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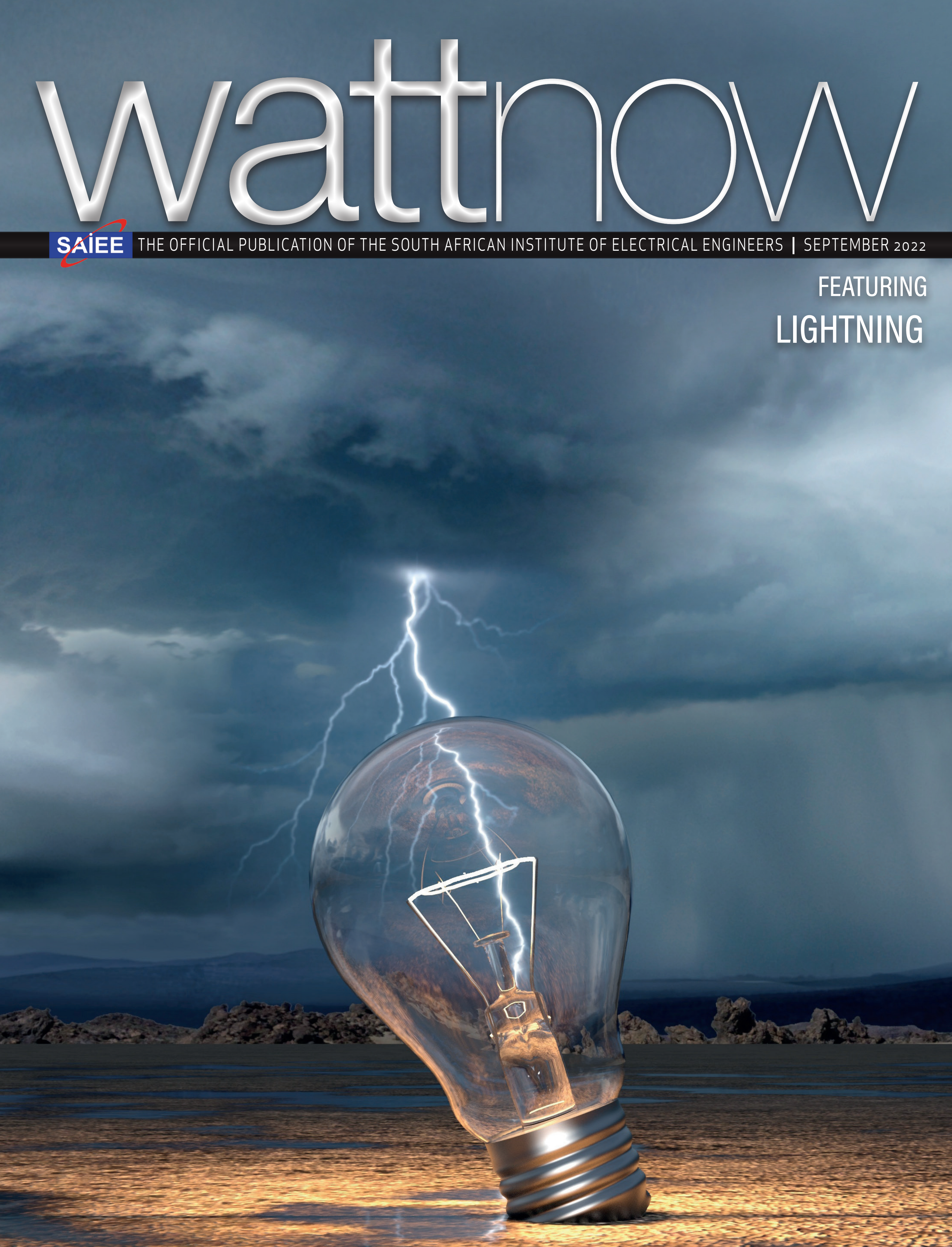
FEATURING
LIGHTNING

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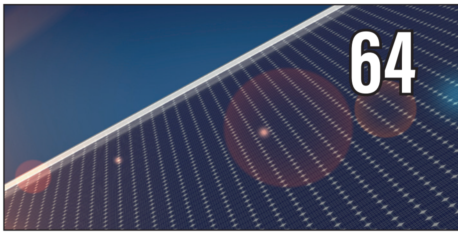

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Dear **watt**now reader,

It is known that approximately 100 people die in lightning strikes every year, and thousands more are injured. The Drakensberg records around 20 lightning strikes per square kilometre per year, while Johannesburg experiences 15 flashes per square kilometre annually. It is for this reason I bring you this wattnow issue featuring lightning.

Our first feature article, "Beware when selecting earth measurement equipment", written by Dr Andreas Beutel, explains that electrical engineers and technicians are often required to measure the resistance of an earth electrode or the resistivity of soil in which an electrode will be inserted. The purpose of soil resistivity measurement, in most cases, is to design an earth electrode adequately. In contrast, the resistance of the finished electrode needs to be measured to ensure that it is within the requirement. Read it on page 39.

Nonkululeko Milliah Ripinga wrote a white paper on "An investigation into lightning initiating veld fires in Western Cape and Eastern Cape Provinces, South Africa", which explains that lightning is one of the major contributing factors to veld fire ignition around the globe. This study assessed lightning characteristics around veld fire events in the Western Cape and Eastern Cape provinces. Find it on page 52.

Renewables is the buzzword globally, and it is apt to inform you that you need lightning protection for wind turbines. It is mentioned in IEC 61400- 24 that an area may see an increase in lightning ground flash density when being populated with tall structures. Thus, if a Wind Farm is built in a specific area, that area will experience an increase in ground flash density due to the strikes on the Wind Turbines. Read this article on "Lightning Protection and Detection for Wind Turbines " on page 58.

As we enter the last quarter of the year, it is time to work on the 2023 budget. SAIEE Members will find the 2023 membership fees on page 67.

The October issue features Cables, and the deadline is 19 September. Please email any articles or news to minx@saiee.org.za.

Herewith the September issue, enjoy the read!

Minx

For the first time in its history, the International Conference on Lightning Protection (ICLP), one of the most prestigious international lightning protection conferences, will take place on the African continent. With some of the most spectacular thunderstorms in the world, South Africa's long history of lightning research and our experienced protection industry, ICLP 2022 and South Africa are a natural fit.

The conference is being hosted by the University of the Witwatersrand (Johannesburg), and will be held in our beautiful Cape Town with Table Mountain as the backdrop. From 2nd October to 7 October 2022, the world's leading lightning researchers and experts will be discussing and sharing cutting edge knowledge and research on lightning and lightning protection.

THE HISTORY OF ICLP

Since its inception in 1951 in Germany, ICLP has become the largest biennial conference that forms a global platform where the academic and industry giants of lightning protection come together and exchange scientific and technological knowledge through presentations, discussion, workshops and exhibitions. Typically, it has an attendance of participants representing over 40 countries.

EXECUTIVE BOARD

The ICLP organization is lead by an executive board consisting of a President, Vice President and Secretary and guided by a scientific committee of the world's leading lightning researchers and academics.

THE LOCAL ORGANISING COMMITTEES

ICLP 2022 South Africa is being organised Prof. Ian Jandrell and his team from the University of the Witwatersrand, Johannesburg. The team consists of researchers from the School of Electrical and Information Engineering.

THE VENUE

ICLP 2022 will be held at the Cape Town International Convention Centre (CTICC). The CTICC is the leading international convention centre on the African continent. The Convention Centre is conveniently located in the central business and entertainment hub of the city and is close to many major attractions and places to stay and eat. The CTICC boasts three stylish roof terraces with views of the Cape Town skyline, Table Mountain and the historic Table Bay Harbour.

Prof. Ian Jandrell
Conference Chair

Prof. Ken Nixon
Conference Vice-Chair

Dr Pieter H Pretorius
Treasurer

Prof. Chandima Gomes
Partnership Chair

Dr Hugh Hunt
Technical Session Chair

Dr Carina Schumann
Social Events Chair

Local Organising Committee

A multi-purpose conference and exhibition centre in the hub of Cape Town's business and entertainment centre, the CTICC combines the impassioned dedication of its capable personnel with a world-class venue that offers a comprehensive array of best-in-class services.

The CTICC is the first convention centre in Africa to gain three internationally recognised management system certifications simultaneously, and the first in the world to align its reporting to the sustainability requirements of the Global Reporting Initiative (GRI) – all of which represents a guarantee of its total commitment to the highest levels of quality, care, safety, and sustainability.

C19Care© safety protocols have been developed in collaboration with health, tourism and events industry leaders, both locally and abroad, and applies National Department of Health guidelines in order to provide a safe and healthy environment for delegates.

TOPICS AND PROGRAM

ICLP 2022 will have leading academics and industry professionals presenting on a range of cutting edge lightning protection topics including Lightning Protection of Renewable Energy systems, EMC considerations, storm prediction and Nowcasting with Artificial Intelligence techniques as well as human safety. Figure 2. shows the draft program for the sessions. ICLP 2022 is CPD accredited for full 5 day notional hours.

OUR PARTNERS AND THE EXHIBITION

ICLP 2022 Cape Town is supported by leaders of both the South African and international lightning protection industry who not only have ensured the conference takes place, but will be present at the event through the exhibition and contributing their knowledge and expertise to the discussions as well. A number of unique partnership opportunities are still available and adaptable to suit your brand / company's specific requirements.

The exhibition provides stakeholders and suppliers to the lightning protection industry with a great opportunity to showcase their products and services to a targeted, relevant and appropriate market. For maximum exposure, all tea/coffee breaks and lunches will take place in the exhibition area.

The conference will also kick off with a welcome reception in the exhibition area on Sunday, 2 Oct. Exhibitors are also invited to host activities and competitions on their stands during the conference. Stand activities will be announced throughout the conference. You also stand a chance to win the Best Exhibition Stand Award.

IN SUMMARY

The 36th International Conference on Lightning Protection (ICLP), Cape Town 2022 is the most important lightning protection and lightning related event this year. Whatever industry and field you are involved in, you are sure to find answers to lightning issues and questions here. wn

Click here to register and find out more!

Exclusive Networks Africa continues its expansion plans throughout the continent

Exclusive Networks Africa, which represents the continental arm of this global, trusted cybersecurity specialist for digital infrastructure, is continuing its expansion into Africa, building presence within the sub-Saharan region in recent months, including the opening of a formal office in Lagos, Nigeria. This adds to the existing offices in South Africa, Kenya and Mauritius.

Because Africa is seen as a growth market by the Group, it is widely recognised as an important investment destination, allowing for a strong focus on the company's vendor partners, both current as well as potential.

This is according to Anton Jacobsz, Managing Director of Exclusive Networks Africa, who clarifies: "Having previously operated in a number of countries across Africa with the support of representatives there, as well as from Head Office in Centurion, Gauteng wherever required, the company was very pleased recently to extend its footprint more formally with increased resources on the ground in Uganda, Madagascar and Nigeria.

"This is in line with our vision to become a pan-African cybersecurity specialist and upgrade our regional presences with formal offices in every country within which we operate."

As the African entity of a global company that is listed on the Paris stock exchange, Euronext Paris, the Ugandan and Madagascan employees were appointed, and the Nigerian branch established, following extensive due diligence which evaluated current and future business trends in the central African, Indian Ocean Islands and West African areas respectively.

"Our business has been doing extremely well this year," says Jacobsz, "with significant growth and very pleasing recent financial results. The branch in Lagos, Nigeria will be able to service the growing West African market in a consolidated manner. As part of the growth strategy across the continent, it was decided that opening a dedicated branch in Lagos made business sense due to its geographical location and position in the heart of the thriving West African region.

"Having been operational in Nigeria for some five years already, we were really pleased to be able to register a formal entity and open up Exclusive Networks Nigeria. The office has been set up and the new team members have moved in. This bodes very well for our expansion plans across Africa."

In its quest to become a significant presence across the key areas in Africa, Jacobsz explains that Exclusive Networks Africa's approach involves identifying the key growth regions.

"We'll start by putting feet on the ground to service those regions, with the team developing the channel and servicing the market," he explains. "Thereafter the goal is to have in-country offices, with the ultimate vision being to open a branch across every country in Africa that we service, across the vast majority of the continent."

Jacobsz believes that countries across the continent should be willing and

enabled to tap into each other's markets in order to grow businesses and, accordingly, profits, to the greater economic benefit of the entire region.

"Put very simply, we in Africa, across different countries and regions, need to start interacting with each other intra-country and across borders in the same the way that business entities across Europe interact with each other across regions," he notes.

Jacobsz adds that the strategy includes distinct elements, such as the growth of existing vendors across existing markets; existing vendors into new potential markets; onboarding new vendors, and finally services.

"The Exclusive Networks Africa services business is a very strong enabler for territories where partners are unable to invest heavily in their own resources, and our footprint across the continent can relieve a great deal of business pressure," he says.

"We offer access to 43 countries on the continent where Exclusive Networks has the footprint, and the ability, to be the partner of choice in taking away the burden of administrative issues such as import functionality, handling of VAT, service operations and so on.

"At Exclusive Networks, we proudly offer market-leading brands across the cybersecurity sphere and differentiate ourselves further with our world class service. We are excited to see our presence in these areas consolidated and look forward to growing our presence in additional targeted countries, in a 'hub-and-spoke' relationship, in due course," Jacobsz concludes.

For more information on Exclusive Networks Africa and its offerings, click here. wn

TOUCHING BASE WITH SAIEE BURSAR:

The Story of Simeon Kruger

The SAIEE Education and Training Committee touched base with Simeon, the 2020-2021 SAIEE bursar. The aim was to gauge his experiences as our bursar and also hear his career plans as he takes the next steps.

By: SAIEE Education and Training Committee & Simeon Kruger

Q: Who is Simeon, where are you from, and how was the situation at home?

A: I am Simeon Kruger, a Bachelor of Engineering (BEng) in Electromechanical Engineering and, more recently, a Master of Engineering (MEng) in Electrical and Electronic Engineering. I matriculated in 2015 from Hoërskool Generaal Hertzog and started studying at the North West University in Potchefstroom in 2016. I was born and raised in Witbank in the Mpumalanga province. I am the youngest of 3 brothers and the son of a pastor and a pharmacist.

I am blessed to say that I have come from a good background. All three of my parents' children were able to go and study, but we required bursaries and study loans to make this possible. Had it not been for a bursary in my final year, I would probably not have been able to finish my BEng degree. Had it not been for the SAIEE bursary, I would not have been able to do my MEng degree. Nevertheless, I am also grateful for the sacrifices my parents made for many years to make it possible for me to get to where I am today.

Q: What did you want to be when you grew up, what subject did you do at school, and how did you learn about electrical engineering?

A: I cannot remember what I wanted to be when I grew up. I think my idea of what I wanted to do changed as I moved through different phases of my life. At one point, I wanted to be an architect. Aptitude tests said that I should become a doctor. But I think as I drew close to a point where I had to go and study, engineering was always going to be the logical choice for me. I was very good at Mathematics and Physical Sciences. I enjoyed physics more than Chemistry, so I knew Chemical Engineering would not be for me. I'm quite grateful for that choice as I have now been exposed to two different engineering disciplines. I chose Electromechanical Engineering partly because it was a new course, so I considered it a niche market. But it was always a step of faith as I was not entirely sure what I wanted to do with my life. My switch to electrical engineering was caused by opportunities that came my way in the form of a potential Master's degree topic. Professor Jan de Kock, for whom I have a lot of respect, offered me the opportunity to work under him on transformers, and this has been a very rewarding two years.

Q: Getting to tertiary: which institution did you attend, how did you hear about it, and how was your experience as a tertiary level student?

A: I attended the North West University Potchefstroom campus. I knew of the NWU as my oldest brother had already studied Electrical Engineering there. Furthermore, at the point of application, my middle brother was studying psychology at the NWU, so having two brothers at the same institution made sense. My experience as a tertiary level student was not the typical experience described by many other students. The four years of undergraduate studies were the hardest years of my life. Engineering is an incredibly taxing course, and there is a reason why so many students switch over to what can be considered easier degrees. I was also fully aware that my parents could not support me and that if I wanted to keep studying, I had to maintain high enough marks to be considered for a bursary. I had therefore set lofty goals for myself, and it required a lot of dedication and discipline to reach them. Nevertheless, I don't regret my decisions, and I'm grateful for where this has gotten me so far.

Q: What financial complications did you face at tertiary?

A: I was fortunate that my parents could take out study loans for my brother and me, which helped carry me through the first three years of my studies. I also had some financial support from the Atterbury Trust, for which I am incredibly grateful. However, when my brother stopped studying in 2018, we knew that finances for my final year would be very limited. God blessed me at the most opportune time with a bursary from a company called Omnia for my final year, which carried me through.

Q: How did you learn about SAIEE and its bursary scheme?

A: In 2019, I was looking for employment after finishing my practical Training with Samancor Chrome Ferromatals. I decided to go back to school full time and do my BTECH. At the time, I needed funding, and I was looking and applying. One afternoon going through my LinkedIn account, I saw a post shared by SAIEE CEO about the bursary. I did not hesitate and applied. I then started paying attention to the organisation and conferences. I got an opportunity to attend the Women in Engineering Breakfast by writing why they should choose me. That year I attended two conferences. One was with SAEEC, where I presented my Renewable energy paper. In 2020 I also attended a Fluke course with SAIEE, where I got four certificates added to my CV.

Q: What impact did the bursary make on you and your future?

A: When I initially started my Master's degree, it would have been funded by a private company. However, my financial support soon fell through, and I knew that without financial support, I would not be able to complete the degree.

I have known about the SAIEE since 2016 due to the nature of my studies. My study leader, Professor Jan de Kock, sent me the application forms for the SAIEE bursary scheme, and I immediately applied. However, I was unaware that they had a bursary scheme; if Professor de Kock had not told me about it, I would still have been oblivious.

Q: What impact did the bursary make on you and your future?

A: The bursary is one of the fundamental reasons I can proudly say that I have an MEng degree. My MEng studies were incredibly rewarding on a personal and an academic level. My qualifications have also opened several doors for me in the professional environment, which I would not have had otherwise. I am incredibly grateful to the SAIEE for gifting me with this opportunity.

Q: What are you doing now? Are you where you wanted to be?

A: I am currently working as a Digital Transformation Analyst at a company called TecEx. This is most definitely not where I envisioned myself while I was studying. Nevertheless, I am part of a dynamic team that works very hard at understanding the fundamentals of the system that allows this company to function smoothly across various departments. In all aspects, I am very grateful for the opportunity to be employed, and I love the young and dynamic culture that this company offers me.

Q: Where do you see yourself in the next 5-10 years?

A: Given how my life has gone over the last six years, this is a very difficult question for me to answer. I started as an Electromechanical engineering student in 2016. I moved over to Electrical engineering in 2020. Covid struck in March 2020, and I was forced to study at Witbank for two years. I lost my job opportunity at Omnia as an engineer in 2021. I became a Digital Transformation Analyst at an Importer of Record Company in January 2022.

I firmly believe that God has a plan for my life, and I would like to be willing to follow His will as He guides me through a process. If this entails staying at TecEx for the next 5-10 years, I am happy to give my best there. In such a case, I hope to move into a management role in the not-too-distant future. If, however, I am not destined to stay here, I hope to move into an even more rewarding job where I can exercise my critical-thinking skills and make a positive impact. Irrespective of the company, or even the field of expertise, I would like to apply myself to become the best I can be and become an expert in the field I am working on.

I am grateful for the wide array of skills that engineering has taught me, and some of these skills are not necessarily tangible. These include the ability to analyse solutions and their feasibility critically, the ability to write technical specifications and the ability to question some of the fundamental assumptions that we so easily make without realising our mistakes. This opens a range of possibilities: from power system simulation to digital transformation analysis to programming. Engineering helps an individual do an exceptional job in all these fields.

To learn more about the SAIEE Bursary Fund, contact Dudu Madondo. wn

iLembe District Development Model One Plan

One district - one plan and one budget. That is the essence of the District Development Model (DDM) One Plan which aims to replace a "silo" approach with all spheres of government – local, provincial and national – aligning plans and resources to achieve the country's developmental outcomes.

The Vuthela iLembe LED Support Programme is assisting the iLembe municipalities in developing the DDM One Plan, which presents an opportunity to approach planning and budgeting in a new way.

The DDM One Plan is a 25- to 30-year strategic plan with a vision to develop iLembe as one integrated area. President Cyril Ramaphosa, in his budget speech in 2019, initiated the DDM One Plan as "a new integrated district-based approach to addressing our service delivery challenges [and] localise[d] procurement and job creation, that promotes and supports local businesses, and that involves communities". Such an approach will require that national and provincial departments have district-level delivery capacity to provide implementation plans aligned with priorities identified in the State of the Nation address.

One Plan will narrow the distance between people and government by strengthening the coordination role and capacities at a district and local level. This will ensure inclusivity through budgeting based on the needs and aspirations of the people and communities at a local level; build government capacity to support municipalities, and strengthen monitoring and evaluation at a district and local level.

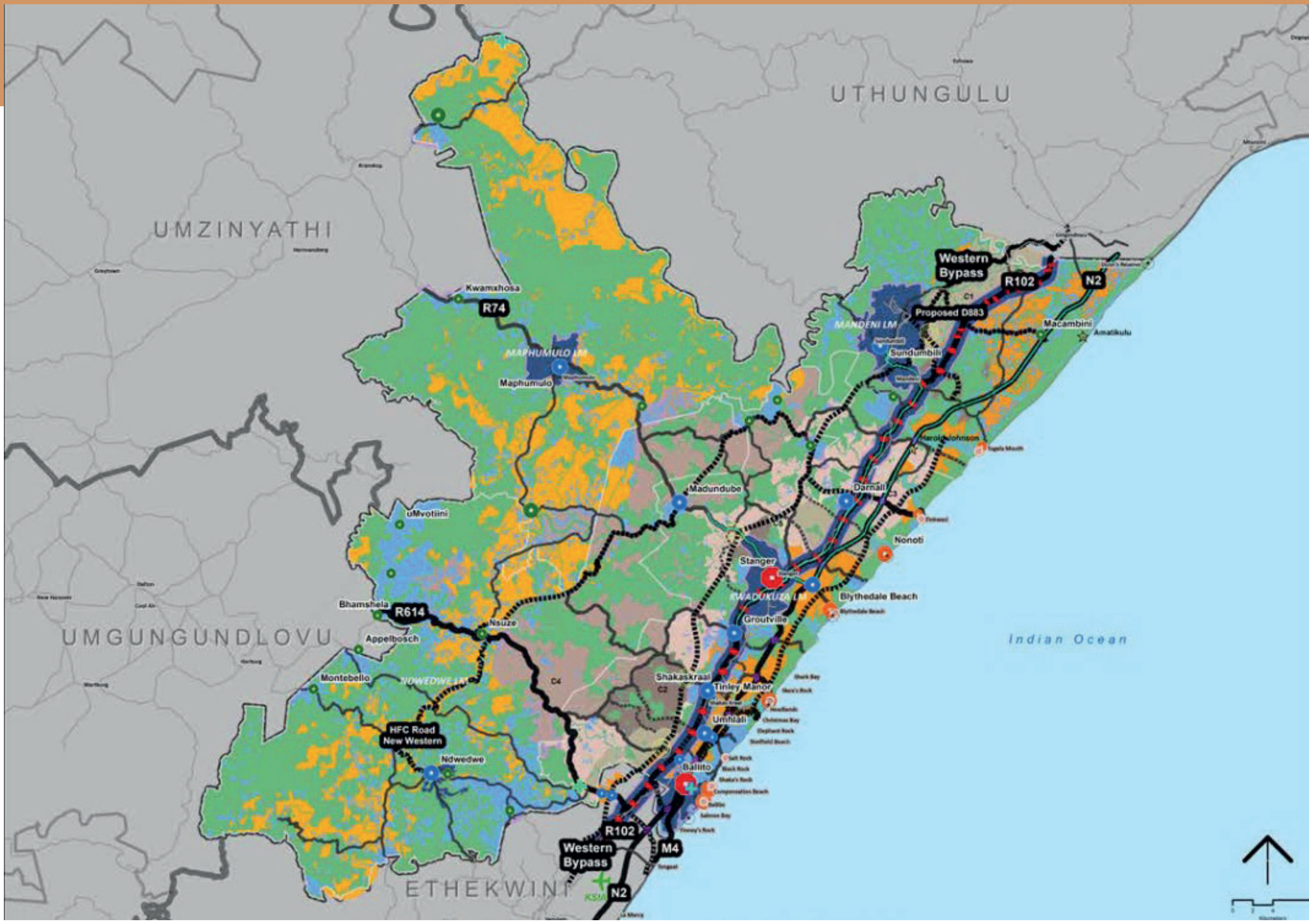
In KwaZulu-Natal, the DDM is closely integrated and aligned with the Operation Sukuma Sakhe (OSS) programme model, which brings together all service delivery stakeholders to provide services in an integrated manner.

The iLembe DDM One Plan includes the four local municipalities of Mandeni, KwaDukuza, Maphumulo and Ndwedwe as one integrated area. Located about 65 km north of the eThekwini Metropolitan Municipality, iLembe is linked by the N2 coastal highway to Durban in the south and Richards Bay in the north, giving it access to the two largest harbours in Africa. Immediately to the south of iLembe, within eThekwini, is the King Shaka International Airport and the renowned Industrial Development Zone (IDZ) of the Dube TradePort Corporation.

The district's main areas of urbanisation and industrial development are found within the KwaDukuza and Mandeni municipalities, whilst Ndwedwe and Maphumulo municipalities are mainly rural in nature. Most rural inland areas are tribal authority areas, characterised by low-income households, subsistence farming and sparse municipal services.

iLembe is a leading commercial, industrial, property development and tourism destination in the province. With a current population of about 694 000, the district has been experiencing high urban growth over the last 20 years with an in-migration of people into the district from surrounding areas. This places the development of economic opportunities and the provision of social and infrastructure facilities and services under huge pressure. The key long-term trends, challenges and opportunities that will direct the future development of the iLembe district are the following:

The population of the iLembe district will continue to increase from its current level of 694 540 persons to 787 078 by 2035



The 2021 Spatial Development Framework of the iLembe district

and possibly as high as 1,072 000 by 2055. iLembe is one of the municipalities in the province with the highest population and economic growth rates, creating the needs and opportunities for infrastructure development, higher levels of employment, basic service delivery and other social and socio-economic services developments.

The existing rural-urban migration trend in the district is expected to continue, resulting in an increased demand for new infrastructure, mainly along the broader coastal urban development corridor between Ballito and KwaDukuza. This is expected to grow northwards toward the fast-growing Mandeni progressively. While inward rural-urban migration and urban densification are taking place, the social and economic development needs of the rural areas of the district must receive attention. Sustainable provision of infrastructure, services, and the development of economic opportunities to enhance sustainable livelihoods will remain focus areas in future. Developing the small-town urban nodes of Ndwedwe and Maphumulo will require continuous and focused attention.

Poverty, inequality, and a lack of basic service delivery, especially in the shadow urban corridor and the rural areas, are embedded characteristics of the district that must be addressed in future. Unemployment levels are high, and household income levels are low. Developing the skill levels of the people of the district is, therefore, important and needs to be addressed.

The district is exposed to the threats of climate change. The frequency of droughts, floods and other extreme weather events is increasing. iLembe should therefore embrace new trends toward sustainable development and formulate long-term policies that place it in a position to engage meaningfully with environmental challenges.

Maintaining the existing infrastructure in the district and meeting the demands for new infrastructure development due to the high population and economic growth are fundamental challenges in the district.

The high levels of social and economic infrastructure, including basic services infrastructures such as water, sanitation, waste removal and electricity infrastructure, can only be addressed by adopting a well-coordinated approach between all levels of government and with the participation of the private sector and civil society.

Economic development leading to employment creation is vitally important in the district. Policies leading to cutting regulatory and administrative red tape, which hinders rapid business development, reviewing the district's industrial and commercial sector development policies and strategies, and maximising the tourism development opportunities are important facets of growing the district's economy. The application of innovative new technology products should be proactively pursued.

The district's location between the two most important harbours in Africa and the presence of the King Shaka International Airport and its associated Dube TradePort is important cornerstones that should be used to propel the long-term economic development of the district.
Investment attraction and retention remain key priorities in the district. Retaining the existing production factors and creating new businesses are crucial to ensure the district's future growth. Formulating policies on the provision of district-wide investment incentives and coordinating the raising of developer contributions by the local municipalities are important.

THE VISION FOR ILEMBE ONE PLAN IS:

"By 2050, iLembe will be a sustainable, diverse growing economic hub providing social well-being and equity of access for all its citizens."
iLembe One Plan is a visionary and transformative plan addressing the following key focus areas:

- Demographic change/people development.
- Economic growth and development.
- Spatial restructuring and environmental sustainability.
- Infrastructure engineering provision and maintenance.
- Integrated service provisioning.
- Governance and financial management development.

KEY FACTORS INFLUENCING FUTURE DEVELOPMENT

These focus areas provide the basis for putting the district on its future growth path. Key factors influencing future development are:

- Acknowledging the global digital transformation of economies and creating opportunities and infrastructure development;
- The need for sustainable development has significant implications for long-term planning, including: Renewable energy.
- Responsible for infrastructure development.
- New economic thinking in line with green initiatives.
- Multi-stakeholder collaboration and collective action.
- The use of new technology.
- Better provision for equity of access by gender, youth, and disability groups.
- Elevating public awareness for sustainable future economic development.

LONG-TERM GOALS

The long-term goals of One Plan are:

- To create a transformed and diversified economy that can provide jobs, attract investment, and create livelihoods for all citizens.
- To establish a new understanding of economic growth that better addresses human needs and makes more efficient use of natural resources.
- To develop communities that cater to local needs, prioritise the vulnerable, and provide practical support and participation to become the cornerstone of human dignity.
- To establish iLembe as a hub of socio-economic development using its urban-rural linkages regarding public transportation, accessibility, and spatial equity.
- To create a biologically diverse environment as a core element of civic space and urban and rural development.
- To develop iLembe with robust infrastructure and bankable projects that boost social development, health, wealth, access to education, public safety, and high living standards.
- To achieve breakthroughs in computing, mobile connectivity, innovation, and advanced intelligence with the ability to provide new services and service delivery systems that truly benefit everyone.
- To coordinate an effective, efficient, and reliable public and private partnership mechanism to manage challenges effectively.
- To formulate bold policy responses that better foster innovation, technological change, and social cohesion and prudently increase productivity.

Joint and collaborative planning at all levels of government, with the involvement of the private sector and civil society, lies at the core of the current One Plan. It is, therefore, necessary that the key programmes are related to institutional building and capacitation, such as:

- Formulating a new social compact: revitalisation of the iLembe Economic Development Facilitation Committee (iEDFC).
- Institution of permanent committees of national, provincial, and local government officials, private sector and civil society that align to the cluster committee structures to plan and monitor implementation of the DDM.
- Addressing the financial sustainability of the district and local municipalities.
- Formalisation and institutionalisation of the DDM One Plan procedures

and processes in the district - the technical and political hub institutional structure to be aligned to municipal decision-making and monitoring.

- Alignment of the DDM and IDP process with specific reference to the full involvement of the national and provincial sector departments in the planning process.

The One Plan should be supported through legislation and regulatory framework to assign responsibilities and implement and monitor.

THE WAY FORWARD

An initial draft of the iLembe One Plan has been circulated to national, provincial, and local government stakeholders for comments and input. An updated draft of One Plan will be circulated to all public and private stakeholders once the relevant structures have reviewed it within the DDM institutional framework.

The structures are four DDM sector clusters and the technical and political hub. There are plans to host a district-wide DDM workshop before finalising One Plan by November this year. wn

Astron Energy
- looking after the future of lubricants

At Astron Energy, we don't accept the status quo, particularly when challenges are industry-wide and costly. We sat down with David MacIntyre, Finished Lubricants Technical Manager at Astron Energy to find out which big innovation solutions have been developed for the energy sector.

Q. What is one of the biggest challenges that the energy sector faces given its reliance on equipment like turbines, hydraulic systems and compressors?

A significant challenge the energy sector faces is the build-up of varnish in lubrication systems. Varnish is a sticky residue that leads to system control valve malfunctions, blockages in lubricant galleries and filters, plus increased bearing friction and heat.

Varnish is caused by oil degradation and primarily through oxidation. Oxidation happens naturally in all lubrication systems due to the presence of oxygen. The oxidation process is accelerated by high temperatures. Excessive system heat is one of the most common triggers. Although lubricant manufacturers use antioxidants to inhibit oil oxidation and extend lubricant life, these antioxidants are gradually used up. For quite some time as the oil gradually degrades and impurities begin forming, these impurities remain dissolved in the oil and don't cause any harm. As more and more accumulate, they begin to condense and polymerise together forming insoluble, suspended submicron particles. The problem is that these deposits aren't collecting at the bottom of tanks but are moving throughout the system instead. Ultimately, these particles become electrically attracted to metal surfaces. When they start sticking to those surfaces, they become tacky varnish, that blocks up systems. Varnish is a wide-ranging term encompassing various types of deposits in oil systems.

A great explanation on how varnish is formed - "The products of lubricant degradation are called sludge and varnish. These products start in the dissolved form and accumulate until the lubricant reaches its capacity, referred to as the saturation point, forcing any excess to convert into insoluble degradation products. In certain instances, deposits form on machine surfaces at the exact location where the oil has degraded. In other cases, the oil degrades in one location, but the insoluble degradation products are carried elsewhere by the moving fluid forming deposits on surfaces. Over time, some deposits can thermally cure to a tough enamel-like coating." (from article in MachineryLubrication by Jim Fitch, Noria Corporation.)

Q. What is the significance of varnish in the energy sector?

The role of turbine oil under ideal circumstances is to lubricate and cool bearings while protecting the system against rust, corrosion and harmful deposits. Since turbine equipment is normally used in key applications, the reliability of rotating machinery and its lubricant is critical. Over time, varnish seriously impedes these functions causing a range of reliability concerns as mentioned above including, increase component wear, valves seizing and sticking, inefficient heat exchangers and overheating of journal bearings, as well as reduce lubricant, filter and seal life.

This makes the process inefficient and reduces the lifespan of components and the lubricant. When you consider that a single turbine oil tank could hold 60,000 litres of oil, having to potentially dump this oil prematurely comes at an extremely high cost.

Q. How can businesses determine if they have varnish in their systems?

Varnish can be very difficult to detect. Most operator have an oil analysis programme to check for contaminants in the oil, but standard oil analysis test may not indicate varnish even if it is present. However, incorporating oil analysis tests such as the RULER test - which monitors the depletion of antioxidants and Membrane Patch Colorimetry (MPC) - which measures the creation of varnish-forming oil degradation products, will measure the precursors of varnish.

The combination of a quality oil and a fit for purpose oil analysis program will payback in the form of increased oil life and greater plant reliability.

Q. How has varnish traditionally been treated?

A common traditional method of varnish removal is chemical cleaning. Chemical cleaning requires the system is "shut down" and chemicals are used to flush the system. The chemicals soften the varnish which is then flushed and captured through fine filters. This process can be time consuming. The system then needs to be flushed again to remove all traces of chemical and contaminants that may contaminate the new charge of lubricating oil.
The requirement that the system be shut down is problematic and alternative solutions that can alleviate this are desirable.

Q. Astron Energy is committed to finding innovative solutions for client challenges. What is the solution for varnish?

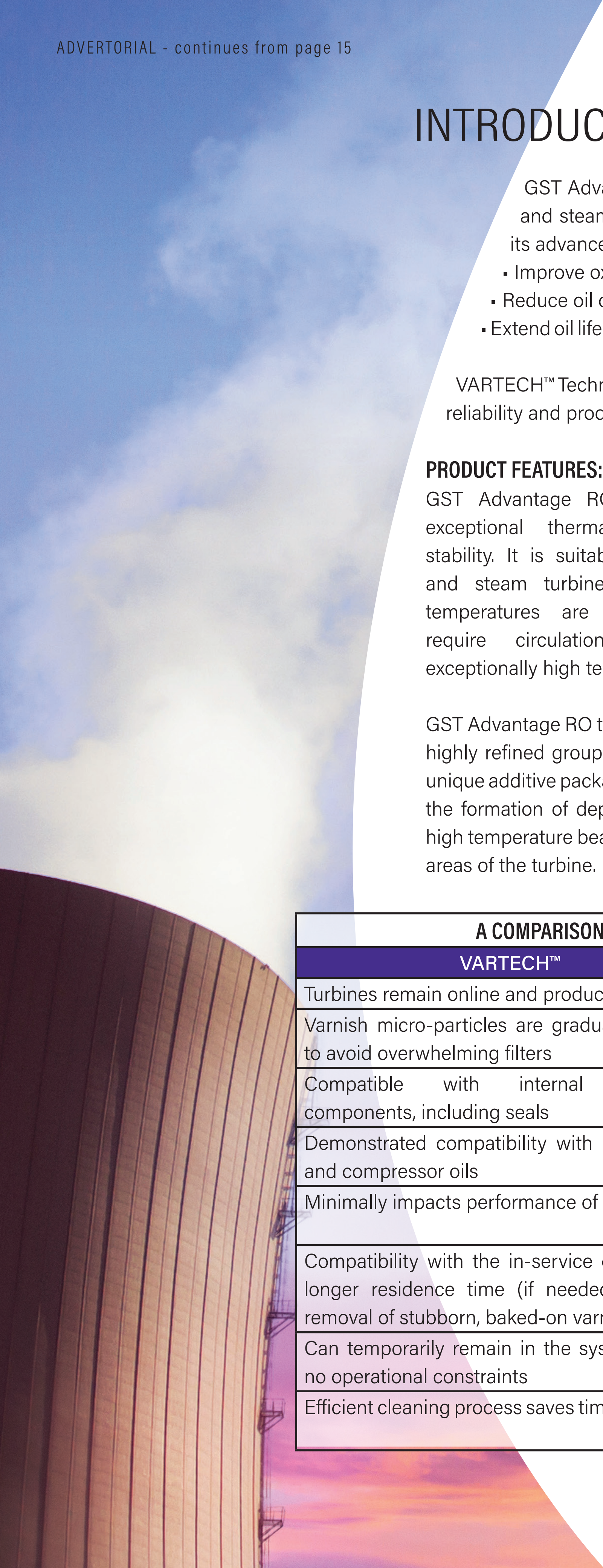
Chevron has developed a product called VARTECH™ that has completely revolutionised how businesses can combat the challenges presented by varnish. VARTECH™ comes in two products, VARTECH™ ISC (Industrial System Cleaner)- a concentrate deposit cleaning product and GST Advantage RO with VARTECH™ – premium turbine oil with VARTECH™ technology that inhibits varnish formation.

For customers who are nearing a routine maintenance cycle which includes an oil change, the VARTECH™ ISC concentrate can be added directly to the oil in use during operation to clean a system of varnish and sludge deposits before a scheduled oil change. It helps prepare the system for optimum performance of a new, fresh oil charge preferably our Caltex GST Advantage RO with VARTECH™. This significantly reduces downtime.

Thereafter, GST Advantage RO with VARTECH™ will prevent varnish build up from taking place as a matter of course while the equipment is operational. This keeps the entire system running optimally and ensures the full lifecycle of oil. The cost saving benefits are extremely high.

Q. Are future applications for VARTECH™ planned?

Absolutely. Chevron are in the process of testing and developing VARTECH™ for other applications, that also suffer from varnish. Widespread adoption of VARTECH™ will significantly reduce both planned and unplanned equipment shutdowns.



INTRODUCING VARTECH™ TECHNOLOGY

GST Advantage RO is the name of our high-performance industrial gas and steam turbine oil. It is formulated with VARTECH™ Technology and its advanced chemistry helps:

- Improve oxidation stability
- Reduce oil degradation
- Extend oil life by limiting harmful precursors that can lead to varnish formation

VARTECH™ Technology inhibits varnish formation to maintain peak performance, reliability and productivity.

PRODUCT FEATURES:

GST Advantage RO turbine oil has exceptional thermal and oxidative stability. It is suitable for use in gas and steam turbines where extreme temperatures are experienced and require circulation systems with exceptionally high temperature stability.

GST Advantage RO turbine oil combines highly refined group II base stocks and unique additive packages that minimises the formation of deposits in reservoirs, high temperature bearings and other hot areas of the turbine.

APPLICATIONS:

VARTECH™ Technology can be applied to non-geared gas, steam and hydroelectric turbines, including:

- Rotating machinery in gas and steam combined-cycle cogeneration units
- Air compressors, turbo-blowers and centrifugal pumps requiring a rust and oxidation inhibited oil
- Marine reduction gears where R&O oils are specified
- Industrial applications requiring R&O type circulating oils with extended service capability.

A COMPARISON OF VARTECH VERSUS CHEMICAL CLEANERS

VARTECH™	COMPETITIVE CLEANERS
Turbines remain online and productive	Shutdown sometimes required
Varnish micro-particles are gradually removed to avoid overwhelming filters	Large pieces of varnish can break loose and settle in other areas of the system
Compatible with internal equipment components, including seals	Harsh chemicals can damage seals and cause leaks
Demonstrated compatibility with most turbine and compressor oils	Has the potential to lower lubricant flash point causing higher fire and explosion risk
Minimally impacts performance of new oil	May accelerate oil degradation, shorten oil life and cause system corrosion
Compatibility with the in-service oil can allow longer residence time (if needed) for better removal of stubborn, baked-on varnish	Short cleaning cycle doesn't effectively clean
Can temporarily remain in the system causing no operational constraints	Repeated filter plugging and shorter filter life
Efficient cleaning process saves time and money	Shorter equipment life and higher maintenance costs

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NATIONAL SEA RESCUE INSTITUTE

Zest WEG Develops a significant manufacturing capability

Over the past 12 years Zest WEG, the South African subsidiary of Brazilian motor and controls manufacturer WEG, has evolved from being primarily a sales and distribution company to a fully-fledged manufacturer working to the best global standards.

"In 2010 WEG acquired a majority shareholding in Zest, which was the WEG distributor in South Africa," explains Eduardo Werninghaus, newly appoint Group CEO of Zest WEG. "While Zest had some manufacturing capability, its focus was on distributing WEG's range in the sub-Saharan market. Once WEG assumed control, the decision was taken to progressively expand the company's local manufacturing capability."

As Werninghaus points out, WEG, founded in 1961, is a truly global manufacturer with factories on all five continents. "In all, WEG manufactures in 12 countries outside of Brazil and the plants in these countries account for almost 50% of WEG's production. Manufacturing is in WEG's DNA and is now part of the DNA of the South African operation. Currently our manufacturing sites in South Africa are able to produce a wide range of equipment with varying levels of local content – more than 90% in the case of transformers and close to 70% for panels and E-Houses."

In Gauteng Zest WEG has two transformer manufacturing facilities. One is in Wadeville and the other in Heidelberg. "These facilities were acquired when we bought out two local manufacturers in 2013 and in 2015," says Werninghaus. "As a result, we now have the capability to locally manufacture transformers up to 45 MVA capacity."

Zest WEG has upgraded and extended the facilities, which are now equipped with state-of-the-art equipment including an impulse voltage generator at the Heidelberg factory which allows the in-house testing of transformers.

Also in Gauteng, Zest WEG – through its automation division – produces a wide range of electrical panels in Robertsham and E-Houses and electrical enclosures in Heidelberg.

In Cape Town, the company has a genset factory and a panel manufacturing facility. The genset site is dedicated to producing custom-engineered gensets and is complemented by an assembly line at Zest WEG's headquarters in Longlake, Johannesburg, which assembles boxed gensets and gear motors.

Werninghaus emphasises that Zest WEG has put a huge effort into building up a network of local suppliers, who contribute to the manufacturing process.

"We don't do this merely to meet government-mandated targets on local procurement but because it is something that WEG has always done," notes Werninghaus. "The company started up in the early 60s in the southern Brazilian state of Santa Catarina which was then very undeveloped so it really had no choice but to develop local suppliers. The process worked extremely well and is now standard throughout our global operations."

While Zest WEG's manufacturing drive has been highly successful, it has not been without its challenges, says Werninghaus. "WEG is a very aggressive company when it comes to manufacturing and is very focused

Local transformer manufacturing at Zest WEG's facility in Wadeville.

on efficiency and productivity and it was by no means easy to translate this WEG culture to the South African manufacturing operations," he remarks. "Nevertheless, our efforts have been rewarded and our South African plants now perform as well as those anywhere else in the global WEG group and work to the exact same quality standards."

On the benefits of local manufacture, Werninghaus says that it helps control costs, allows the customisation of products and also gives Zest WEG the ability to adapt much faster to changing specifications and regulations. "Most of all, however, it gives us a significant advantage in supplying the key African market. South Africa is the gateway to much of the continent and it's a strategic imperative for WEG to have a strong manufacturing and supply hub serving the African region." wn

Zest WEG's local manufacturing facility for E-Houses in Heidelberg.

Zest WEG's local automation manufacturing facility.

IEC Young Professionals Essay Competition - Candidates

ABOUT THE IEC YOUNG PROFESSIONALS PROGRAMME:

The IEC Young professionals' (YPs) programme was started by the International Electrotechnical Commission (IEC) in 2010, targeting engineers working in the electrotechnical industry in the age group early 20s to mid- 30s.
The objective is to ensure that the technical work of the IEC would be future-proofed with a growing number of new generation technical experts familiar with standardisation and the role of the IEC.

The first IEC YP programme took place in 2010, and South Africa was represented then and every year.

DR WARREN JAMES FARMER

Essay title: How can standardization be used to enhance the integration of renewables into the power system while reducing the energy cost of the end-user?

Age: 27

THE ESSAY

In the era of fossil and nuclear power generation, the synchronous machine generator serves as the heart of the power system. The design and operation of the power system network and its components are all done around the synchronous machine generator.

With the world becoming more environmentally conscious, focusing on environmental sustainability, and slowing down the effects of global warming, the power system is doing its part by transitioning from fossil fuel to renewable energy generation sources. The shift in the generation source includes the transition from synchronous generators to power-electronic inverters, which converts non-synchronous and intermittent generation (wind and solar photovoltaic power) to network-compatible synchronous output. The displacement of synchronous machine generators with inverter-based generation means the power system is losing valuable resources and services (fault current compensation and inertia for system frequency transient stability) necessary for the operation and stability of the power system.

Large-scale integration of inverter-based renewable energy sources introduces several new challenges and opportunities in power system operation. Large-scale integration of intermittent inverter-based generation impacts the power system fundamentally. A safe transition requires the development of new skills, knowledge, strategies, and innovation which requires investment from different sectors such as government, utilities, and manufacturers, of which the end-user will carry the financial costs. Standards can guide the energy transition process and assist in universal compatibility, comparisons, and collaboration to decrease breakdowns, increase efficiency, and accelerate the adoption of renewable energy, from which the end-user will ultimately benefit financially.

As the world enters the era of renewable energy, proper standards can lead the way for efficient, reliable, and cost-effective transition. This paper describes various ways standardization can enhance the integration of renewable energy while reducing the energy costs to the end-user. The focus is primarily on the power system network side, although the demand-side (user load) is also briefly touched.

First, a brief overview of the role standards can play in enhancing and integrating renewables. Second, we explore how renewable energy affects the cost of electricity through its impact on the power system infrastructure. Following up on the cost of integrating renewables like wind and solar power, and the importance of ancillary services in the "new" power system. In light of the aforementioned topics, we explore how standards can provide internationally harmonized solutions leading to global benefits and ultimately reduce the end-users' costs for electricity. Next, we mention a current project on developing a testing standard, that highlights the importance of testing standards to ensure reliability and safety in the environment the power system and renewable energy sources operate in. This essay then dives into the impact standards can bring directly to the end-users through efficient appliances, reducing energy consumption and thus saving the end-users money. Lastly, the conclusion highlights the key areas in how standards can enhance the integration of renewables into the power system while reducing the energy cost of the end-user.

Adoption of renewable energy projects

With global warming concerns, many countries collaborate on a global scale to reduce the emissions of greenhouse gasses. The introduction of what is known as a carbon tax - imposing a direct cost on each ton of greenhouse gas emissions emitted – is a policy to incentivize economic activities to reduce their contribution to carbon emissions [1].

A renewable energy portfolio standard (RPS) can mandate and promote the adoption and utilization of renewable energy sources [2] [3]. A renewable energy portfolio standard requires a certain percentage of a utility's sales come from eligible renewable energy technologies. The mandate gives a minimum projection of renewable energy integration and utilization in countries or states. The goal of the renewable portfolio standard policy is to deploy zero-carbon renewable resources. A clean energy standard (CES) or a renewable energy portfolio standard can promote the adoption of renewable energy by taxing processes with carbon emissions, making clean and renewable energy more cost-effective than other non-clean alternatives.

The process of integrating renewable power plants is a costly and technically challenging task. Development of standards based on experience and lessons learned can provide best practices for development projects. Clearly defined goals and expected timescales give investors and other stakeholders confidence in the development process.

Standards also provide effective communication between different parties. Industry standards give clear guidelines, interfaces, and output quality for all individual components and construction of projects. The use of standardization minimizes misunderstandings and incompatibilities, which may result in malfunctions, damage, or financial loss.

The task of billing electricity consumption and the rumination of electricity producers rely on accurate metering. Fair and agreed-upon metering mean a standard must specify the metering methodology and accuracy to ensure no disagreement between different parties. Standardized rates and tariff calculations also prevent excessively escalating costs.

Renewable energy as a “free” energy source?

Renewable energy sources such as wind and solar are seen by the public as free natural energy and thus the solution for clean and low-cost energy. Although the generation resources are free, the challenges they introduce comes at an operational and a financial cost. Without the proper thought-out implementation of renewable energy source integration, the power system's operating costs can increase, offsetting the "free" energy source thus resulting in more expensive electricity for consumers.

There are numerous publications and news articles on how the price of solar and wind energy has dropped below that of fossil fuels per kilo-watt hour (kWh) in the last decade [4] [5]. These price calculations are under the operational assumptions of the fossil fuel-powered power system network. The simplifying assumptions (intentional or unintentional) yield comparison values that are essentially not comparable.

The synchronous generator, primarily driven by fossil fuels, sets and stabilizes the system frequency through the online rotational inertia. The inertia acts as an instantiations responsive energy source to minimize power imbalances (between generation and demand, including system losses) due to network disturbances (faults). The power system is built and developed around alternating current (AC), oscillating at 50 or 60 Hertz, to enable efficient power transmission using transformers to step up and down the voltage and current. The synchronous generator also strengthens the power system by freely providing voltage and fault current support. Fossil fuel power stations are also dispatchable, giving the network operator control to balance the generation with the demand. These services are currently not available from intermittent and inverter-based generation utilities. The decommissioning of fossil fuel power stations (synchronous generator driven), and the increasing integration of inverter-based renewable energy sources, thus creating a decline in the free services and resources included with synchronous machine operation. These services will need supplementation from ancillary service providers at a financial cost to the system operator and finally costing the end-user.

Ancillary services

The large-scale integration of intermittent and inverter-based distributed energy sources makes the power system more complex and unstable. The shift from synchronous machine generation to inverter-based generation means the power system loses essential resources like mechanical inertia and fault level current. The integration of renewable energy cannot be at the cost of power system stability. The loss in synchronous generator resources means ancillary service providers must compensate for this decline to ensure power system stability.

There is increasing interest in the literature on creating virtual or synthetic inertia to address the inertia decline [6]. The objective of the virtual is to control an inverter in such a way that it emulates the inertial response of synchronous generators. An additional requirement for virtual inertia implementation is a fast-responsive energy source like a battery or supercapacitor behind the inverter representing the kinetic energy of the synchronous machine's rotor [7]. The advantage of virtual inertia control on inverters means that inverter-based renewable energy power plants can implement this to serve the power system network. The disadvantage of virtual inertia is the inherent time delay due to signal (voltage waveform for its frequency) measurement and processing to deploy active control, unlike the immediate passive response of synchronous generators [7]. This technology is still in concept and not mature for use yet. Synchronous condensers are, however, currently a practical solution. Installing synchronous machines and repurposing decommissioned power plants to operate in synchronous condenser mode can restore and increase system inertia as part of ancillary services.

The conversion of old synchronous generators to synchronous condensers is another area needing proper standardization. There will be a need for new structures (markets) to provide support services to the power system and thus allow, from a technical aspect, the integration of renewable energy sources. Historically, these support services came for free with synchronous generators driven by fossil or nuclear fuel. Decommissioning old synchronous generator power plants in favour of inverter-based renewable energy create a market need for ancillary service providers, which introduces additional financial costs to the power system operation.

The additional cost of ancillary services will drive up the overall cost of renewable energy, which will go to the end user's bill. The development of standardized practices can minimize the cost of implementing ancillary services to ensure continuous operation and quality supply while maximizing the integration of renewables to decrease electricity generation costs.

Internationally harmonized solutions

International standards provide harmonized solutions through compatibility, comparability, and collaboration. System and network components following international standards have a high degree of compatibility to integrate components and link to other networks, which has the advantage of economies of scale in the production of network components. The benefit of producing network components at a large scale is cost-effective production (producing specialized components at a lower cost per unit) which leads to savings for the end-user.

The transition to renewable energy is relatively new, and lessons on this technology and industry will be indubitably learnt. The industrial learning process can be a costly period where the end customers will ultimately pay. The more and the sooner the industry matures, the more cost-effective the integration process becomes. The benefit of using international standards is that the implementations are comparable, giving way to learning from international experience. A global knowledge pool and accumulating experiences deliver a faster learning period for efficient and durable solutions. Since engineers and technicians use the same international standards, it becomes easier to collaborate and share knowledge. All the benefits (compatibility, comparability, collaboration) from internationally harmonized solutions contribute to lowering the financial cost of integrating and operating renewable energy sources.

International standards also help governments accelerate the integration of renewable energy sources while reducing financial costs. Since the development of an international standard is done by a community of international experts who have experience in research, testing, development, and implementation, mean countries do not need to spend the cost to gain the necessary knowledge to develop these standards. A standard for renewable energy integration thus eliminates "re-invention of the wheel", which reduces the cost of renewable energy integration and ultimately helps end-users. The sooner the cost of energy production comes down, the sooner the end-users benefit financially.

Due to renewable energy integration and the policies around renewable energy being relatively new, the financial investment into renewable power plants (wind and solar) have the novelty as an additional risk factor. The development and presence of standards around renewable energy and its integration portray a maturity in the industry, which can only help attract financial investment to increase the integration of renewable energy.

The installation/integration of renewable energy sources and all the necessary components following a standard can ensure efficient operation, fewer breakdowns, and less consumption for end customers thus reduce the overall demand. An increase in demand relative to the supply (generation) is a force that raises the price of electricity for the end-users.

Veld fire project

An increase in renewable generation plants with an increase in total generation will lead to network expansions, i.e., transmission and distribution lines from the renewable energy plants and more energy customers connecting to the power system network. The locations with favorable natural resources for renewable energy are typically not near the demand (areas with high population density), which further drives the need for network expansion by building more power lines.

High voltage transmission lines are bare conductors, i.e., no insulation material around the wires. The air surrounding the wires functions as the insulation layer. The lines must thus have adequate spacing between themselves and sufficient clearance from other structures and trees to avoid high voltage arcing. The arcing can cause high current flow, overheating conductors, electrical losses, voltage dips, affecting the quality of electricity supply and component damages.

Currently, power system networks are equipped with fuses to isolate fault areas from the rest of the network, thus protecting network components. The most common type of fuse in the field is the Expulsion fuse, which shatters and drops onto the ground when triggered. There have been claims and eyewitness reports that these expulsion fuses cause ground fires when the hot incandescent particles from the expulsion fuse drop on surrounding grass fuels. With the increasing size of the power system network comes growing requirements for network protection and the usage of fuses. Fuses must be tested to determine their risk to the environment. My current work responsibility at Eskom is to propose and draft a standard to test expulsion fuses to discern the risk of starting a veld/ground fire.

Fuses are only one component of the power system network. The veld fire risk project is an example of how testing standards for various network components are necessary for safeguarding power system components, the system, the surrounding areas, and life within these areas. Renewable energy integration is only possible in an already robust system which must conform to a standard and suitable testing standards for adequate reliability.

End-user appliances

Standards and regulations require appliances to meet specific energy usage standards before they can be imported and sold to consumers [8]. Standards and regulations can protect consumers from purchasing electric apparatus that use a wasteful amount of electricity and improve the energy efficiency of appliances. Since the standards and regulations on consumer appliances define a minimum energy performance rating for electrical appliances, energy inefficient appliances cannot enter the market and sold to consumers. In addition, standards send a signal to manufacturers to improve the energy efficiency of their products. Consumers benefit from energy consumption standards since appliances available for purchase are more energy-efficient and cost less to run because of the electricity savings accumulating over the device's lifetime.

Household consumers are more likely to install solar photovoltaic than any other renewable energy source for their generation. Although the price of solar photovoltaic panels is steadily decreasing, the main drawback of solar energy is the generation period. Solar photovoltaic power generation is only during periods of solar irradiation, which does not coincide with the usage pattern and the time of peak energy consumption (morning and evening when energy consumption is the highest). Battery energy storage can compensate for the time mismatch; however, the cost of batteries increases the total upfront installation cost above the scope of consumers' budgets [9]. An alternative to battery energy storage is to feed energy into the power system network during the day while households are at their work and the solar energy production is at its highest. These households could receive energy credits for the energy fed into the power system network. The energy credits can then be exchanged for energy from the power system during periods of low or zero solar energy production.

It may be that businesses or households with no adequate rooftop area also want to generate their own solar or other forms of renewable energy to reduce their electricity bill. These consumers may find suitable offsite locations applicable for renewable energy production and then have an agreement to "transfer" the generated energy to the area of consumption over existing transmission and distribution networks. This concept is known as energy wheeling [10].

The reality of consumers also becoming energy producers enhances the integration of renewable energy while reducing the cost to the end-users. The network expansion, however, increases the power system's complexity and hardens the work of the network controller (power flow and balancing). Large-scale integration of grid-tie inverters from various manufacturers and models connecting to the power system network introduces harmonics into the network. The increase in harmonics is detrimental to the power quality. This evolution requires appropriate standards for the inverters, connection, and operation to ensure integrity, quality, and continuous operation.

Conclusion

In conclusion, the transition to renewable energy is changing the power system at its core. The generation footprint will shift from large and centralized to smaller spatially distributed generation units. The changes to the power system are from the topology to the fundamental operation. This transition needs guidance in the form of standards based on industry experience, expertise, and research. Using renewable energy standards will ensure compatibility of system apparatus and comparable experiences and thus ease collaboration of knowledge. In terms of operations, standards can also ensure proper and efficient functionality. All these factors contribute to lower costs for the end-users of electrical power generation.

MR PITSO SEKHOTO

Essay title: How can standardization be used to enhance the integration of renewables into the power system while reducing the energy cost of the end-user?

Age: 31

SABS

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

Two Young Professionals have the opportunity to attend the IEC Young Professionals Workshop to be held in conjunction with the IEC General Meeting in San Francisco, United States of America: **31 October to 4 November 2022.**

INVITATION

South African young professionals, Engineers, Technologists from the Electrotechnical discipline are invited to participate in the 2022 IEC Young Professionals Workshop by writing an essay on the following topic.

TOPIC

How can Standardization be used to enhance the integration of Renewable power system while reducing the energy cost of the end user.

GUIDELINES

1. Essays must be typed using (Arial,11 point) and should consist of +/- 3500 words (5 - 6 pages excluding the cover sheet provided).
2. Essays must be original and unpublished; plagiarised entries will be rejected.
3. Essays must be written by the entrant; co-authored essays will not be accepted.
4. Copyright of the essay entered will be assigned to the South African Bureau of Standards.

ARE YOU

- A young and dynamic manager, engineer or technician aged between 20 – 35?
- Are you interested in working with or developing standards or conformity assessment schemes?
- Working for a company, business, industry or studying at an institution that uses or benefits from IEC International Standards or conformity assessment systems?
- Wanting to become more involved in IEC-related activities?

THE ESSAY

1. INTRODUCTION

1.1 Standardization

Standardization is the process of developing and mandating standards-based and compatible technologies and processes within a given industry [1]. Standards for technologies can ensure that the quality and consistency of technologies are adhered to and all the technical, environmental, and safety issues are not addressed using different ways or methods. A non-standardized approach to issues can lead to inconsistencies and compromises in quality, safety, etc., which might result in fatalities and huge variations in costs to the end-user [2]. Figure 1 indicates how a standard is developed and the stages involved:

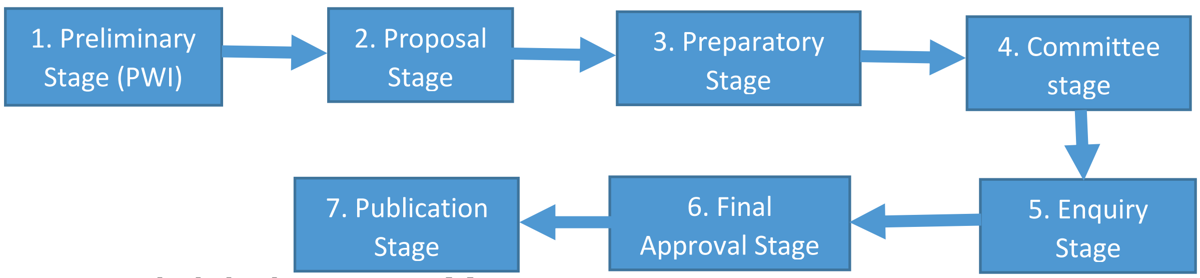

Figure 1: Standards development stages [2]

Standards provide written instructions and conformity assessment verifies that these instructions are properly applied in real-world technical devices and systems [2]. The purpose of a standard is to help researchers understand the value of innovation and enable them to conduct their research effectively. Furthermore, standards allow manufacturers to produce products of consistent quality and performance which will enable the end-users to reduce operational and maintenance costs by improving safety, quality, and risk management. Conformity assessment is a tool that can be used in ensuring that the end-user cost is optimized and all the challenges that come with the integration of renewable energy systems are addressed detailed in section 2.2 below.

1.2 Renewable energy

Renewable energy is derived from the earth's natural resources, which are not finite or exhaustible, but can be replenished at a reasonable rate as it is being consumed [3]. There are mainly five main renewable energy systems namely: Wind, Solar, Biomass, Hydro and Geothermal as shown in Figure 2 below.

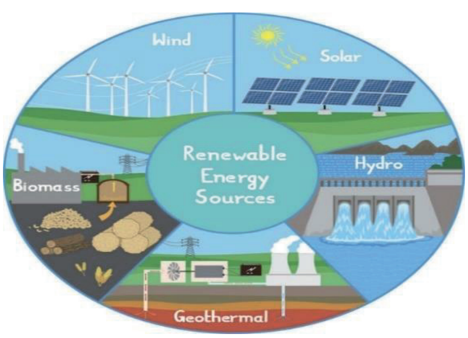

Figure 2: Renewable energy sources [4]

The essay will only cover the wind and solar energy systems, the integration challenges of those energy systems, and how standardization can improve integrated challenges whilst reducing the cost of the end-user.

1.2.1 Wind energy systems

Due to the increasing demand for more power in the world, Wind energy systems (WES) are one of the most viable sources of power as they offer clean energy and they produce no greenhouse gas emissions during operation[5]. Moreover, the WES uses an abundant source (wind) to generate electricity and they require little land, The WES has grown significantly high within the past years and more work has been done on them to better improve the technology, operation, maintenance, and most importantly to better harness the available wind. The WECS are made up of components namely: Rotor, Drive train, Generator, Nacelle, and Yaw system, controls, tower, and Foundation [5] and [6]. All the components must be designed and optimised to ensure the turbine generates enough electricity at any given wind profile as the amount of power generated is highly dependent on the availability of the wind.

i. Types of Wind turbine systems

There are two types of wind turbines namely the Vertical Axis Wind turbine (VAWT) and the Horizontal axis wind turbine (HAWT) [5], [7], and [9]. The names given to the two types of turbines are derived from how the turbines harness the wind energy and the name is derived from the axis in which the blades rotate about or on with reference to the tower when in operation.

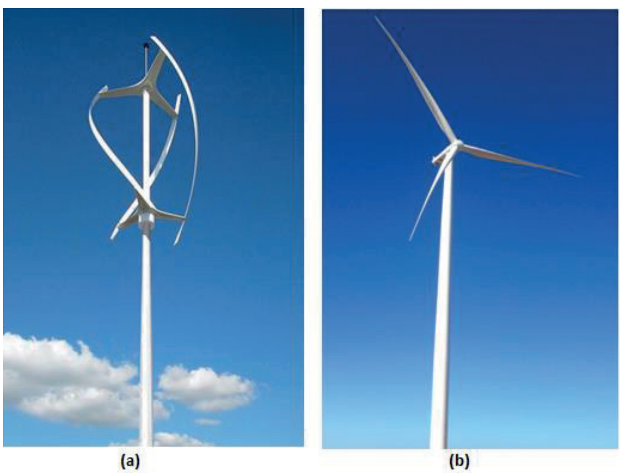

Figure 3 (a) Vertical Axis Wind energy system turbine [4]; (b) Horizontal Axis Wind energy system turbine [8]

Figure 3(a) above indicates the VAWT blades and main shaft only. The other components are not indicated, the reason being their located-on ground level. This has the advantage that it enables easy maintenance to be done to the WES [9].

ii. Operation of Wind energy system

WES are dependent on the availability of the wind in other to generate power. The WES can operate in three regions with respect to the wind speed, namely: Cut in speed, rated output speed and the Cut-out speed as shown on Figure 4 [6], [10] and [11]. The wind direction required to put the WES into service is referred to as the cut in speed [6]. The cut in speed is typically between 3-4 meters per second (m/s) as shown on Figure 4. When the wind speed is less that the cut in speed the turbine is left in idle mode, and it is not integrated to the electricity network (Grid). As the wind speed increases above the rated output wind speed, there is a risk of damaging the rotor and over spinning the blades. At this point the turbine is stopped and the rotor is brought to standstill [11].

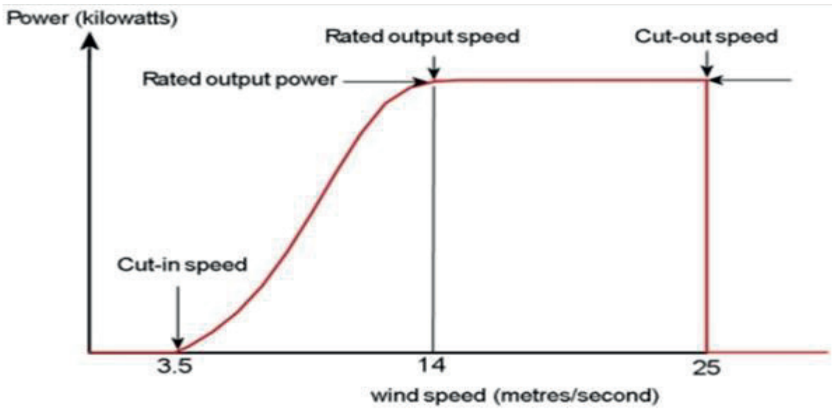

Figure 4: Power generated with respect to speed for WES [11]

iii. Wind energy challenges

When WESs are integrated into the grid there are a couple of problems and challenges that they must overcome and are essential for smooth integration. The problems or challenges can be categorized into three parts, the WES operation challenges, electricity network challenges, and lastly the WES generators challenges. The impact of these challenges on the power quality is very crucial and must be taken into consideration for optimally integrating the WES into the grid.

iv. South Africa's wind availability

The use of WES as an additional and alternative power source is increasing in South Africa. This is because renewable systems offer clean energy and can easily be erected the number of wind farms in South Africa is increasing due to the fact that the wind profile of the country is good and enable the WES to operate optimally depending on where the wind farm will be located. Figure 5 indicates that the wind profile is more suitable for a wind farm in coastal areas as most areas have a speed in the range of 4 - 9m/s.

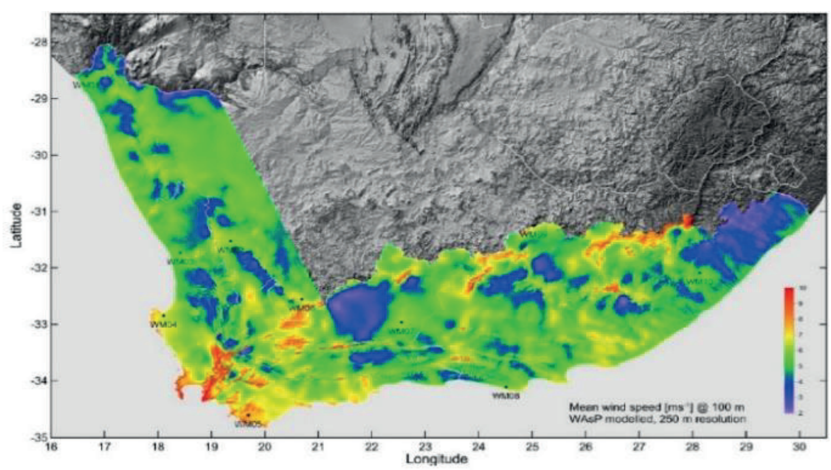

Figure 5: South Africa's wind energy profile and availability [12]

The reason why the speed range is acceptable is that as shown in Figure 5 the cut in speed for WES is in the range of 3-4 m/s, depending on the generator type and the technology used. So, the wind profile indicates that the mean speed will be able to operate the WES as the minimum of 4m/s can be achieved and better winds can be accessed if better sites are identified and established.

1.2.2 Solar energy

i. Solar Energy Definition

Solar energy is used to power equipment such as watches, calculators, cookers, water heaters, lighting, water pumping, communication, transportation, power generation, and many more. Solar energy, like all other renewable energies, is very safe and environmentally friendly [13]. There are two main types of solar energy technologies namely: photovoltaics (PV) and concentrating solar-thermal power (CSP). Solar technologies convert sunlight into electrical energy either through PV panels or through mirrors that concentrate solar radiation also known as CSP. This energy can be used to generate electricity or be stored in batteries or thermal storage. Solar photovoltaic modules are where the electricity gets generated but are only one of the many parts in a complete photovoltaic (PV) system or CSP system, there needs to be a full system that covers the integration of the Solar energy to the grid. Solar energy systems come in all shapes and sizes depending on the point of Integration and MW rating of the system.

ii. South African solar energy availability and challenges

The southern African region has sunshine all year round. The annual 24-hour global solar radiation average is about 220 W/m2 for South Africa, compared with about 150 W/m2 for parts of the USA [12]. Most areas in South Africa have an average of more than 2 500 hours of sunshine per year, and they have the average solar-radiation levels ranging between 4.5 and 6.5kWh/m2 in a day as shown in Figure 6 below. This makes South Africa's local resource one of the highest in the world [12].

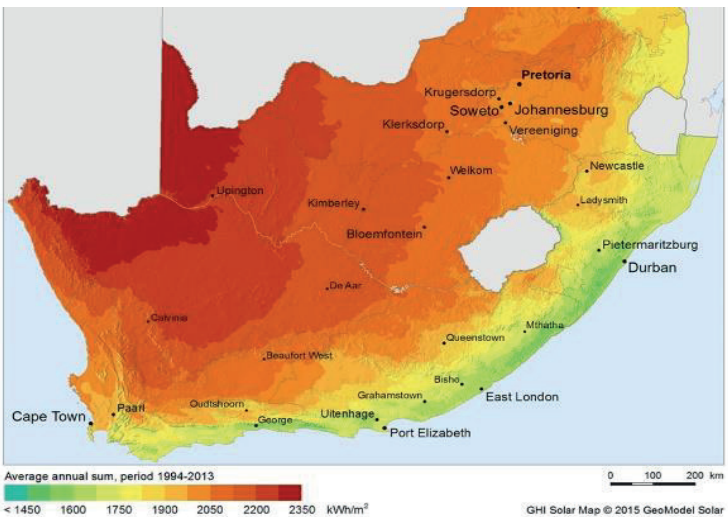

Figure 6: South Africa's solar energy profile and availability [12]

The use of solar energy is the most readily accessible resource in South Africa. It lends itself to several potential uses and the country's solar-equipment industry is developing [12] and [14]. Standardization will ensure that the solar energy potentials are fully explored.

2. MAIN CONTENT / THEME

2.1 Integration of renewable energy systems, requirements, standards, and grid code compliance

All renewable energy sources have different operating characteristics and it is, therefore, necessary to make a standard procedure for integrating renewable energy sources in the integrated system [15] and [22]. It is important to manage the power quality that renewable energy produces and to ensure that renewable energy systems operate accordingly and assist the grid during faults with problems such as voltage dips, faults, etc. This is achieved through the process of ensuring that the renewable energy system is optimally designed and operated and technically the voltage and frequency characteristics are of an acceptable standard. Figure 7 below indicates the classification of the potential challenges that are faced by renewable energy systems.

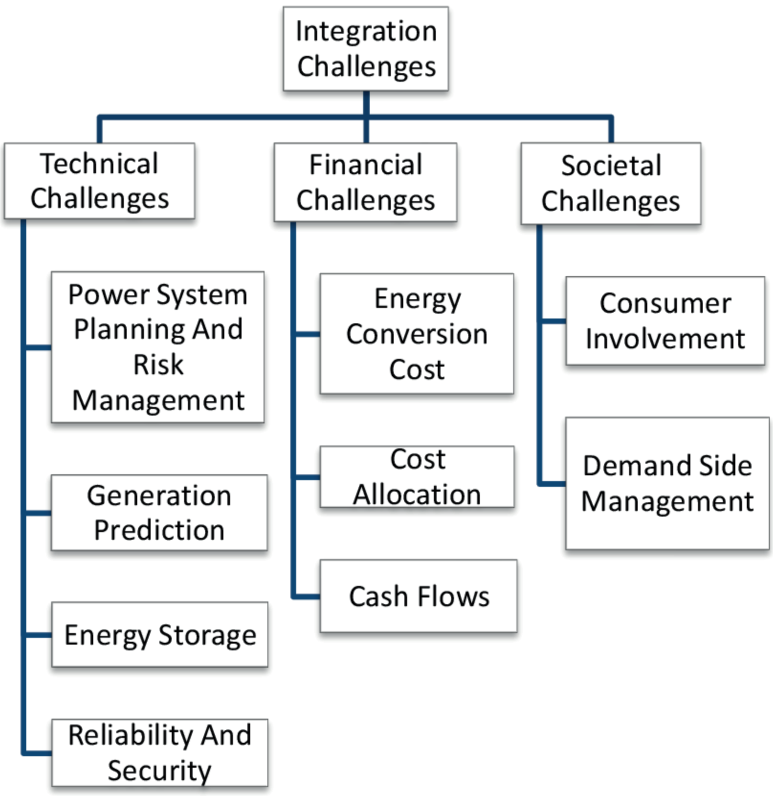

Figure 7: Classification of potential challenges in the integration of renewable energy resources. [15]

The challenges can be classified as technical, financial, and social challenges as indicated in Figure 7 above. Different companies have different ways and methods of addressing the challenges and thus the end-user costs are not standardized as solutions to various challenges are different across the industry. Standardization or having a set of options given as solutions to various challenges will enable the end-user to be able to design, operate and maintain the renewable cost-effectively with a proven solution that will not yield challenges in the future as those challenges then increase the end-user's costs. Section 2.1.1 and 2.1.2 below indicate how standardization via the South African grid code assists in ensuring that everyone has a baseline and assists with technical issues that deal with the integration of renewable energy into the South African grid.

2.1.1 South African grid code requirements

The objective of the grid connection code is to specify minimum technical and design grid connection requirements from the renewable systems. In South Africa, it can be integrated either at transmission voltage or distribution voltage level. The requirements cover the requirements of all different types of renewable energy and take into consideration the rated power output that they are injecting to the grid.

2.1.2 Different categories of renewable systems

Renewable energy systems can be divided into three groups which take into consideration the amount of rated power they inject at the POC. The groups are category A group which covers requirements of wind farms of the output power ranging between 0-1 MVA, category B covers the range 1-20 MVA, category C are wind farms that produce power rating of 20 MVA or higher. It is important that the power quality of the categories is maintained according to the requirements. The grid requirements, power quality, and control requirements of category C wind farms will be discussed in this research. Power quality is defined as the characteristics of electricity at a given point in the grid, the power quality is determined by looking at a set of technical parameters such as: voltage or current quality, harmonic distortions, voltage dips, supply interruptions, and frequency supply [16] and [17].

2.1.3 South Africa's power challenges and grid compliance problems

In South Africa, wind farms have a few challenges when it comes to meeting the grid code requirements, and thus that affect the amount of Wind farm that can be integrated. Most wind farms obtain temporal exceptions to operate outside the parameters specified in the grid code requirements and temporal exceptions are granted with the agreement that the issues shall be addressed and solved in an agreed timeframe, so a company will opt for the exception when the solution is costly at that given time and not the impact the decision can have on the grid. The exceptions granting process must be standardized and optimized so the end-users have a set of options provided to them and those options must be cost-effective and address the integration issue.

2.1.4 Energy Costs

Renewable energy systems have grown rapidly in recent years. The rapid growth is driven by environmental policies and the sharp cost reductions for solar photovoltaics and wind power systems. The electricity sector remains the brightest spot for renewables with the strong growth of solar photovoltaics and wind in recent years. However, electricity accounts for only a fifth of global energy consumption, and the role of renewables in the transportation and heating sectors remains critical to the energy transition [18]. Renewable energy systems can be of good value if they are standardized even in those sectors. Wind and solar PV installations can provide a smooth power output when the power plants are dispersed over a large area and there would be short-term fluctuations in the combined aggregated power output that can be avoided almost entirely by spreading solar PV and wind power plants across South Africa. This then means that these two energy sources can economically and technically supply bulk power to meet large parts of the country's electricity requirements. Solar PV output is higher during the day and wind output is higher in the evening which means the energy cost of each balance each other [12].

2.2 Conformance to the standard

Conformity assessment is the process of verifying that a standard or technical specification was applied in the design, manufacturing, installation, maintenance, or repair of a device or system. Conformity assessment itself needs to use a standardized approach [19]. Before a product can enter a market, it generally needs to be able to demonstrate to the buyer or regulator that it is safe and performs as promised in terms of energy efficiency, reliability, sustainability, and many other criteria [19]. Conformance assessment is a tool that can assist in enhancing the integration of renewable power systems while reducing the energy cost of the end-user. This assessment is carried out according to a set of well-defined rules to ensure consistency. Moreover, the conformity assessment assists the Governments and regulators have the resilience of infrastructure and are better able to protect their people from risks [19]. Furthermore, with renewable energy systems, Government can protect the environment and provide alternative clean energy. The end-users receive proof about a product's or system's safety, performance, and reliability. Also, Investors can trust that industry-wide best-practice has been applied and their investment is secure. The major advantage for end-users with the conformity assessment is that duplication tests are avoided, there is standard practice and common understanding across the industry, products are brought to market faster and at less cost, and the product and solutions provided comply with all the necessary regulations and requirements [21]. A lack of standardization often results in large numbers of incompatibilities and inconsistencies for a given renewable energy system. As a result, a lack of standardization limits the growth and penetration of renewable energy systems and is costly to the end-users [20]. The cost comes from technology maturity, lack of research, and investment in the technical solutions that deal with the integration of the renewable energy systems into the grid detailed in Figure 7 above.

3. CONCLUSION

In conclusion, standards help researchers understand the value of innovation and enable them to do it effectively. Furthermore, they allow manufacturers to produce products of consistent quality and performance which will enable the end-users to reduce operational and maintenance costs by improving safety, quality, and risk management.

The conformance assessment is a tool that can assist in enhancing the integration of renewable power systems while reducing the energy cost of the end-user. As an example, duplication of testing will largely be avoided, and products can be brought to market faster and at less cost. The different renewable energy systems and product will be type tested once and when it meets the assessment requirements other companies can then buy the product as an off the shelf solution which has been proven. wn

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Beware when selecting earth measurement equipment

By: Andreas Beutel (FSAIEE) Eskom Holdings SOC Ltd

Earth electrodes serve important functions in power systems, for example to:

- Maximize the likelihood that, in the case of an earth fault, there is sufficient current for electrical protection such as circuit breakers to trip.
- Keep step and touch potentials to a safe level.
- Limit the probability of back flashovers on transmission lines.
- Protect equipment from being damaged by dangerous fault currents or voltages.
- Provide an effective connection for the return current on single-wire earth return (SWER) and high voltage direct current (HVDC) schemes.

Lightning protection systems also have earth electrodes, the function of which is to safely conduct lightning current to earth.

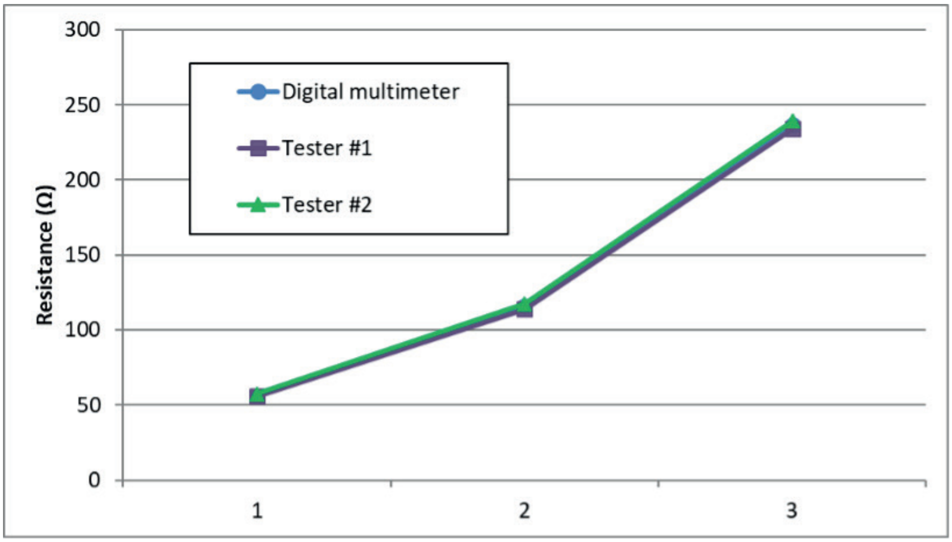

Fig 1: Sanity check of two makes of earth resistance measurement equipment

Electrical engineers and technicians are often required to measure the resistance of an earth electrode or the resistivity of soil in which an electrode will be inserted. The purpose of soil resistivity measurement in most cases is to adequately design an earth electrode, while the resistance of the finished electrode needs to be measured to ensure that it is within the requirement. Periodic maintenance measurements of electrode resistance may also be required.

It is therefore important to understand – and hence to have confidence in – the

capabilities of the equipment used to perform these measurements. It is also important to ensure that the equipment is functional before using it.

Two different models of such equipment were therefore tested in a laboratory before performing measurements in the field. The laboratory test involved the measurement of the resistance of three different resistors. The results – plotted in Fig 1 – show excellent agreement between the measurement equipment and a digital multimeter.

However, very different soil resistivity measurements were at times obtained in the field using these two testers. Fig 2 shows an example of a measurement with good agreement between the two testers (measurement 1) and one where the measurements differed widely (measurement 2).

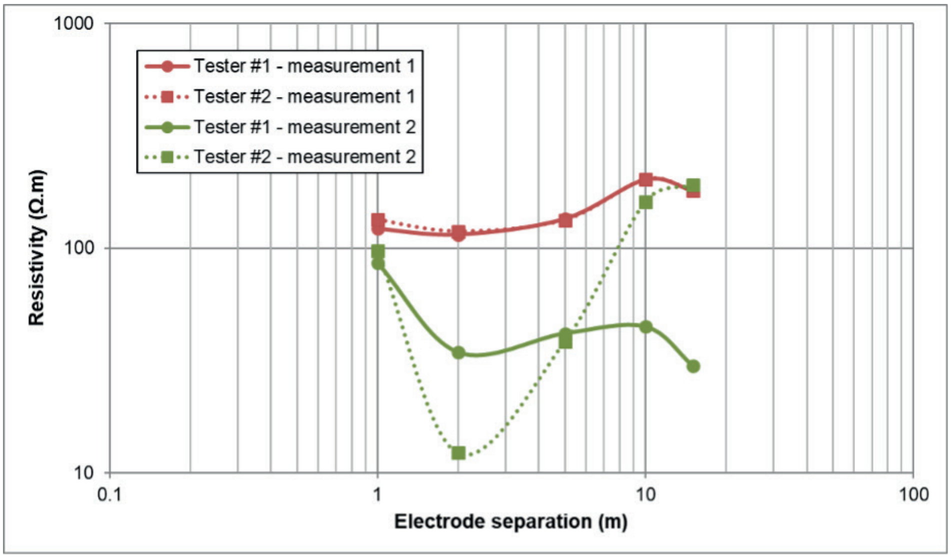

Fig 2: Example of discrepancy in soil resistivity measurement

The need was therefore identified to investigate this in more detail. This was performed as follows:

- Evaluating standards related to this measurement equipment. Much information was found for performing measurements, but little for selecting the equipment used for the measurements.
- Theoretically investigating the effect of probe depth on resistivity measurements to determine whether this could explain the erroneous measurements. This

showed that errors in probe depth while performing the measurements do not explain the errors shown in Fig 2.
- Performing tests using discrete resistors in a laboratory to mimic different values of soil resistivity and contact resistance, and performing similar tests for earth resistance measurement. This found a range of issues that can be addressed by a systematic laboratory evaluation of test equipment prior to its purchase.

The results are then discussed.

A third product was added, to give a larger sample of manufacturers.

RELATED STANDARDS

The standards that the manufacturer of each product claims compliance to, or otherwise lists in their product documentation, are listed in Table 1. Table 1 shows that no standard is common to all three testers.

IEC 61557-5 is the only standard that specifically covers earth resistance testers, but it applies only to low voltage distribution systems. A drawback of this standard is the high – at least at face value –uncertainty (error) requirement of ±30 %. The calculation method of the uncertainty is also complex.

SANS 10199 deals with the design and installation of earth electrodes, and therefore covers measurement of soil resistivity. The Wenner and Schlumberger methods are specified. Both methods use four electrodes (measurement probes) inserted into the ground with predefined spacing. In both cases the outer electrodes are used to inject a current into the ground and the inner electrodes measure the voltage produced by that current. The resulting resistance is used to calculate the resistivity. The methods differ in the spacing between the probes. Practical tips for performing the measurement is included, but measurement equipment is covered only in a very short section.

SANS 10199 also specifies the method of measurement of earth electrode resistance. The fall-of-potential method is specified in this regard, for small and medium-sized electrodes. For large (grid) electrodes, such as those used for substations, the method by Tagg is recommended. Practical assistance with performing these is included.

The IEEE has two standards that are relevant to the earth resistance and soil resistivity testing. IEEE Std 80-2013 (IEEE Guide for Safety in AC Substation Grounding, including 2015 corrigendum) only has a few sections relevant to this article, including the observation that the Wenner four-pin method is the most popular method for measuring soil resistivity and that its results are not significantly affected by the resistance of the test electrodes or by the holes made when inserting the electrodes into the ground. It also notes that conductive objects buried in the soil under test can invalidate measurements.

IEEE Std 81-2012 (IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System) has much relevant information, such as:

- The impedance of the test pegs can significantly affect the accuracy of impedance measurements, but there are ways of minimizing the associated errors. Also, the effect is not as serious when using the fall-of-potential method.
- Sufficient current must flow in order to obtain accurate and reliable measurements.
- Soil resistivity can be measured using one of two methods: the "variation of depth method or three-point method" and the four-point (Wenner) method. The latter appears to be more practical.
- Resistance of earth electrodes can be measured in one of several ways: two-point method (where the resistance of the electrode is measured in series with an auxiliary electrode), three-point method (two auxiliary earth electrodes are used to measure the resistance of the earth electrode under test), fall-of-potential method (also using two auxiliary electrodes), Tagg method, clamp-on or stakeless method and a combination of the fall-of-potential and clamp-on methods.

BS 7430:2011 (British code of practice for protective earthing of electrical installations, including corrigendum No. 1) contains similar soil resistivity measurement methods to IEEE Std 81-2012. Four earth resistance test methods are also given, all of which are variations of the fall of potential method.

SANS 10199, IEEE Std 81-2012 and BS 7430:2011 contain much useful information about earth electrodes and about performing related measurements. These standard are therefore recommended for further reading for interested readers.

Effect of electrode depth on resistivity measurements

Equation (2) of IEEE Std 81-2012 was used to calculate the apparent soil resistivity as a function of test electrode separation and depth, when using the Wenner method. The soil resistivity was calculated for different probe depths and was compared to the case where the probe depth is ignored (i.e. set to zero). The results are listed in Table 2. An earth resistance of 10 Ω was used, but the same errors were obtained when using 100 Ω and 1 kΩ.

Standard	Standard name	Tester #1	Tester #2	Tester #3
BS 7430 (1992)	Code of practice for the earthing of electrical installations	X		X
BS 7671 (1992)	Requirements for electrical installations (IET wiring regulations)	X		X
NFC 15-100	French electrical installation regulations	X		X
VDE 0413-7 (1982)	It was not possible to find this standard			X
IEC 60364	Low-voltage electrical installations	X		X
IEC 61010-1	Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements	X	X	
IEC 61557-1	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 1: General requirements	X		
IEC 61557-5	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 5: Resistance to earth	X	X	
IEC 60990	Methods of measurement of touch current and protective conductor current	X		
IEC 60529	Degrees of protection provided by enclosures (IP Code)	X		
IEC 61326-1	Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements	X	X	
VDE 0100	Erection of low voltage systems	X		
VDE 0141	Earthing in AC systems with nominal voltages of greater than 1 kV (unable to find this)	X		
EN 50173	Information technology – Application-neutral communication cable systems	X		
IEC 62305	Protection against lightning	X		
IEC 61000-4-2	Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test		X	
IEC 61000-4-3	Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test		X	

Table 1: Standards to which test equipment claims compliance or otherwise listed in product documentation

Table 2 shows that errors due to variations in electrode depth do not explain the errors of Fig 2. The next step was therefore to investigate the effect of different values of soil resistivity and earth electrode resistance (depending on the test performed) and contact resistance between the test probes and the soil.

EFFECT OF DIFFERENT VALUES OF SOIL RESISTIVITY AND CONTACT RESISTANCE

The circuit in Fig 3 was used. The Wenner method was chosen since that appears to be the most practical and popular. The measurement equipment under test ("tester" in the figure) injects a current into the outside loop of the circuit, which consists of three discrete resistors to mimic the ground (RGL, RGM and RGR) and a resistance to model the contact resistance of each current electrode (RCL and RCR). The tester measures the voltage across RGM (effectively the "resistance under test") via its two contact resistors (RVL and RVR).

The test circuit of Fig 3 was set up by mounting the seven required resistors on a bread board, as shown in Fig 4.

Probe separation (m)	Probe depth (cm)					
	5	10	15	20	25	30
1	0.4%	1.7%	3.7%	6.2%	9.1%	12.1%
2	0.1%	0.4%	1.0%	1.7%	2.6%	3.7%
5	0.0%	0.1%	0.2%	0.3%	0.4%	0.6%
10	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
20	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 2: Effect of probe depth on resistivity measurements

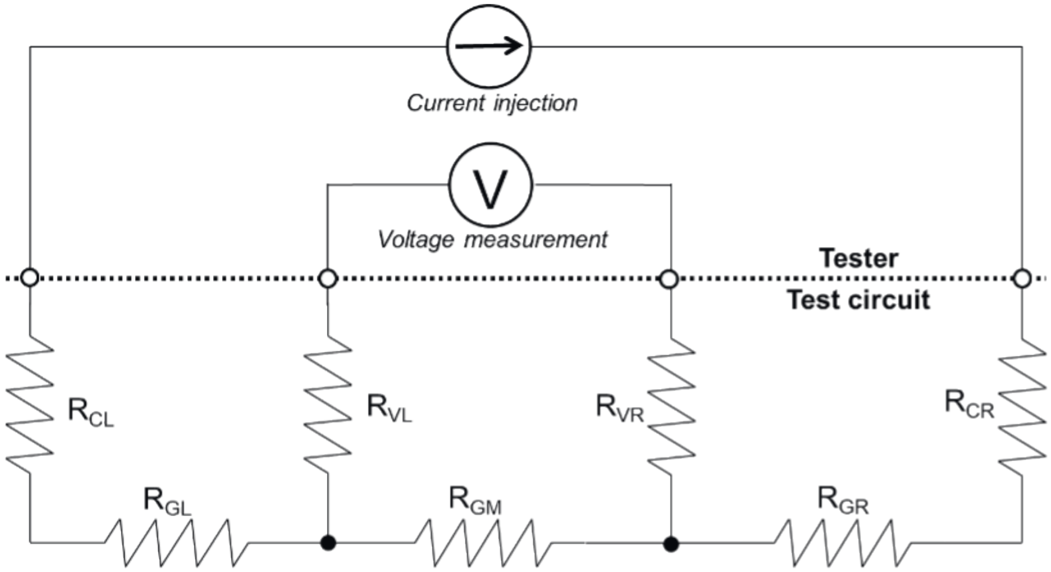

Fig 3: "Soil resistivity" laboratory test circuit

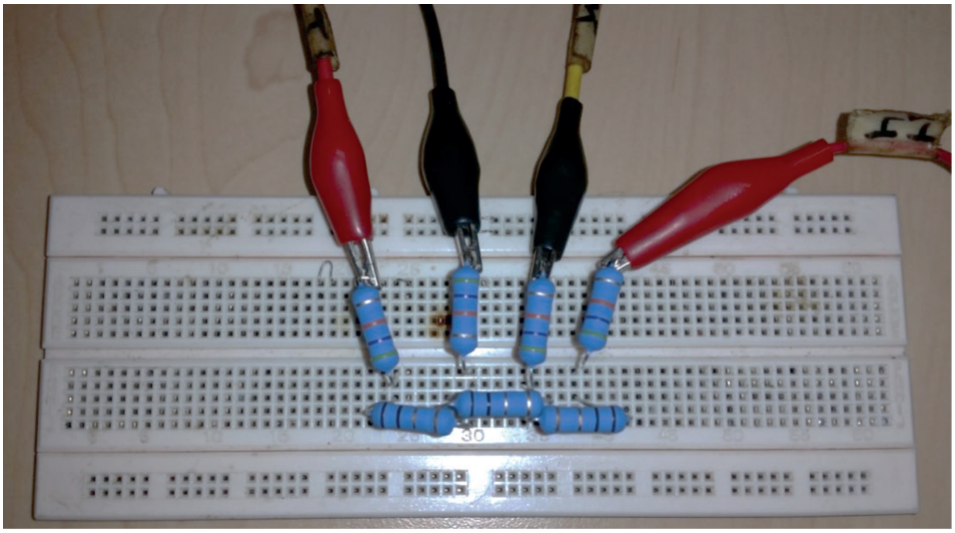

Fig 4: "Soil resistivity" laboratory test setup

Probe separation	Soil resistivity				
	10 Ω.m	100 Ω.m	1 kΩ.m	10 kΩ.m	100 kΩ.m
1 m	1.6 Ω	16 Ω	159 Ω	1.6 kΩ	15.9 kΩ
2 m	0.8 Ω	8.0 Ω	80 Ω	796 Ω	8.0 kΩ
5 m	0.3 Ω	3.2 Ω	32 Ω	318 Ω	3.2 kΩ
10 m	0.2 Ω	1.6 Ω	16 Ω	159 Ω	1.6 kΩ
15 m	0.1 Ω	1.1 Ω	11 Ω	106 Ω	1.06 kΩ
20 m	80 mΩ	0.8 Ω	8.0 Ω	80 Ω	796 Ω
50 m	30 mΩ	0.3 Ω	3.2 Ω	32 Ω	318 Ω

Table 3: Measured resistance as a function of probe separation and resistivity

Probe contact resistance ($R_{CL} = R_{VL} = R_{VR} = R_{CR}$)	Soil resistance ($R_{GL} = R_{GM} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ**	22 kΩ
10 Ω	X	X	X	X	X	X	X	X	X
100 Ω					X	X	X	X	
1 kΩ	X	X	X	X	X	X	X	X	X
10 kΩ					X	X	X	X	
47 kΩ*	X	X	X	X	X	X	X	X	X
56 kΩ			x			x		x	
100 kΩ						X			
150 kΩ						x			
200 kΩ						x			

** 46-49 kΩ   ** 19-19.7 kΩ*

Table 4: "Soil resistivity" laboratory tests performed

The range of resistors needed for the three ground resistances (RGL, RGM and RGR) was determined from the expected range of soil resistivities and electrode separations, as shown in Table 3. The lower limit of RGx was therefore chosen as 0.01 Ω. The upper limits of the resistances were chosen using the specifications of the three testers: all specified a maximum of 20 kΩ for soil resistance and 50 kΩ for contact resistance.

The actual tests performed are listed in Table 4. Time limitations meant that not all tests could be performed, hence the fact that some cells are empty. The tests marked with "X" were performed using all three testers, those marked with "x" were only applied to Tester #3 since this one proved to have a wider range than advertised.

The values measured by the three testers were compared to the values measured by a digital multimeter. The multimeter cannot accurately measure at 1 Ω and below, errors calculated for those resistances may therefore not be accurate due to lack of a reliable comparison (the labelled resistance was used for comparison purposes).

"SOIL RESISTIVITY" LABORATORY TEST RESULTS

These are tabulated in Tables 5-7. The colour coding used is explained in Table 8. Testers #1 and #2 include the option of displaying the measured resistance (from which the resistivity can be calculated) or calculating the resistivity if the user enters the probe separation. Tester #3 does not include the second option.

The results show that the range of soil resistivity that each item of test equipment is able to measure varies greatly, even though the manufacturers' specifications are relatively similar. Also, the built-in resistivity calculation does not always give the correct result. However, it should be noted that errors calculated for soil resistance of 1 Ω and below are not necessarily accurate, due to the inability to accurately determine the actual resistance at those low values. In any case, the results cast doubt on the suitability of relying on conformance to IEC 61557-5 as the sole measure of equipment performance.

EFFECT OF DIFFERENT VALUES OF EARTH ELECTRODE AND CONTACT RESISTANCES

The laboratory tests were repeated for the case where the resistance to earth of an earth electrode is measured. The three-point method illustrated in Fig 5 was used. The electrodes in the first figure are included for illustration only, they were not used during testing. The three testers were put through their paces using a three-electrode test – using three connections (wires) and four connections. All testers offer the option of making the measurement using four wires. They can hence also be used in three-wire mode by making the required connections externally to the test equipment. Testers #1 and #2 also offer the setting of using the three-wire method via internal connection to the measurement equipment.

The laboratory testing principle is much the same as was used for the

Probe contact resistance ($R_{CL} = R_{VL} = R_{VR} = R_{CR}$)	Soil resistance ($R_{GL} = R_{GM} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω	-	-10.0%	-3.0%	-4.0%	-1.7%	0.2%	0.2%	0.1%	-
100 Ω					2.9%	0.1%	-0.5%	-0.2%	
1 kΩ	900%	0%	20%	-1.9%	1.9%	0.1%	-0.5%	-0.2%	-
10 kΩ					2.4%	0.1%	-1.5%	-	
47 kΩ	-	-	-	-	-	-	-	-	-
56 kΩ									
100 kΩ						-			
150 kΩ									
200 kΩ									

Probe contact resistance ($R_{CL} = R_{VL} = R_{VR} = R_{CR}$)	Soil resistance ($R_{GL} = R_{GM} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω	-	20.4%	2.9%	3.9%	1.9%	-1.0%	-0.4%	0.0%	-
100 Ω					0.9%	0.4%	0.5%	-0.2%	
1 kΩ	-1492%	-59%	-11.4%	2.7%	-0.1%	0.2%	0.2%	-0.2%	-
10 kΩ					-0.1%	0.2%	-0.1%	-	
47 kΩ	-	-	-	-	-	-	-	-	-
56 kΩ									
100 kΩ						-			
150 kΩ									
200 kΩ									

Table 5: "Soil resistivity" laboratory test results for Tester #1 – displayed resistance (above) and resistivity for 1 m electrode separation (below)

Probe contact resistance ($R_{CL} = R_{VL} = R_{VR} = R_{CR}$)	Soil resistance ($R_{GL} = R_{GM} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω	0.0%	0.0%	1.0%	-4.2%	-0.9%	-0.7%	-2.2%	-5.4%	-5.4%
100 Ω					0.9%	0.9%	1.8%	5.2%	
1 kΩ	-	-40%	10.0%	-3.6%	1.3%	1.8%	2.3%	5.6%	-5.6%
10 kΩ					16.1%	11.0%	4.2%	7.8%	
47 kΩ	-	-	-	-	-	-	-	-	-16.9%
56 kΩ									
100 kΩ						-			
150 kΩ									
200 kΩ									

Probe contact resistance ($R_{CL} = R_{VL} = R_{VR} = R_{CR}$)	Soil resistance ($R_{GL} = R_{GM} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω	93%*	13%*	10.9%*	5.4%	9.0%	9.1%	-	-	-
100 Ω					10.1%*	10.1%*	-	-	
1 kΩ	-38%	-4.5%	21%	6.3%	10.0%*	10.3%*	-	-	-
10 kΩ					16.8%	21%	-	-	
47 kΩ	-	-	-	-	-	-	-	-	-
56 kΩ									
100 kΩ						-			
150 kΩ									
200 kΩ									

** Apparent incorrect calculation of resistivity from resistance by the instrument.*

Table 6: "Soil resistivity" laboratory test results for Tester #2 – displayed resistance (above) and resistivity for 1 m electrode separation (below)

Probe contact resistance ($R_{CL} = R_{VL} = R_{VR} = R_{CR}$)	Soil resistance ($R_{GL} = R_{GM} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω	160%	12%	0.4%	-3.9%	-0.7%	-0.1%	-0.5%	-0.7%	-
100 Ω					0.6%	0.1%	-0.2%	0.6%	
1 kΩ	110%	-5.0%	9.4%	-2.3%	0.6%	0.1%	0.2%	0.7%	-
10 kΩ					1.4%	0.6%	0.8%	1.2%	
47 kΩ	-	-	2.2%	-8.6%	-3.3%	-2.4%	-2.9%	-2.7%	-
56 kΩ			25%			-2.8%		-3.3%	
100 kΩ						4.6%			
150 kΩ						-6.5%			
200 kΩ						-7.2%			

Table 7: "Soil resistivity" laboratory test results for Tester #3 – displayed resistance

< 10%
10-30%
>30%

Table 8: Colour coding used for laboratory test results

soil resistivity tests. The combinations of resistances tested are listed in Table 9. The tests were chosen to roughly cover both substation (0.1 Ω to 10 Ω) and distribution (10 Ω to 100 Ω) applications. All of the chosen tests could not be performed due to time constraints, so the most reasonable ones to fit into the time available were chosen.

It was pointed out at a later date that RGL will always be less than RGR, leading to the effect of RGR being insignificant, so RGR should be added to RC – this has been updated in Fig 6. The blocks with red text in Table 9 and in the test results can therefore be ignored, if necessary. A similar exercise may be necessary for the circuit used to evaluate the soil resistivity measurement function (Fig 3).

Probe contact resistance ($R_V = R_C$)	**Earth resistance ($R_{GL} = R_{GR}$)**								
	0.01 Ω	**0.1 Ω**	**1 Ω**	**10 Ω**	**100 Ω**	**1 kΩ**	**10 kΩ**	**19 kΩ**	**22 kΩ**
10 Ω		X	X	X	X				
100 Ω		X	X						
1 kΩ		X	X						
10 kΩ		X	X						
47 kΩ		X	X	X	X				
56 kΩ									
100 kΩ									
150 kΩ									

Table 9: Laboratory "earth electrode" measurements performed

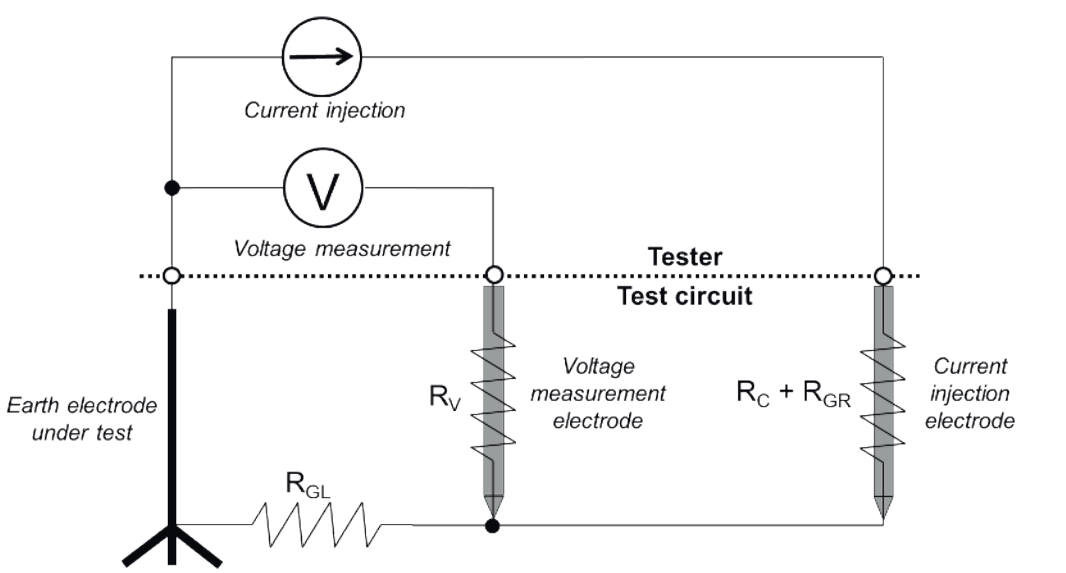

Fig 6: More accurate "earth resistance" laboratory test principle (three-wire internally connected method as an example)

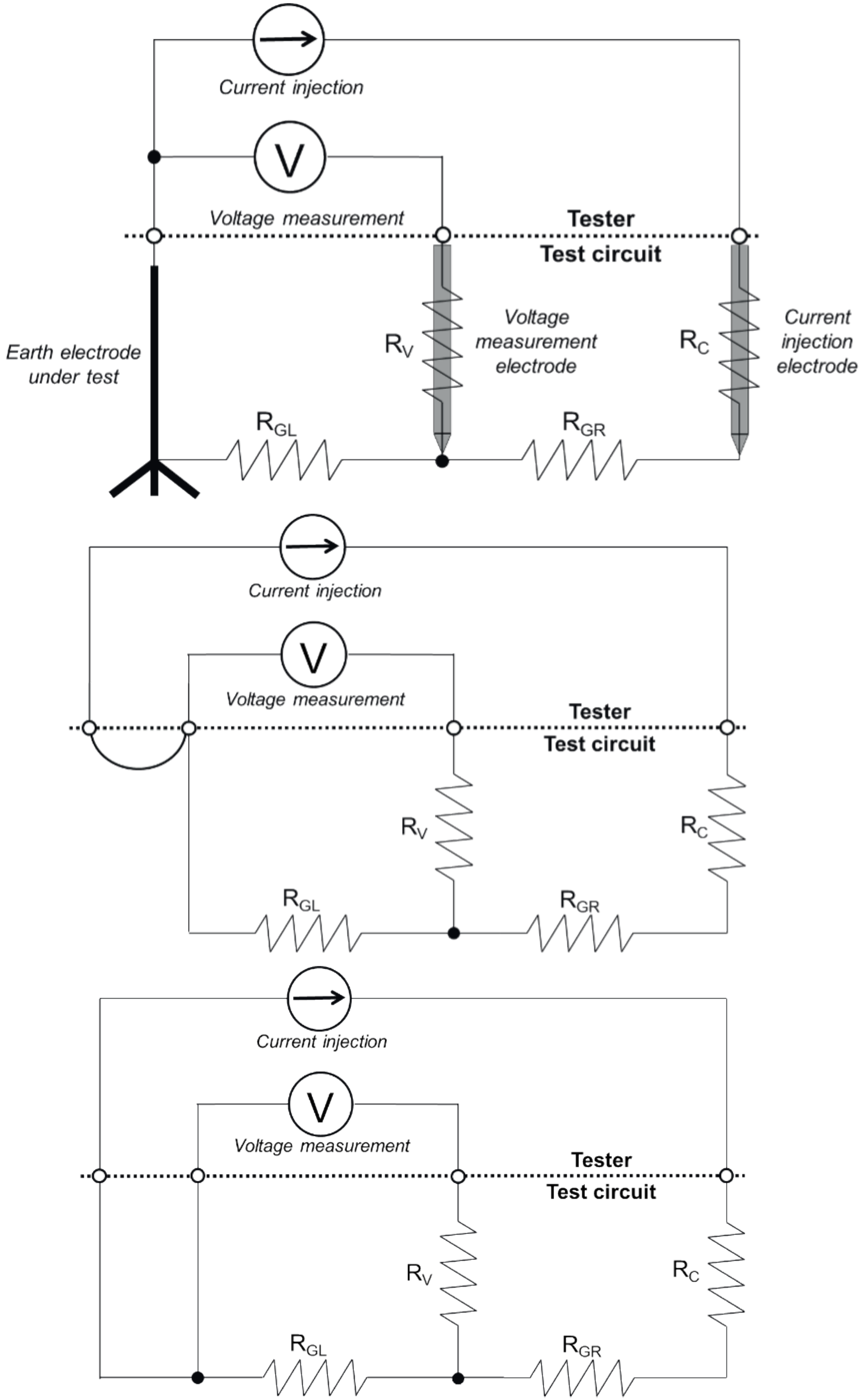

Fig 5: Laboratory "earth electrode" resistance test principle – 3-wire internally connected (above), 3-wire external connection (centre), 4-wire connection (below)

"EARTH ELECTRODE" LABORATORY TEST RESULTS

These are tabulated in Tables 10, 11 and 12. The same colour coding as before (Table 8) was used. The uncertainty around errors calculated for earth electrode resistance of 1 Ω and below should once again be noted. That notwithstanding, Tester #3 produced mostly very accurate results using the four-wire method, but not using the three-wire method. However, it did give an error for one of the measurements. Testers #1 and #2 produced mostly accurate measurements above 1 Ω, but there are some exceptions. In any case, more measurements would be required to produce a more complete table, in a similar way as was performed for soil resistivity measurement.

DISCUSSION

It is very important to accurately and confidently measure the resistance of earth electrodes and the resistance of the soil in which they are used. SANS 10199, IEEE Std 81-2012 and BS 7430:2011 give useful information about performing these measurements. IEC 61557-5 provides performance requirements for the measurement

3-wire internal									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		380%	33%	3.8%	0.1%				
100 Ω		650%	42%						
1 kΩ		990%	97%						
10 kΩ		400%	90%						
47 kΩ		900%	0%	-3.8%	0.1%				

3-wire external									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		330%	20%	-3.8%	-1.8%				
100 Ω		270%	68%						
1 kΩ		1050%	54%						
10 kΩ		600%	100%						
47 kΩ		-	-	-3.8%	0.1%				

4-wire									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		-40%	-0.4%	-4.1%	-1.8%				
100 Ω		-30%	-1.0%						
1 kΩ		-20%	0%						
10 kΩ		-100%	-10%						
47 kΩ		-	-	-3.8%	0.1%				

Table 10: Laboratory "earth electrode" test results for Tester #1

3-wire internal									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		450%	41%	8.7%	-0.3%				
100 Ω		440%	153%						
1k		900%	97%						
10k		1430%	221%						
47k		13050%	1802%	110%	-0.7%				

3-wire external									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		190%	33%	-2.3%	-0.2%				
100 Ω		830%	20%						
1k		130%	15%						
10k		660%	303%						
47k		12890%	1588%	134%	0.8%				

4-wire									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		-10%	-1%	-4.4%	-0.8%				
100 Ω		0%	0%						
1k		10%	3%						
10k		640%	66%						
47k		16050%	1186%	81%	0.5%				

Table 11: Laboratory "earth electrode" test results for Tester #2

3-wire external									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		70%	7%	-3.6%	-0.6%				
100 Ω		100%	16%						
1 kΩ		72%	142%						
10 kΩ		1200%	109%						
47 kΩ		100%	51%	-2.4%	0.6%				

4-wire									
Probe contact resistance ($R_V = R_C$)	Equivalent earth electrode resistance ($R_{GL} = R_{GR}$)								
	0.01 Ω	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	19 kΩ	22 kΩ
10 Ω		2.0%	-1.0%	-4.1%	-0.7%				
100 Ω		4.0%	1.6%						
1 kΩ		2.0%	1.7%						
10 kΩ		2.0%	-0.4%						
47 kΩ		-	-5.5%	-5.1%	-1.7%				

Table 12: Laboratory "earth electrode" test results for Tester #3

equipment, but only for earth resistance measurement in low voltage distribution systems. No other standard was found that specifically covers this type of measurement equipment.

The test results in this article indicate that one should not be relying on compliance to IEC 61557-5 as the sole criterion for acceptable measurement equipment performance. The test results also show that some measurement equipment performed better in some applications than in others, e.g. wet or dry soil or substation or distribution network use.

It has also been shown that the automatic soil resistivity calculation of some equipment can give erroneous results. It is also shown that the four-wire earth resistance measurement method gives more accurate results than the three-wire method.

Earth resistance and soil resistivity measurement equipment should therefore ideally be evaluated by the end user in a similar way as was done here – and for the intended application – before the equipment is purchased. However, this is a time-consuming process and thus needs to be refined and optimized. Performing such verification tests nevertheless has merit because obtaining an incorrect measurement without the user knowing this could result in serious safety consequences or additional cost due to damaged equipment or having to modify a system after it has been constructed.

ACKNOWLEDGEMENTS

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An investigation into lightning initiating veld fires in Western Cape and Eastern Cape Provinces, South Africa

Lightning is one of the major contributing factors to veld fire ignition around the globe. This study assessed lightning characteristics around veld fire events in the Western Cape and Eastern Cape provinces.

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This was achieved by mapping the spatial-temporal distribution of lightning-igniting fires within a 10 km radius and lightning evens with a 2-week window. GIS applications were utilised for spatial-temporal assessment of lightning and fire events over seven years (2009- 2016).

The study showed that Eastern Cape recorded more lightning and veld fires compared to the Western Cape province. Using the 10 km radius of the veld fire search criterion, approximately 81% of recorded lightning-initiated events could be matched within 14 days of the lightning-initiated wildfire report date. The output of the study was encouraging and can be an input to non- commercial lightning and veld fire monitoring systems.

INTRODUCTION

Lightning-induced veld fire is one significant concern for fire forest conservations and fire management agencies across the globe (Vecín-Arias et al. 2016). While there is a significant relationship between veld fires, weather and lightning, there is still much unknown about the likelihood of ignition. Individual lightning storms can result in larger numbers of fires clustered in space which can easily overwhelm suppression efforts (Kilinc and Beringer 2007). It is therefore important to investigate lightning-induced veld fires because some result in death and destruction of property. Investigations can be accomplished by utilising Geographical Information systems and Remote sensing technology.

Numerous studies have mapped and assessed the distribution of veld fires associated with lightning (Keane ate al., 2001; Nastos et al., 2014; Read et al., 2018). For instance, Riaño et al. (2002) classified Landsat TM imagery by fuel type in the Iberian-Mediterranean forests of Cabañeros National Park, Spain, focusing on spectral, texture, and elevation attributes. Their study achieved an overall accuracy of 83% and reported that classification errors were largely attributed to fuel types differentiated by vegetation height and understory vegetation. Keane et al. (2001) mapped lightning and veld fires using Remote Sensing by conducting image classification, computing vegetation indices, and photography interpretation for assigning fuel characteristics. Nastos et al. (2014) conducted a Spatio-temporal analysis of lightning activity over Greece—using a precision lightning network. More specifically, their study analysed data on lightning location and time-of-occurrence (TOA), which was retrieved from Hellenic National Meteorological Service (HNMS) using an operational precision lightning network (PLN). The output of the study revealed that spatial variability of lightning showed their incidence within specific geographical regions. Higher frequencies of lightning strokes appeared over the Sea area Aegean compared to land during the winter period against mountainous regions during the summer. Vecín-Arias et al. (2016) analysed lightning-induced fire occurrences in the central plateau of the Iberian Peninsula. Their study used logistic regression and random forest regression techniques to analyse the presence/absence of at least one lightning-induced forest fire in a 4 × 4 km grid cell between 2000–2010. The data was retrieved from the lightning detection network (LDN). With the increase in a plethora of datasets, there are still limited studies applying GIS to map the spatial-temporal distribution of veld fires in the developing world.

It is imperative to explore the synergies of lightning tracking systems with GIS and Remote Sensing techniques, which are cost-effective. Such incorporation will assist in efficient association and analyses of the Spatio-temporal distribution of lightning-induced fires to respond efficiently to veld-fires. Thus, this study will analyse the lightning-induced veld fires in the Western Cape and Eastern Cape provinces of South Africa. This will be achieved by mapping the spatial-temporal distribution of lightning-igniting fires in the two provinces and quantifying lightning-initiating fire events.

METHODOLOGY

STUDY AREA

The study was conducted in the two coastal provinces of South Africa (Eastern Cape and Western Cape) (Figure 1). The Eastern Cape province is located in the South Eastern part of South Africa. Eastern Cape province comprises Grassland, Savannah, Forest, Thicket, Succulent Karoo and Fynbos biomes (Rutherford et al., 2012). The Western Cape province is situated on the southwestern coast of the Country. The province comprises different biomes dominated by Forest and Fynbos (Rutherford et al., 2012). The climate in both provinces is typically associated with warm, dry summers. The temperature rises from 15 ˚C to 27 ˚C at the coast and 18 ˚C to 32 ˚C inland.

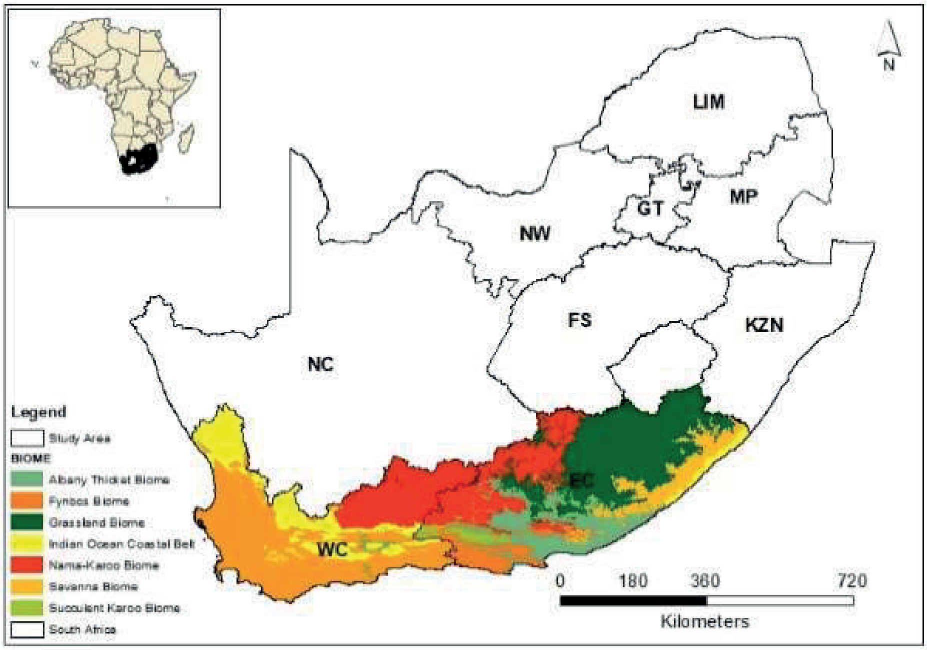


Figure 1: Study area map showing locations of the Eastern Cape and the Western Cape Provinces.

DATA AND METHODS

VELDFIRE INCIDENCES

Veld fire-incidences/events data were obtained from the Advanced Fire Information System (AFIS) database. The database provides a complete description of every reported veld fire information, including the time, date, and location of the ignition. More specifically, this study utilised data spanning from 2009 to 2016 for Eastern Cape Province and the Western Cape Province due to the availability of the data on the AFIS database.

LIGHTNING CHARACTERISATION

To characterise lightning and veld fires, a study was guided by the principles presented by Schultz et al. (2019), who analysed the Spatial, Temporal and Electrical Characteristics of Lightning in Reported Lightning-Initiated Wildfire Events in the United States of America. A command-driven data query was developed in the ArcGIS (ESRI® ArcGIS 10.6, Redlands, California, USA, which was utilised to retrieve information for veld fire and lightning incidents in the study area. This query utilised criteria guided by Müller and Vacik (2017) and Schultz et al. (2019) study on identifying characteristics of lightning igniting veld-fires. The following characteristics were utilised in this study, and a more detailed narration of the choice of parameters found in the referenced studies:

i. Cloud-to-ground lightning stroke was considered instead of cloud-to-cloud lightning strokes (Muller et al., 2013).
ii. A 14 days time frame before the proposed date of the veld fire (Schultz et al., 2019).
iii. A 10 km radius to concentrate on veld fires in a 10 km spatial extent of the lightning strike (Schultz et al., 2019).
iv. Fire events with temperature brightness values of more than 300K (Saba et al.,2006).
v. Single positive lightning under <10 kA was excluded from the analysis, even if they were the nearest events because studies have shown that these discharges are approximately 90% cloud to cloud and not Cloud to Ground lightning (Diendorfer 2007).

Temporal dynamics of objects over a given period can be assessed using change detection analysis of multi-temporal images (Roy and Inamdar 2019). Initially, the study utilised Google earth images to identify and correlate areas where veld fires were recorded from the database retreated.

Buffering, which involves the creation of a zone of a specified width around a point, line or polygonal area, was utilised to provide a constraint of a 10 km radius. These buffer zones were exported to google earth images where particular locations of fires were identified. Google Earth imagery was utilised in this study due to the absence of field data collection. It is also high-resolution imagery; hence, it has been adopted as one major source of field data collection (Tamiminia et al., 2020).

RESULTS

WESTERN CAPE PROVINCE ANALYSIS

On average, lightning events were recorded at 373308 events compared to an average of 9237 for fire events. Furthermore, there were fluctuations in the recorded lightning strokes and fire events. The highest strokes were recorded in 2012, and the lowest lightning strokes were recorded in 2010. A closer look at 2009 shows 374 lightning events and over 111 veld fires (Figure 2). Out of all the recorded and reported veld fires, it was noted that incidences of lightning occurred within 14 days and a 10 km radius. The fire events occurred mostly in January, February and March, and few events were recorded around April, September and December in 2009.

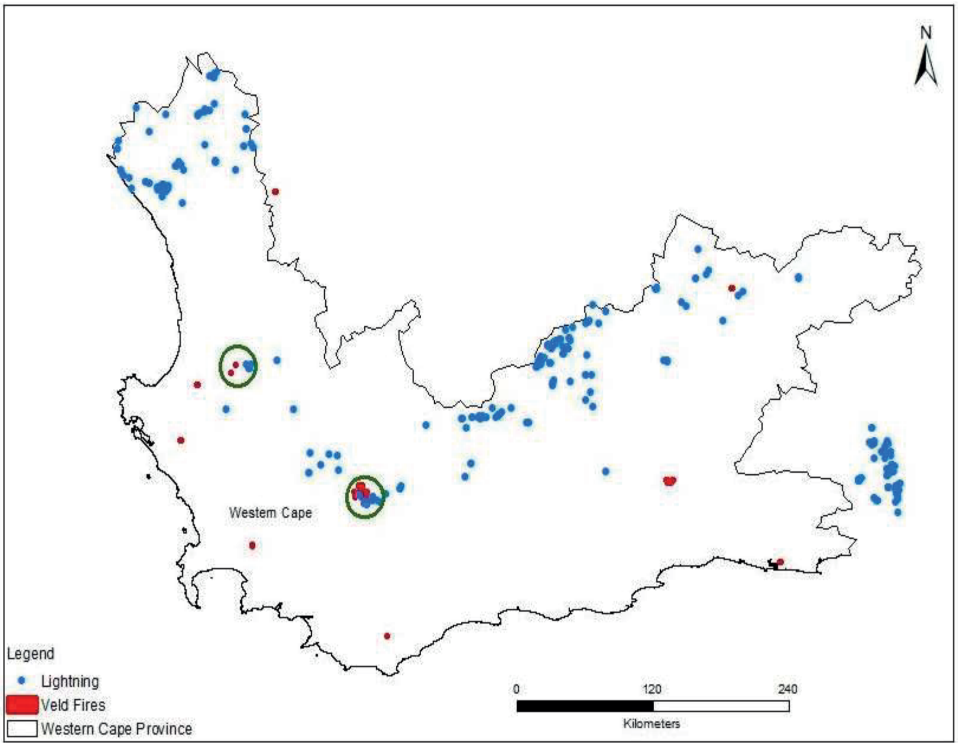


Figure 2: Map of Western Cape boundary showing lightning strikes and fire events

Lightning currents were recorded from the lightning events within a 10 km radius of a fire event. The highest positive current was greater than 40kA, and the highest negative current was greater than 45 kA. Two positive peak lightning events were observed within 10 km, with the shortest distance of 6km and the longest distance of 10 km. The lowest peak distance was approximately 9 kA, and the highest peak was 42 kA. The fire events records resulted in one likelihood of lightning smouldering event for the fire in 2012. Overall, there is an 80% likelihood that the fire event was ignited by lightning on both positive and negative polarity, with a very high likelihood of positive lightning.

The overall analysis of the lightning in the Western Cape province between 2009 and 2016 shows more negative lightning than positive lightning. The lowest positive peak was recorded at approximately 5 kA, and the highest positive peak was at 42 kA. Negative lightning polarity contributed 77% towards the fire events, with 74% of those negative lightning peak currents below 20 kA. Therefore, it is expected that 80% of the positive or negative lightning with a peak current below 20 kA might have ignited the forest. According to the query set in the study, the results above yield a high likelihood of lightning igniting fires due to lower values of peak currents. Lightning currents less than 20 kA for negative peak lightning always carry a continuous current, and peak current magnitude above 20 kA for positive lightning contributes to the lightning igniting fires.

EASTERN CAPE

The study results show that multiple lightning events were recorded around the fire event within a 10km radius in the Eastern Cape province. In 2009, there were nine fire events, with lightning events occurring on the same day and weeks before fire flames could be observed or recorded by the satellites. This incident recorded the maximum negative peak current of 62 kA at a distance of 2.7km from the fire event as of January 2009, and 175 lightning events were recorded on the same day.

The incident recorded the maximum positive peak current of 40 kA measured at a 7km distance from the fire. Out of a total of 902 lightning events analysed, 84% (761) were identified as negative lightning polarity, and 16% (141) were identified as positive lightning polarity.

Further analysis of the positive lightning resulted in excluding lightning activities below 10 kA, leaving 85 lightning activities. The maximum peak positive current value of 40.4 kA was recorded simultaneously. The maximum value for negative lightning was 62 kA, and the lowest (4.8 kA). Positive lightning yielded a 12% likelihood of lightning fires igniting in 2009.

Negative lightning polarity was further analysed to determine the extent of negative lightning likelihood. A total of 213 lightning events had a peak current between 3 kA and 20 kA, indicating a 78% potential of lightning igniting fires in the Eastern Cape for 2009.

In the year 2011, a total of 9120 fire events were recorded. However, only ten fire events had the likelihood of it being caused by the recorded lightning events considering the date of capture (14-day period) and distance from the lightning event (10 km radius) as well as the 10 km radius of the fire event (Figure 3). A total of 479 lightning events were recorded within the 10 km radius of the fire events, with 67% being negative lightning polarity and only 23% from positive lightning polarity. The peak current was recorded at 97 kA for negative polarity within 2km and 84 kA for positive lightning about 7km from the fire event. The negative lightning polarity was further analysed to determine the extent of negative lightning with a peak current below 20 kA. Two hundred fifty-four lightning events had a peak current of less than 20 kA, a total of 79% of negative lightning polarity with a high likelihood that fire was initiated from lightning activity.

In 2012 there was 79% of negative lightning polarity with a high likelihood that fire was initiated from lightning activity. In 2013, 7179 fires were recorded throughout the year and 32767 lightning events. Furthermore, 16189 lightning events occurred within 14 days, most of which were recorded in the Northeastern part of the Eastern Cape Province. In 2013 there was 51% of negative lightning polarity with a high likelihood that fire was initiated from lightning activity. In 2014 there were a total of 4530 recorded fires in the Eastern Cape Province. Fourteen thousand fifty-two lightning events were recorded in the 14 days and 10 km radius. The highest positive current was recorded at 86 kA, and the lowest positive current was recorded at 2 kA. The positive current ranged

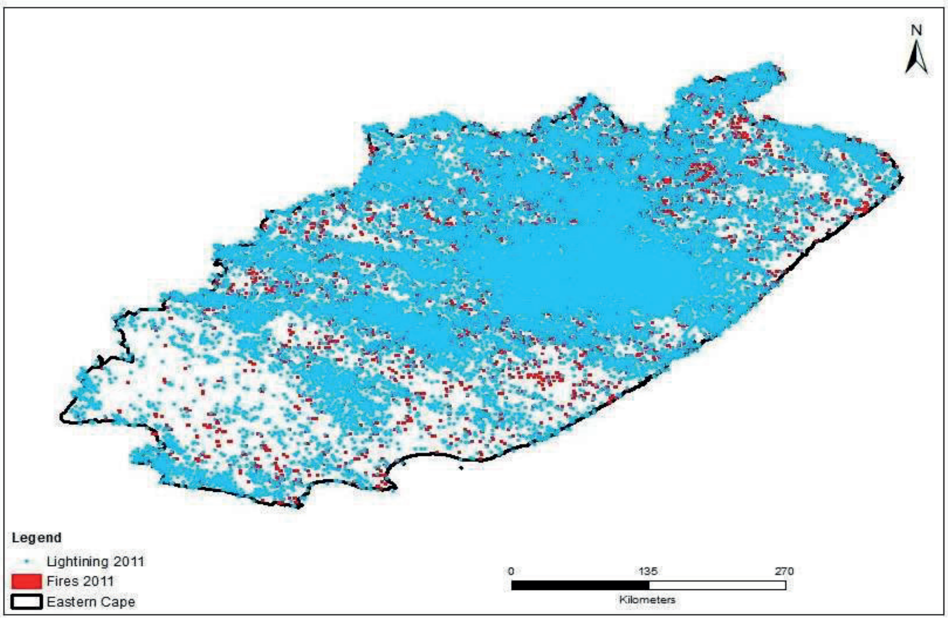


Figure 3: Lightning and fire events recorded in 2011 in the Eastern Cape Province

between 1 kA and 156 kA, and the negative current ranged between 2 and 156 kA. Considering the criteria set in the study, a combination of the above-recorded chances of lightning igniting fires results in a 44% likelihood of any of the fire events being caused by lightning.

A total of 1524 fires were recorded in 2015 from January to December, with 34947 lightning events. A total of 22275 lightning events were recorded within the 10 km distance. Eight thousand three hundred forty lightning events were recorded within the 14 days of the fire events. The values of the positive current ranged between 2 kA and 142 kA. In addition to that, the values for the negative current ranged between 2 kA and 119 kA. Considering the criteria set in the study, a combination of the above-recorded chances of lightning igniting fires results in a 67% likelihood of any of the fire events being caused by lightning.

A total of 882 fires were recorded in 2016 from January to December, with 34947 lightning events (Figure 4). Five thousand four hundred sixty-one lightning events were recorded in 14 days. The positive current recorded in the 14 days and 10 km radius of a veld fire shows the highest value of 101 kA and the lowest value of 2 kA. In addition, values of the negative current ranged between 3 kA and 180 kA. Considering the criteria set in the study, a combination of the above-recorded chances of lightning igniting fires resulted in a 73% likelihood of any fire events being caused by lightning.

DISCUSSION AND CONCLUSSION

The study set out to analyse the characteristics of lightning-induced veld fires in the Western Cape and Eastern Cape provinces of South Africa. The areas were chosen because of the lack of studies on the association between lightning and fire events. The study's objective included characterising lightning-initiating fires in the Western Cape and Eastern Cape provinces. Map the spatial-temporal distribution of lightning-induced fires in the Western and Eastern Cape provinces and Spatial-temporal quantification of lightning-initiating fire events. Similar studies have been conducted in different environments. For instance, Müller et al.

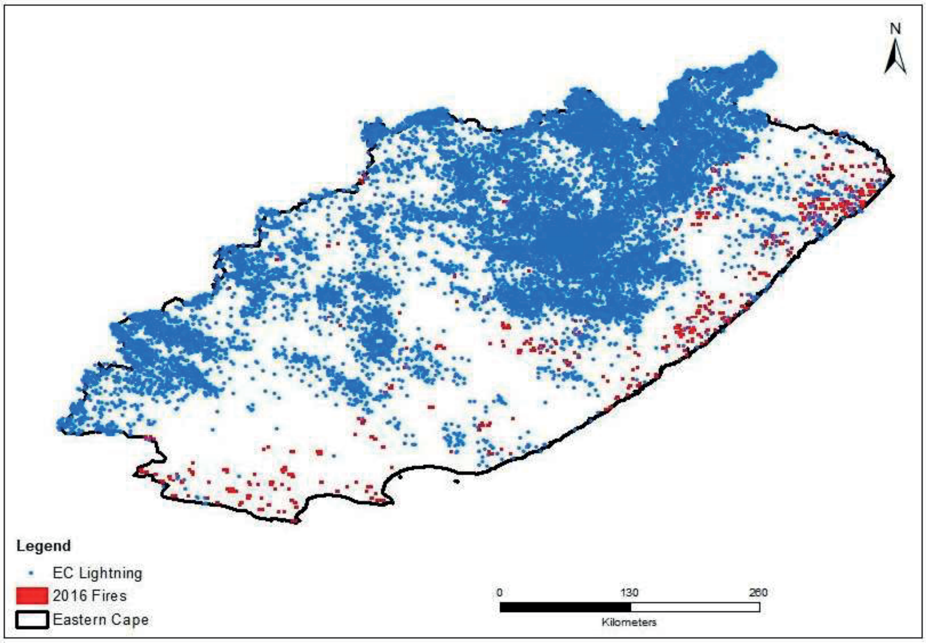


Figure 4: Lightning and fire events recorded in 2016 in the Eastern Cape Province

(2017) analysed the characteristics of lightning-igniting forest fires in Austria. Their study reported that positive lightning was significantly more likely to induce a veld fire.

Larjavaara et al. (2005) conducted a spatial distribution of lightning-ignited forest fires in Finland. They reported 70% of all lightning-ignited forest fires in the most sparsely populated municipalities to 63% in the most densely populated rural municipalities. A similar conclusion of these studies was also arrived at in our study, showing the likelihood of veld fires being ignited by lightning.

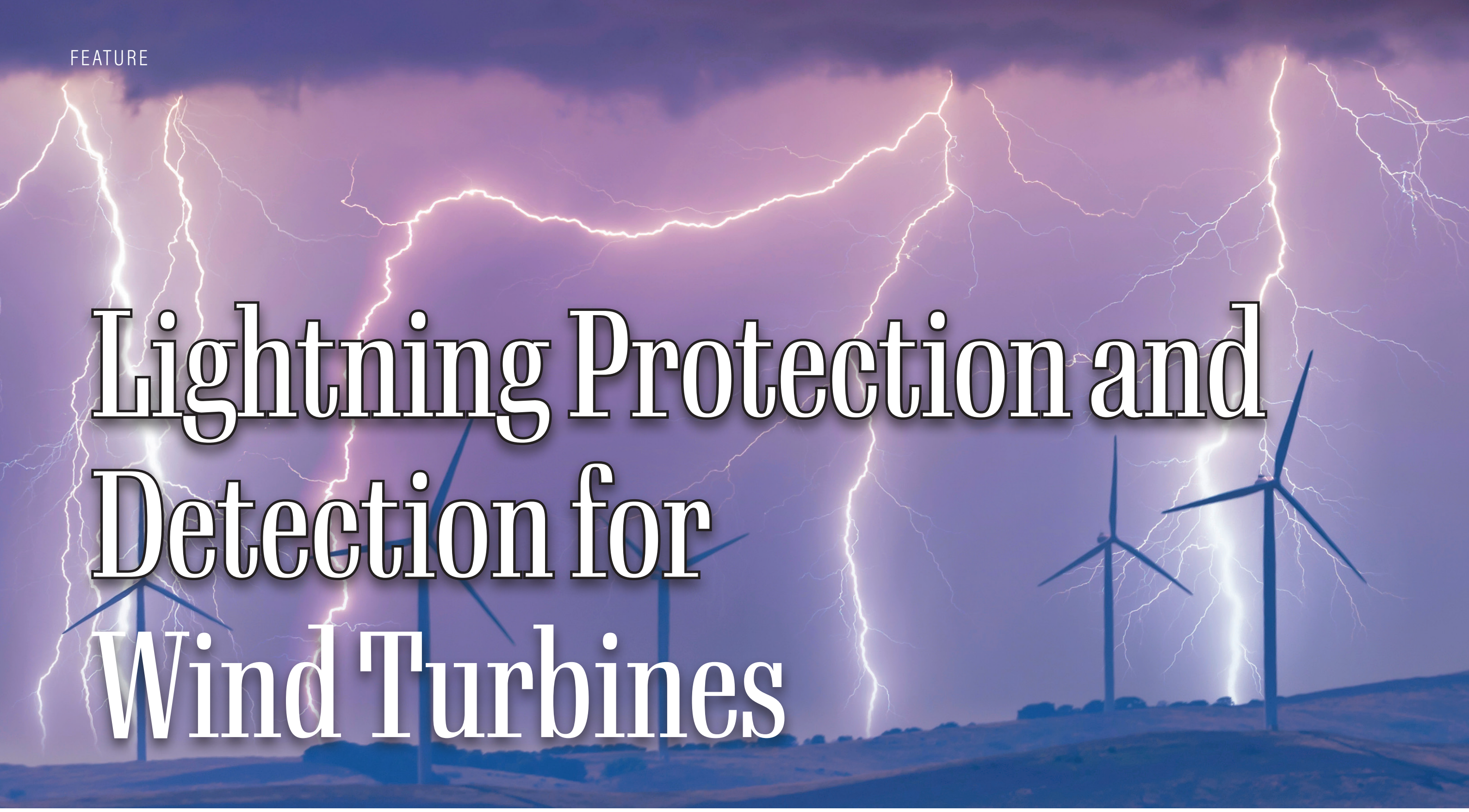
The smouldering effect for Western Cape and Eastern Cape indicates the likelihood of lightning igniting fires because findings are rationally similar to findings from Austria, Australia, Canada and other parts of the world. Lightning fires were observed three days and more days after lightning. Results indicated low negative peak magnitudes lower than 20 kA, and negative strokes with a peak magnitude of less than 20 kA have a continuous current for any discharge duration.

In the Western Cape Province, over 35 lightning events were analysed, and 6 were fire events with distances within a 10km radius from the fire event. 85% of the lightning events were more than 4km away from the fire event, with lower peak current values below 20 kA. To some extent, one of the reasons for lightning igniting fires can be attributed to wind speed, lightning continuing current and dry fuel load, where significant factors for the fire to occur either as an ignition, hold over and flames, and remains stronger within the 1-4km radius of the fire event. Similar observations were alluded to by Pineda et al. (2014), who characterised lightning related to wildfire ignitions in Catalonia, Spain. It was also noted that invader species in the Western Cape Province had increased the drought rate and fire events.

The results showed that Eastern Cape recorded more lightning and veld fires than Western Cape. Additionally, in Western Cape and Eastern Cape, it was observed that negative lightning polarity was the leading factor for the characteristics of lightning around fire events, with the majority between 3 kA and 180 kA peak current magnitude as indicated. Most lightning fires in this study occurred at an altitude >2000 m above sea level and were rare below 500 m. This pattern can be partly explained by the low fuel loads and the natural vegetation in the landscape.

Considering all the results, there is a significantly higher amount of positive lightning that ignites veld fires due to a higher chance of CC and the critical factor for lightning fire ignition. Verifying the assumed importance of CC requires alternative methods (videos) to observe such occurrences. Video observations of lightning that ignite fires are a rather expensive method.

Recommendations for future investigations into the biomass of the vegetation and the wind speed are needed to quantify the results and develop the probability algorithm of lightning strikes in the Western Cape and South Africa overall. The algorithm and risk assessment will assist the Country in identifying a threat/risk of fires before they become catastrophic. Spatially explicit models should be tested to obtain estimates of averages and distributions of fire sizes and intervals of lightning. wn



Lightning Protection and Detection for Wind Turbines

It is mentioned in IEC 61400-24, that an area may see an increase in lightning ground flash density, when being populated with tall structures. Thus, if a Wind Farm is built in a specific area, that area will experience an increase in ground flash density due to the strikes onto the Wind Turbines. This is seen in the calculation for number of dangerous events to a Wind Turbine, where the ground flash density (N_G) is corrected to ground strike-point density (N_{SG}), by multiplying with a factor of two ($N_{SG} = 2N_G$).

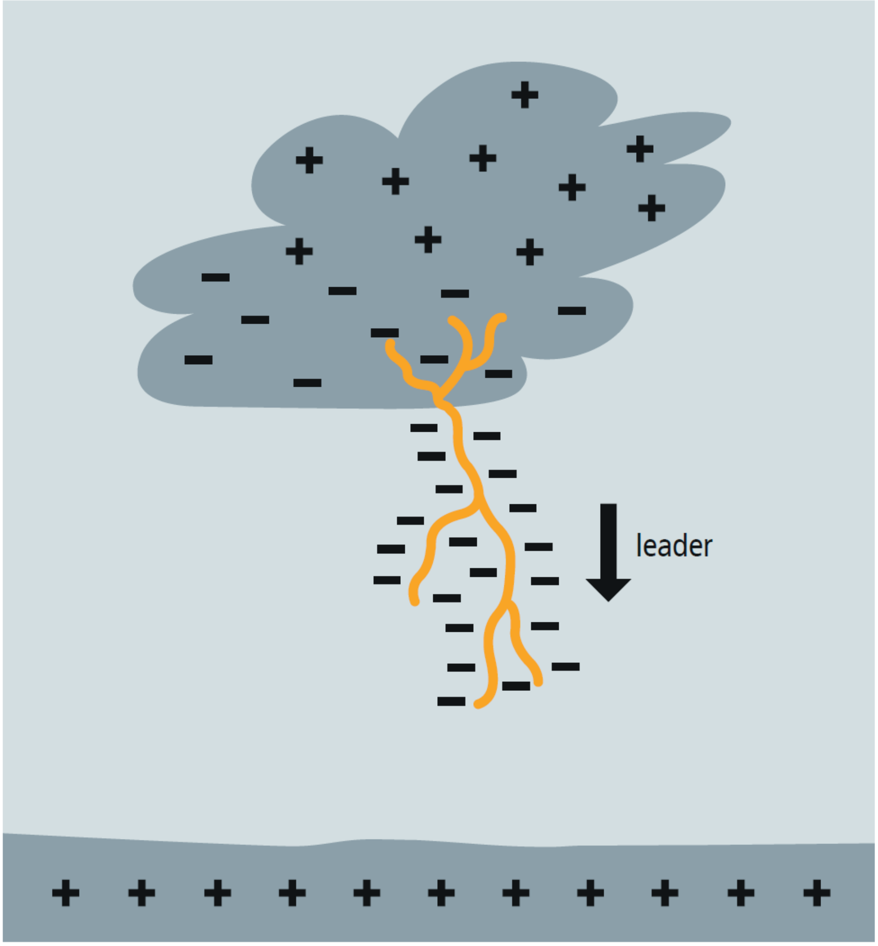


Figure 1: Downward negative stroke (cloud-to-ground).

This is mainly due to the phenomenon that tall structures (especially Wind Turbines) are subjected to upward lightning more frequently than it would be to downward lightning. Downward lightning strokes, make up more than 90% of all recorded lightning strikes globally (IEC 62305-1), but upward lightning carries higher peak values of current and carries more charge content, causing more damage. The concept for upward lightning and downward lightning is shown in Figure 1.

Figure 1 shows that the stepped leader (first stroke), originates from the clouds and terminates on the ground. This is the most common way that lightning events may occur. The polarity of such a strike can be either positive or negative, depending on the charge polarity on the ground.

Figure 2 shows an example of upward lightning. This is typical for tall structures, where charge accumulates from the ground, and continues up the tall structure, causing the leader to originate from the tip of the tall structure and

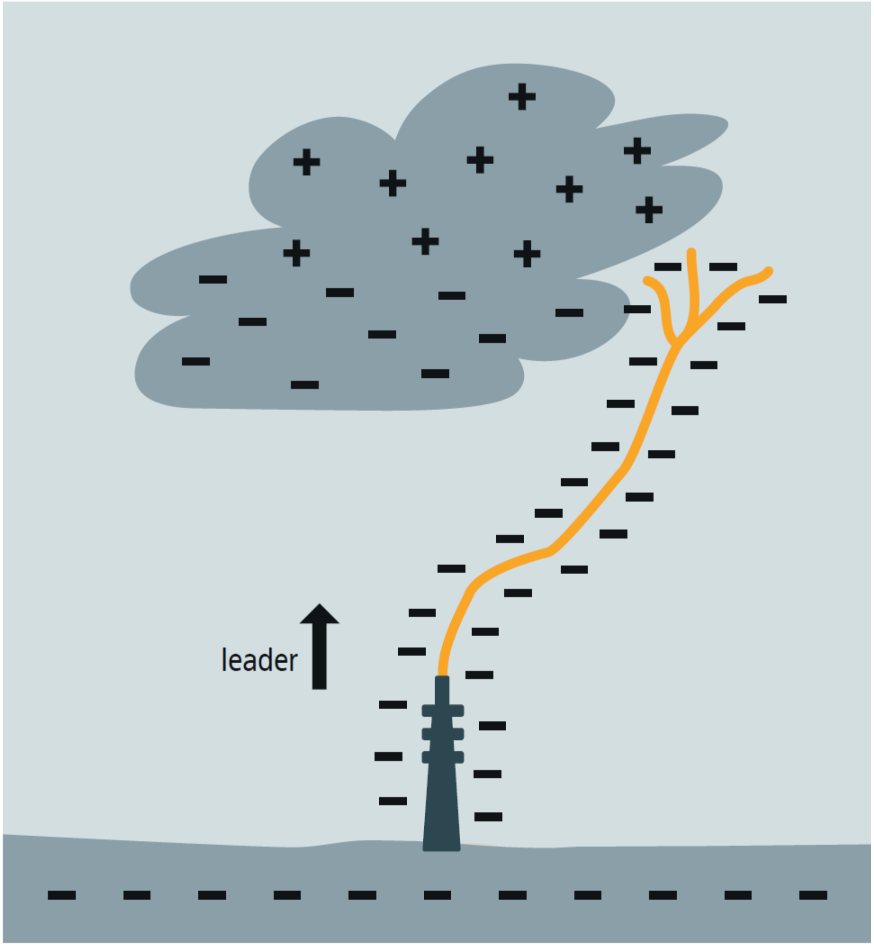


Figure 2: Upward negative stroke (ground-to-cloud)

terminate into the clouds. The polarity can be either positive or negative, based on the charge polarity of the ground. This causes high amounts of damage as all the energy originates from a single point on the structure.

According to IEC 61400-24, Wind Turbines are required to have an internal lightning protection system installed by the manufacturer (typically according to Lightning Protection Level I). This system consists of electrically continuous connections from the earthing system, through the tower reinforcing and up to the blades of the turbine. The blades contain an internal down-conductor which runs along the length of the blade and connects to lightning receptors on the blades. These lightning receptors are typically the size of a coin but can be larger. Some manufacturers, design the entire tip of the blade to be made up as a metallic lightning receptor. An example of a lightning receptor on a blade is shown below:

Figure 3: Lightning receptor for turbine blade

As 90% of all lightning strikes to a Wind Turbine is upward lightning, the following occurs to the lightning protection system of the Turbine during a lightning strike:

- Charge accumulates on the ground,
- The accumulated charge moves up the turbine, towards the blades through the reinforcing of the tower,

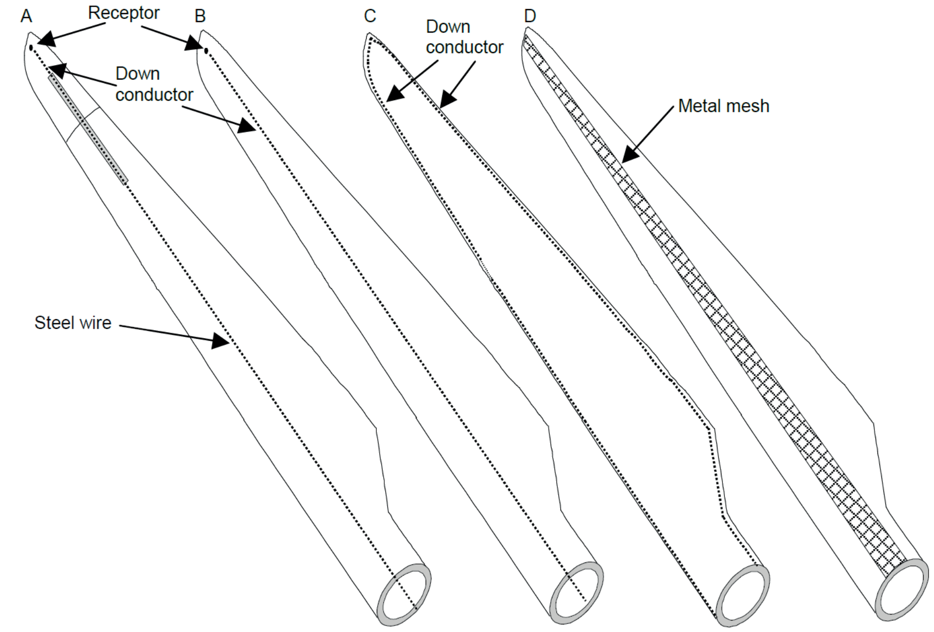


Figure 4: Lightning protection concepts for modern wind turbines

- The charge further moves through the blades toward the receptors and
- Lightning current leaves the blade through the receptor.

This phenomenon puts strain on the lightning receptors within the blade, as these receptors have limits. The first point is that the peak value current limit should correspond to the peak value of the lightning protection level (LPL). For LPL I, the receptor should be able to withstand strikes of up to 200 kA.

Further to this, upward lightning also carries continuous current, or high levels of charge content. According to IEC 61400-24, a blade receptor should be able to withstand an accumulated charge content of 900C, or a single event of 300C.

This means, that if a blade sees multiple strikes, of which the accumulated charge exceeds 900C, or a single strike exceeds 300C, the receptor will be damaged beyond repair, and could result in larger repairs to the blade. **These limits need to be verified with the Turbine Manufacturer.**

Below are examples of damage to receptors within their manufacturing limits and outside of the limits. If the damage is within the charge limits, only the receptor needs to be replaced, which is cost effective and has limited down-time. If the charge content falls outside of the limits of the receptor, the receptor could be damaged in such a way that it can't be removed, and sections of the blade, or even the entire blade would need to be replaced. This becomes costly and results in long down-time.

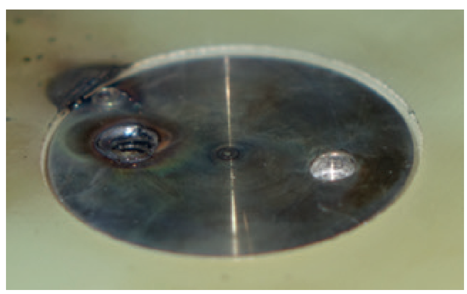


Figure 5: Damage to receptor within charge limits (20c)

With the high lightning activity in South Africa, it is essential that the number of strikes to the blades are measured with their corresponding charge ratings to avoid catastrophic damage and long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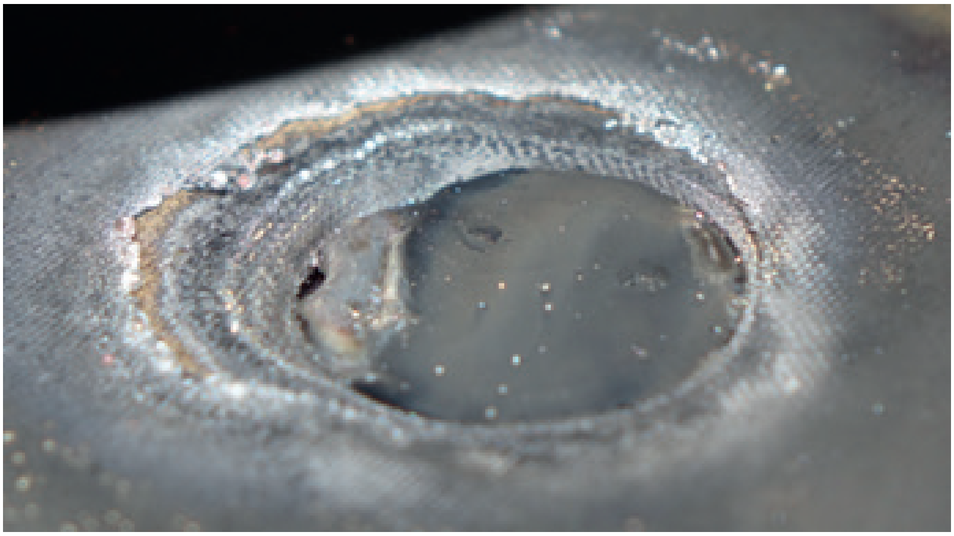
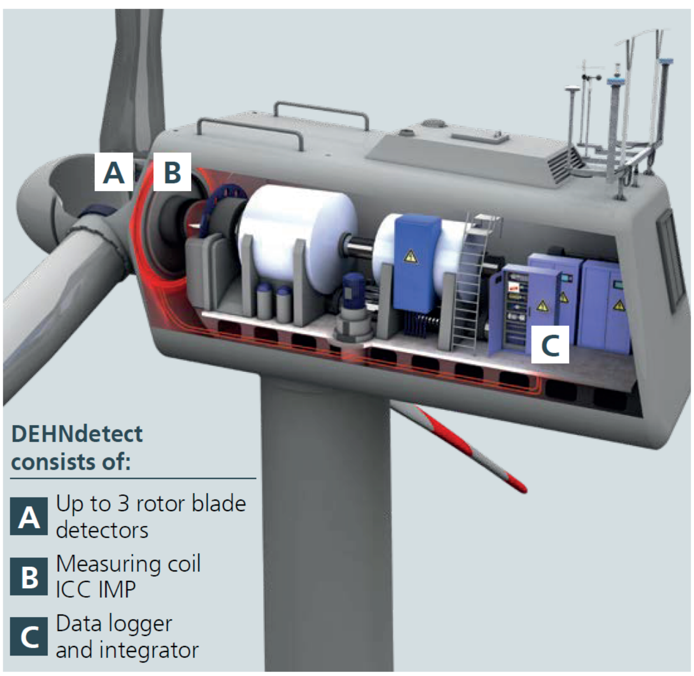


Figure 6: Damage to receptor outside of charge limits (4 strikes of 300c = 1200c accumulated)

down-time. DEHNdetect reliably detects lightning events preventing expensive maintenance work and long downtimes. Damage resulting from a lightning strike does not necessarily lead to the immediate failure of the turbine and, as a result, lightning events often remain undetected. Especially in the case of upward flashes the initial long stroke current flowing is only a few 100A and can be the main cause of melting, e.g., on the receptors of rotor blades.

The system is installed within the Nacelle of the Wind Turbine, around the shaft by means of a Rogowski coil which measures all the current on the blades. Further blade detection units may also be installed during the manufacturing of the Turbine which further give information on which blade was struck.

For more information on DEHNdetect, please contact DEHN AFRICA. wn



DEHNdetect components	
	**DEHNdetect DL** Data logger with different interfaces for integration in IT systems.
	**DEHNdetect Integrator** Processing of the measuring signals and transmission to the data logger. **DEHNdetect ICC IMP** Measuring coil for measuring long stroke and impulse currents. Measuring range 60 A to 250 kA.
	**DEHNdetect BDU** Detector for the wireless detection of lightning current in the rotor blade.

Figure 7: Example of DEHNdetect measuring system installation

Out with the silver, in with the copper

A NEW BOOST FOR SOLAR CELL PRODUCTION

By Britta Widmann, Fraunhofer-Gesellschaft

The rising price and low availability of raw materials, especially silver, lead to higher costs in producing photovoltaic modules. Fraunhofer researchers have developed an electroplating process that involves substituting silver, an expensive precious metal, with copper, which is more readily available. They have also succeeded in replacing the polymers that are usually left over after electroplating processes and are expensive to dispose of by using easily recyclable aluminium for masking. The spin-off PV2+ was launched to bring the technology to the market quickly.

When it comes to generating electricity from renewable energies, photovoltaics are a mainstay. Modern heterojunction solar cells have a particularly low CO_2 footprint because of the low amounts of silicon used to produce them. When it comes to industrial production, they achieve the highest levels of efficiency.

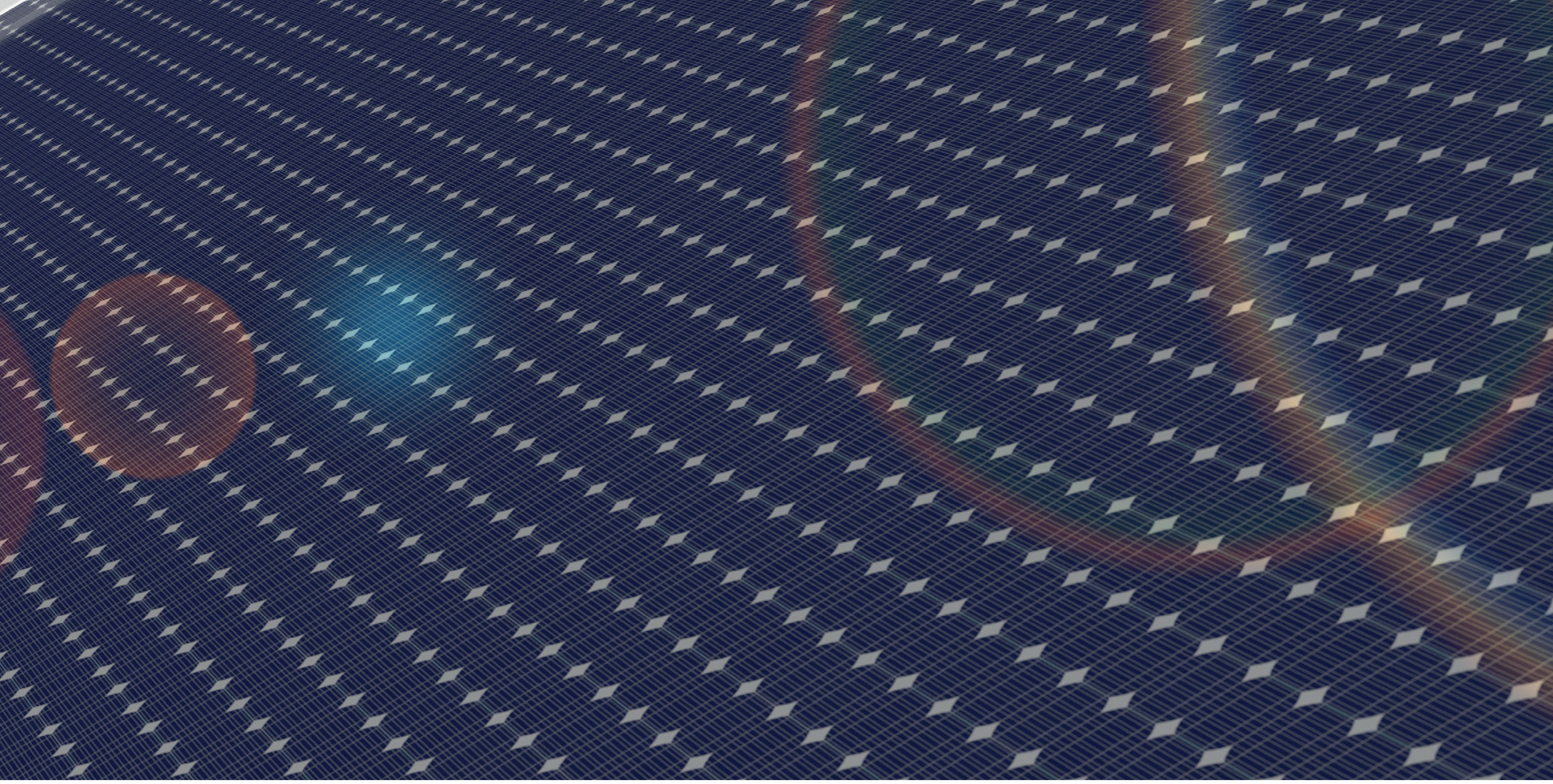
As a result, the chances are high that this technology will become the standard in production. There are figures to show the growing importance of photovoltaics. According to the International Renewable Energy Agency (IRENA), more than 96 TWh of energy was produced by photovoltaic systems worldwide in 2012, which rose to nearly 831 TWh by 2020. According to the German Environment Agency, the amount of electricity generated from photovoltaics in Germany rose from almost 27 TWh to almost 50 TWh in the same period.

This is by no means the limit of what photovoltaics can offer. However, when manufacturing solar cells, valuable silver is used for busbars and contacts, which conduct the electricity generated in the silicon layer through solar radiation.

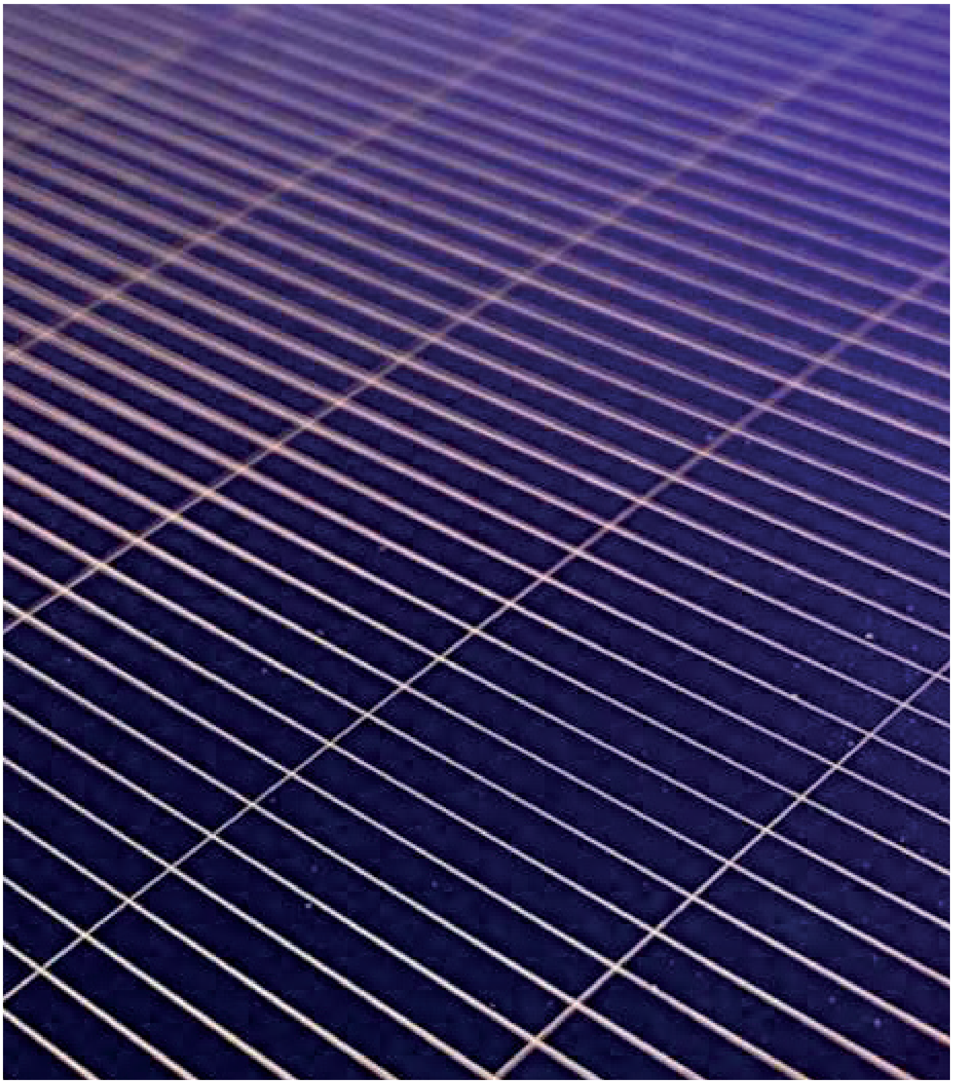
The cost of this precious metal is rising—even today, silver accounts for around 10% of the manufacturing price of a photovoltaic module. Moreover, there are only limited quantities of metal available on Earth. The solar industry processes 15% of the silver mined, but this proportion is set to rise sharply due to the industry's high growth rate. This will not be viable, however, as other sectors, such as electromobility and 5G technology, also report an expected future increase in their use of silver. The solar industry requires breakthrough technological innovations to realise its full potential.

COPPER FOR SOLAR CELL CONTACTS

Researchers at the Fraunhofer Institute for Solar Energy Systems ISE have taken on this challenge. With about 1,400 employees, this Freiburg-based institute is the largest solar research institute in Europe. A team of researchers led by Dr Markus Glatthaar, an expert in metallisation and structuring, has developed an electroplating process for the promising heterojunction technology to replace silver with copper. Copper is many times cheaper and more readily available than silver.



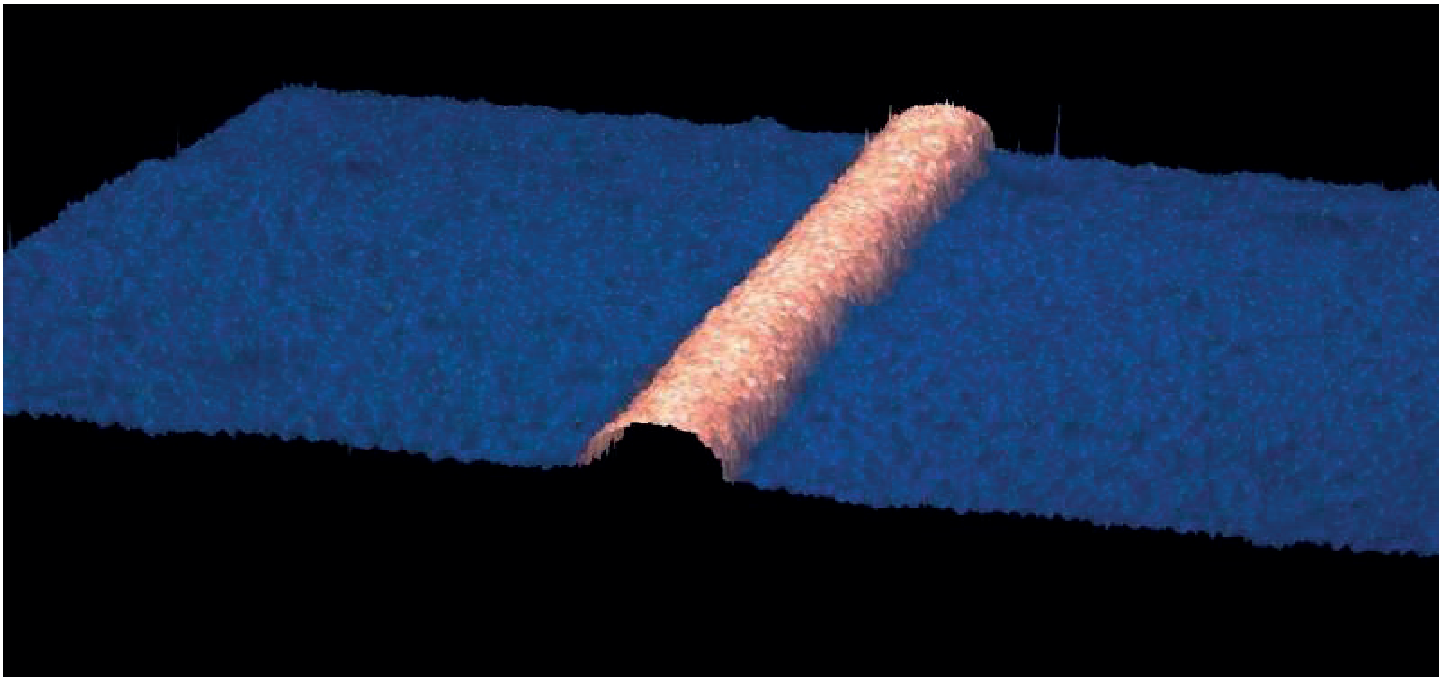
To ensure that the electrically conductive surface of the solar cell is not completely electroplated with copper, the areas of the surface that should not be coated must first be masked. These areas are covered by a coating that has an electrically insulating effect, thereby preventing them from being electroplated. The copper layer will only build up in the areas not coated with the insulation.



At just 19 micrometers in width, the copper contacts are extremely thin. As a result, the light-sensitive silicon layer does not experience much shading. Credit: PV2+

The researchers have made another significant advance here: Until now, expensive polymer-based lacquers or laminated foils have been used in this industry to mask the silicon wafer in the electrolyte bath. Disposing of polymers is an expensive process that generates a lot of waste. Dr Glatthaar and his team have been able to substitute the polymers with aluminium. Just like copper, aluminium is fully recyclable. Switching the materials twice, from silver to copper and from polymer to aluminium, also brings twice the benefit: Producing solar cells is more sustainable and significantly cheaper.

A scientific breakthrough: Innovative electroplating and improved electrolytes



Three-dimensional confocal microscopy image of a copper contact produced using the laser-assisted process developed by PV2+. The contact's exact, semi-circular shape ensures a high electrical conductivity level. Credit: PV2+

But how did the researchers manage to replace silver, an expensive precious metal? "We developed a special electroplating process that makes it possible to use copper instead of silver for the busbars," explains Dr Glatthaar. This even improves conductivity—the copper contact lines are particularly narrow because of their laser structuring.

Due to the copper line's extremely small width of only 19 µm (micrometres), the light-absorbing silicon layer experiences less shading than the silver lines. This and the high conductivity of electroplated copper improve the electricity yield.

The Fraunhofer team has also made a second technological achievement using aluminium as a masking layer. The difficulty here is the electrically conductive nature of aluminium, which renders it unsuitable to use as a mask at first glance. The Fraunhofer researchers took advantage of the fact that aluminium can form an insulating oxide layer on its surface. However, this layer is only a few nanometers thick. "We were able to adapt the process parameters and develop a special type of electrolyte which ensures that the aluminium's extremely thin, native oxide layer can reliably fulfil its insulating function. This was an important milestone for the success of our research project," Dr Glatthaar is pleased to report.

As recyclable materials, both copper and aluminium can bring photovoltaic production much closer to the circular economy, improving environmental and social standards in the process. "Given that we have sufficient supplies of copper in Germany, the supply chains are much shorter, and the price is less dependent on international raw material markets or foreign suppliers," adds Dr Glatthaar.

SPIN-OFF PV2+ BRINGS SOLAR TECHNOLOGY TO THE MARKET

To bring the promising technology to the market more quickly, Fraunhofer ISE launched the spin-off PV2+. The letters "P" and "V" stand for photovoltaics, with "2+" indicating the double positive charge of copper ions in the electroplating bath. The company is also based in Freiburg, with Fraunhofer researcher Dr Glatthaar acting as CEO. He is aiming to set up a pilot production plant together with industrial partners as early as the start of 2023.

As Prof. Andreas Bett, institute director of Fraunhofer ISE, explains, "These innovative solar cells are an important stepping stone to a future power supply based on renewable energies.

They will give the photovoltaics industry a much-needed boost. The spin-off has huge potential to quickly and successfully establish itself on the market. And of course, we are particularly pleased that these technologies were developed at our institute." wn

SAIEE South African Institute of Electrical Engineers

113 YEARS 1909-2022 SAIEE

MEMBERSHIP FEES EFFECTIVE 1 DECEMBER 2022

The Council meeting held on 2 September 2022 approved subscription & entrance fees as from 01 December 2022 as per schedule indicated below.

PLEASE NOTE: In terms of Bylaw 3.2 annual subscriptions are due on 1st December 2022

MEMBERSHIP FEES CAN BE PAID IN MONTHLY RECURRING PAYMENTS

Council agreed to a discount for fees paid before 31 March 2023. Members are therefore encouraged to pay promptly to minimize increase impact.

Grade of Membership	Annual Subscriptions paid before 31 March 2023		Annual Subscriptions paid after 31 March 2023		New Members FEES * see Notes 1 & 4 below.	
	RSA incl VAT (R)	Outside RSA excl VAT (R)	RSA incl VAT (R)	Outside RSA excl VAT (R)	RSA incl VAT (R)	Outside RSA excl VAT (R)
Student	165	143	198	172	198	172
After 6 yrs study	1 714	1 491	2 057	1 789	2 057	1 789
Associate	1 714	1 491	2 057	1 789	2 057	1 789
Member	1 895	1 648	2 274	1 977	2 274	1 977
after 6 years	2 214	1 925	2 657	2 310	2 657	2 310
after 10 years	2 317	2 015	2 780	2 418	2 780	2 418
Senior Member	2 317	2 015	2 780	2 418	2 780	2 418
after 6yrs/age 40	2 511	2 184	3 013	2 620	3 013	2 620
Fellow	2 511	2 184	3 013	2 620	3 013	2 620
Retired Member (By-law B3.7.1)	1 065	926	1 278	1 111	n/a	n/a
Retired Member (By-law B3.7.3)	nil	nil	nil	nil	n/a	n/a

1. The fee for all new applications is R3224.00, including an entrance fee of R950.00. On election to the applicable grade of membership, the new member's account will be adjusted accordingly, and refunds/additional payments will be made on request. The entrance fee for Students is free, and new Student applicants require payment of R198.00.
2. Transfer fee to a higher grade is R504.00 for all grades of membership (except Students within three months of qualifying).
3. Members are encouraged to transfer to a higher grade when they qualify. It will be noted that the fees of Member and Senior Member grades after 10 and 6 years, respectively, are equal to the fees at the next higher grade.
4. Members elected after May 2023 pay a reduced subscription fee.
5. By-law B3.7.1 reads, "Where a member in the age group of 55 to 70 years has retired from substantive employment in the engineering profession, such member may make written application to Council for recognition as a retired person and a reduced membership fee".
6. By-law B3.7.3 reads, "any member complying with the conditions of B3.7.1 but who has been a member of the Institute for not less than 25 consecutive years, shall be exempt from the payment of further subscriptions." Members who comply with the requirements of By-Law B3.7.3 may make written application to Council for exemption from paying subscriptions".
7. By-law B3.9 reads, "any member in good standing who has been a member for fifty (50) consecutive years shall be exempt from the payment of further subscriptions."
8. Members not in good standing by failing to pay their subscriptions by the end of June of each year will, subject to Council decree, be struck off the SAIEE membership role.
9. Members in good standing, no longer in substantive employment, and do not receive payment or salary for work done, may apply to Council for a reduction in their annual subscriptions.
10. The members' monthly magazine ("wattnow") is available online. Members who require a hard copy may acquire the same on request and for a nominal fee subject to minimum uptake numbers.
11. Members who wish to pay their membership fees in recurring payments should activate the payments on their banking portal. Members will only receive the early bird discount if their fees are fully paid by 31 March 2023.

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01/09/2022	Legal Liability: Occupational Health and Safety Act (OHS Act)
01/09/2022	Blockchain and Money
06/09/2022	Fibre Optics
07/09/2022	Cable Theft webinar - open to all
08/09/2022	President's Invitational Lecture - Hybrid Event
13/09/2022	Design of Economical Earthing Systems for Utility Installations
13/09/2022	KZN Centre presents: eThekwini's Independent Power Producer Procurement Programme
14/09/2022	Select, Maintain & operate your Rotating Electrical Machines like a Pro
15/09/2022	Anatomy of Wind Turbines
20/09/2022	Fundamentals of Developing Renewable Energy Plants
21/09/2022	Writing Good Technical Specifications
22/09/2022	71st Bernard Price Memorial Lecture: Provably Beneficial Artifical Intelligence
27/09/2022	Linear Electric machines for use in Gravity Energy Storage Systems
29/09/2022	Earthing and Lightning Protection
29/09/2022	Hack Lab
29/09/2022	Finance Essentials for Engineers

OCTOBER 2022

04/10/2022	Transformer Construction, Operation, Maintenance, Testing and Protection
04/10/2022	Design Thinking and Innovation for Engineering Professional
05/10/2022	Network Frequency Controls
05/10/2022	Photovoltaic Solar Systems
11/10/2022	New Engineering Contract (NEC)
13/10/2022	High Voltage Measurement and Testing
13/10/2022	Fundamentals of Practical Lighting Design for Commercial and Industrial Applications
18/10/2022	IOT Standards and Application
24/10/2022	Select, Maintain & operate your Rotating Electrical Machines like a Pro
25/10/2022	Water Security Driven by IR4.0 - 3-day virtual symposium - Day 1 - open to all
26/10/2022	Water Security Driven by IR4.0 - 3-day virtual symposium - Day 2 - open to all
26/10/2022	Power Systems Protection
27/10/2022	Water Security Driven by IR4.0 - 3-day virtual symposium - Day 3 - open to all
31/10/2022	Fundamentals of Medium Voltage Protection

Section & Chapter, Centre Webinars | SAIEE Academy Online Training | SAIEE Academy Classroom Training