 JUNE

1981 IBM retired its last "STRETCH" mainframe. It was part of the 7000 series that represented the company's first transistorized computers. At the top of the line of computers - all of which emerged significantly faster and more dependable than vacuum tube machines - sat the 7030, or STRETCH. Seven of these computers, which featured a 64-bit word architecture and other innovations, were sold to national laboratories and other scientific users. L. R. Johnson (a senior member of the staff at IBM's Thomas J. Watson Research Centre) first used the term "architecture" when he described the STRETCH.

22 JUNE

1990 One of the Cold War's best known crossing points between East- and West-Berlin, Checkpoint Charlie, was dismantled in Berlin. The Cold War was a period of geopolitical tension between the Soviet Union



with its satellite states (the Eastern Bloc), and the United States with its allies (the Western Bloc) after World War II.

23 JUNE

1994 After nearly 20 years of suspension from the UN, South Africa was readmitted. South Africa had been one of the 51 founding members of the original United Nations all the way back in 1945 but was suspended from the UN and all its associated work in 1974.

24 JUNE

1992 Musician Billy Joel finally finished high school at the age of 43! He did not graduate with Hicksville High School's class of 1967 as he was busy starting his musical career. The late nights meant that he overslept and missed an English exam. Unlike the other qualifications he received, that were honorary, he had to work for this one and send in samples of his work!

25 JUNE

1998 Contact was lost with the Solar and Heliospheric Observatory (SOHO), a spacecraft built by a European industrial consortium led by Matra Marconi Space. Contact was re-established 16 Sep 1998, and by mid-October scientists were reactivating the science instruments. Since its launch on 2 Dec 1995, SOHO gave solar science a new ability to observe simultaneously the interior and atmosphere of the Sun, and particles in the solar wind and the heliosphere.

26 JUNE

1906 What is considered to be the world's first grand prix - The 1906 Grand Prix de l'Automobile Club de France (The 1906 French Grand Prix) was held on 26 and 27 June 1906, on closed public roads outside the city of Le Mans.

27 JUNE

1985 US tennis player Anne White was warming up for her match against fifth seed Pam Shriver in the first round at Wimbledon, when she removed her tracksuit and revealed an all-white lycra body suit. It created quite a stir among the crowd and photographers.

28 JUNE

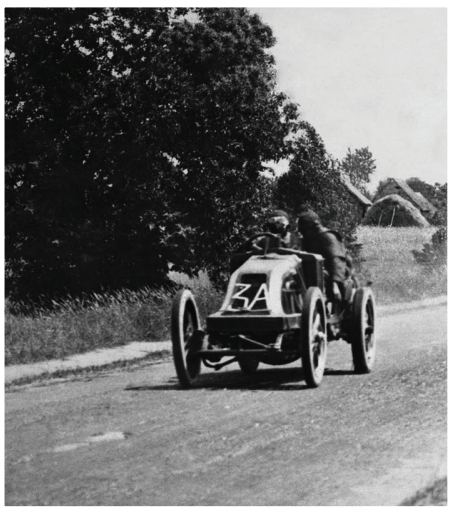
1978 SeaSat (Seafaring Satellite), the first Earth-orbiting satellite designed for remote sensing of the Earth's oceans, was launched. It collected more information about the oceans than had been acquired in the previous 100 years of shipboard research.

29 JUNE

2013 The Tour de France started in Corsica.

30 JUNE

1980 The United Kingdom had set Decimal Day for 15 February 1971, and a whole range of new coins were introduced. wn



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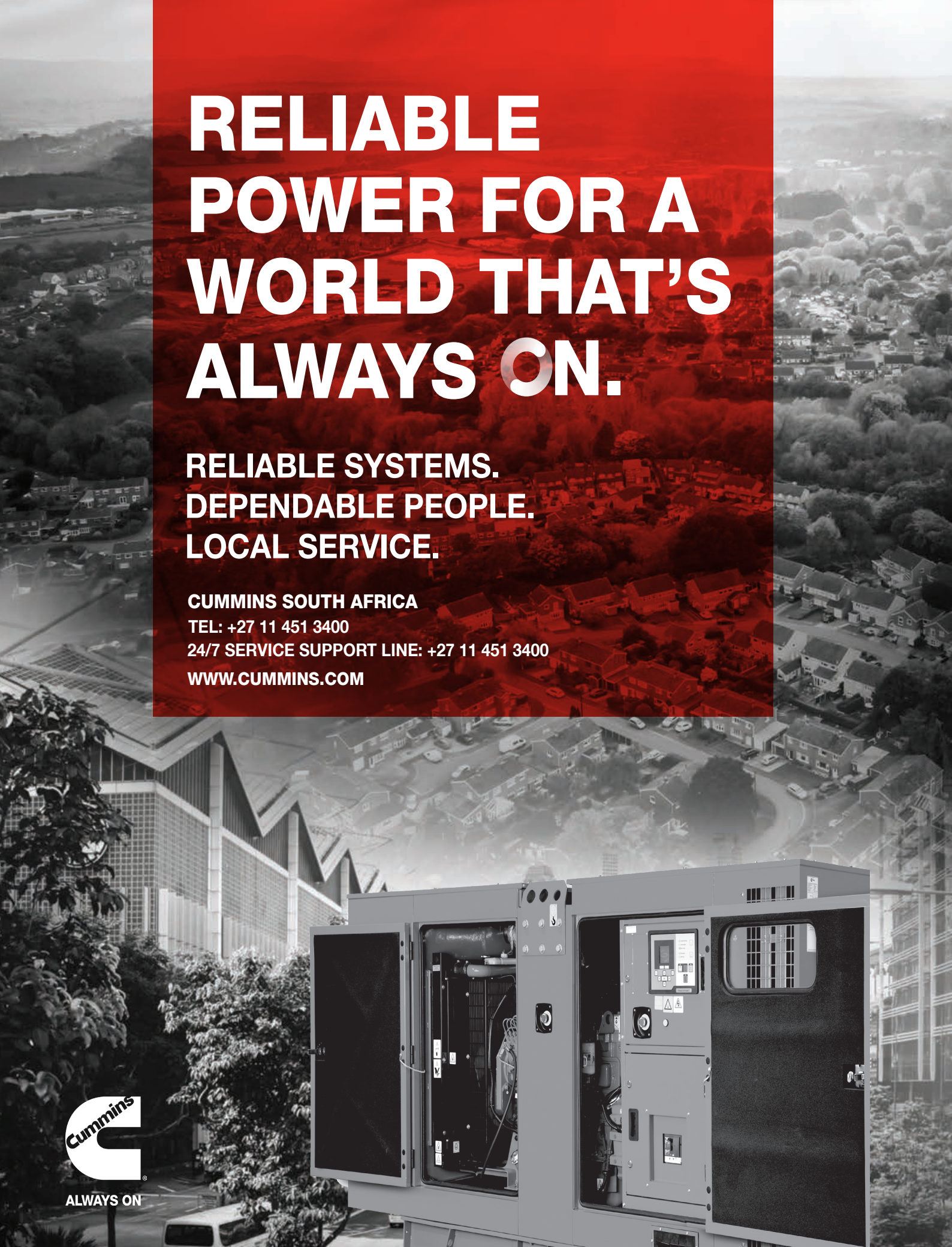
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