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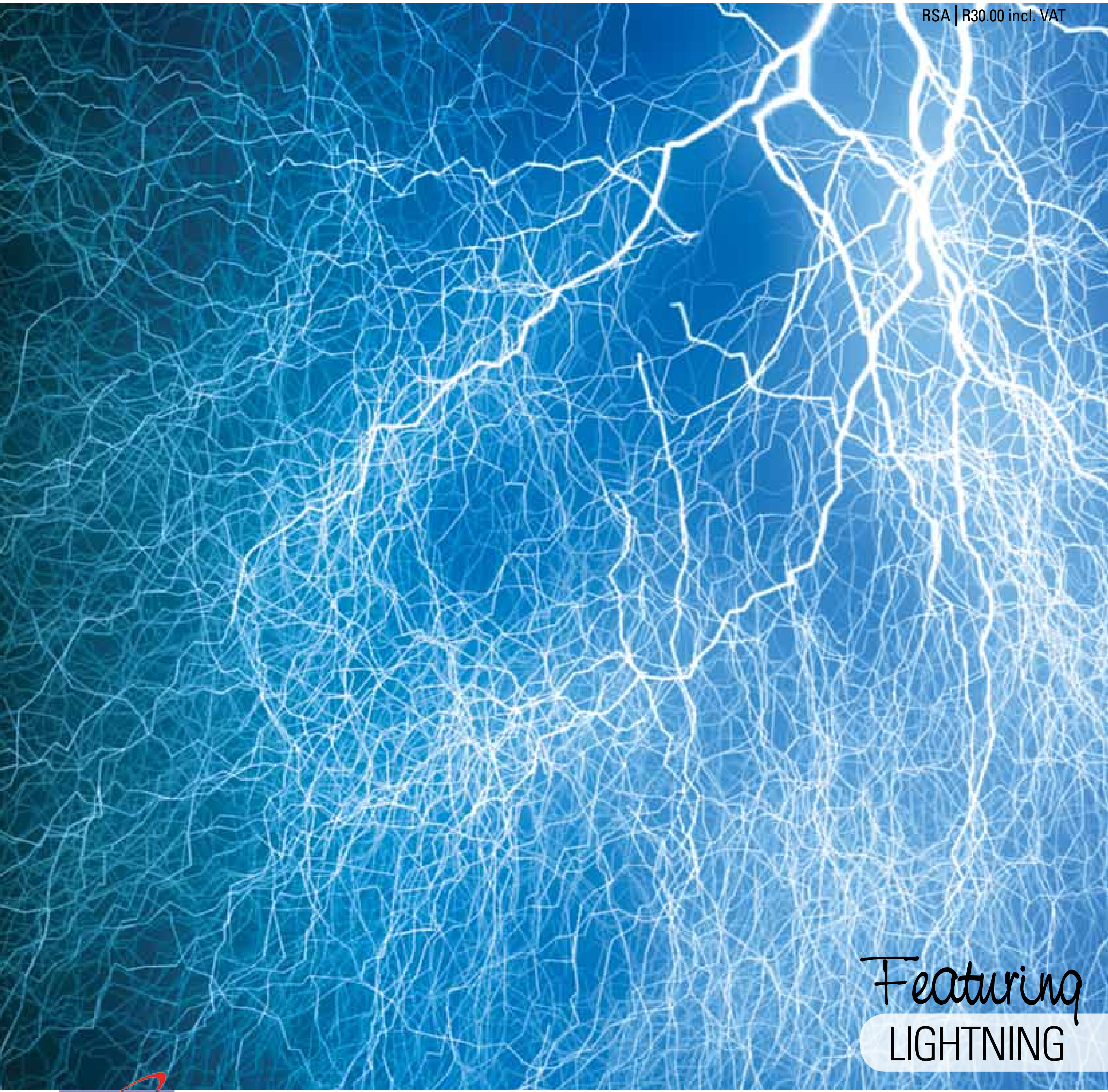

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THE OFFICIAL MOUTHPIECE OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS | **JULY 2014**

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wattnow magazine

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So, July is upon us and brings with it cold and windy days - in some areas in South Africa, even wet days, filled with lightning and thunderstorms. This issue of **watt**now focuses on Lightning and our feature article, "Lightning and Surge Protection for Wind Turbines" can be found on page 20. This article takes an in-depth look at how to protect wind turbines from downtime.

Our Technology section sports a brilliantly written article by Patrick O'Halloran on the evolution of medium voltage power cables. In this article he shares with us how technology has improved over the years, and how to correctly install the latest technology.

Anton Schmidt shares with us his memories on protecting distribution lines in the late 80's. Read his memoir on page 48.

We have another lip-smacking good piece of history aptly written by Dudley Basson on Michael Faraday & James Maxwell. This article, on page 50, tells us about why these two scientists became giants in their respective fields. An absolute must read!

"My Opinion", page 58 is written by Max Clarke – about keeping the lights on. I fully agree with him, let me know your thoughts.

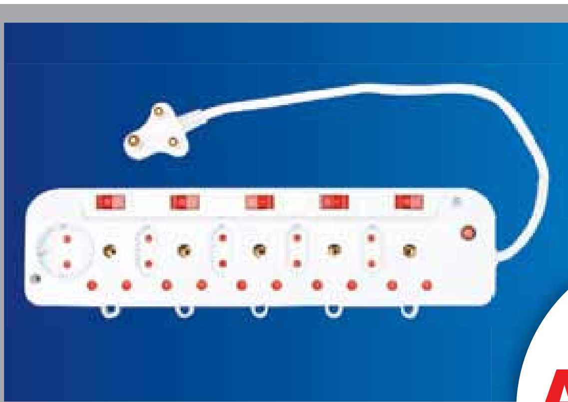
The August issue features Mining – if you have any dusty old paper you want to see published, send it to me.

Herewith the July issue, enjoy the read.

Minx

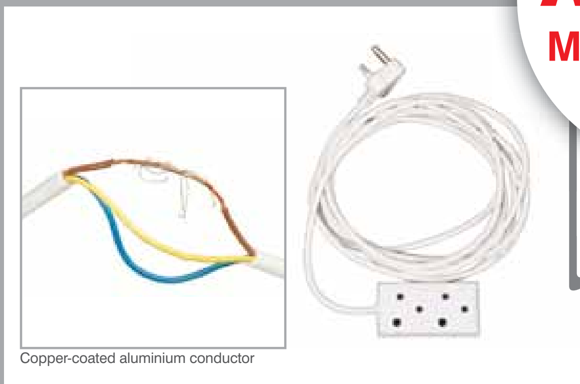
Earn CPD Credits

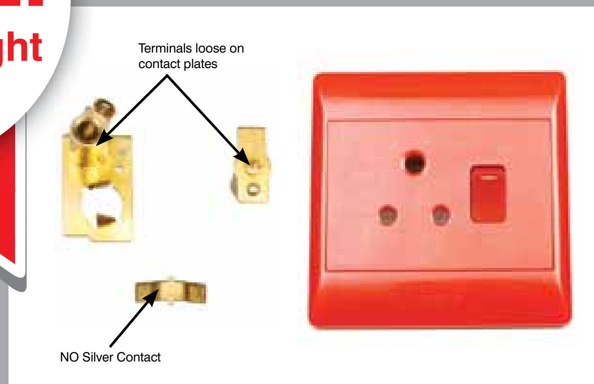
*Visit www.**watt**now.co.za to answer the questions related to these articles to earn your CPD points.*



BE AWARE!

Make the right choice





These products *are unsafe!*

How can you tell?

There are many sub-standard electrical products and services on offer to South African individuals and organizations, usually at lower prices than those that meet safety and functionality requirements.

The blatant flouting of regulations applicable to many of these products and services is one issue. The danger that these offerings pose to users is of much greater concern.

SAFE house™
Suppliers you can trust

The South African Safehouse Association has been established to combat this proliferation of dangerous products and services by:

- Making the market aware of the risks in using such products and services
- Exposing sub-standard products and services
- Persuading specifiers, suppliers and distribution channels not to recommend or to offer such products and services for sale

The products depicted here are but a handful, typifying how easily such products can be purchased or specified, often without the buyer being able to see or recognize their deficiencies. These products each contravene one or more of the following compulsory standards: **SANS 164-1, SANS IEC 60884-1, SANS 164 - 2, SANS 164 - 6, SANS 60884-1 and SANS 60227-5.**

If you cannot see the danger, ask for products and services supplied by a Safehouse member.
Safehouse members have signed a code of conduct - your assurance of their commitment to responsible behaviour.

The SA Safehouse Association is an independent, registered, non-profit organization established by the electrical industry and committed to communicating with customers. For more information about the SAFEhouse Association: Pierre Nothard Cell: 083 414 4980
Tel: 011 396 8140 | Email: pierren@safehousesa.co.za | **www.safehousesa.co.za**

Be Safe. Recommend and use SAFEhouse members' products and services:

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*For participating members please see the Safehouse website **www.safehousesa.co.za**

As at 14/05/2014

Greetings to all our Members from SAIEE House, Johannesburg.

We have implemented the new administration for the Republic of South Africa. Our immediate task is to go forward and help our administration of the next five years in securing our vision of a world class South Africa and a better quality of life for all our people.

Our first stop was to go and see our only Honorary Fellow, Dr. Ian McRae.

We requested Gerda to make contact. With immediate response, Dr. McRae summoned us for afternoon tea. Stan Bridgens, John Gosling and I met Dr. McRae at his home in Bedfordview. We had the most engaging and uplifting conversation; we spoke about yesterday, today and tomorrow.

We immediately set in motion our reach out to National leadership. We have lots of work ahead and our country needs every engineer to report for national duty.

Our voluntary contribution in the service of our members, society and South Africa gathers momentum. Every member must look inward and go forward with strength and confidence, we can do it. Go to your student chapter meeting, to your centre meeting, to your section meeting, to your Council Committee meeting; table your ideas and suggestions on how we can all make our own contribution towards building the world class South Africa we deserve. Think big, be bullish and be strong; we are winners!

Our Institute was established in 1909 and we trust it will still be around for centuries to come. As present day members, we will become a distant memory. Time is free. Let us explore how best we can leave behind more assets for our future members. One asset category that we should consider is that of the "Fixed Asset: Land and Buildings". Imagine we made an investment yesterday in the docks of Cape Town, which is now the multi-billion rand Waterfront Complex. It is never too late. I have challenged our Centres to think big and to think long term. Let us capture our voluntary energies of today and ensure that our energies of today are never wasted, but serving our members of tomorrow. We are always looking for venues for meetings, for hosting distinguished lectures and for continuous professional development courses. I am sure we can construct the business case for local investment in land and buildings in lieu of paying for our hard work as volunteers. We must turn down the tap of cash flows and redirect the money towards investments. I leave this idea with our centre membership and leadership to develop.

Southern Cape, with its deep quality of life and slow environment which is all wrapped by rolling hills and mountains presents the ideal environment to capture and nurture the wisdom and experience of our Southern Cape members. We have a great opportunity to grow and develop our own "think-thank, models and modules" on how best we can excite the youngsters of today to become the engineering giants of tomorrow, on how best we can grow the university student of today to become the customer focussed engineer that will deliver solutions to customer satisfaction, on how best we can enhance the workings of the professional engineer of today to make him or her and his enterprise "World's Best". I have left this idea with our team in George and tasked our Honorary Vice President to report back to Council.

The focus on our students of electrical engineering gathers speed. We want every third and fourth year student to be a registered member of the Institute (non negotiable), to be an activist of engineering and society on campus, to be an integral part of our Centre and Section Operations and to be a leader of our Institute in the service of society.

The birth of our "Junior Council" is imminent. Students will become deeply involved with our Senior Members and Fellows in Industry, Public Utilities and Public Enterprises. They will make their own arrangements, schedules and timetables for vacation work, for in service experiential learning, for in service engineer in training supervision and mentorship and for their coaching as in continuous professional development.

Just as the students grow their presence and strength within the Institute, will they reach out and pull in the scholars of mathematics and science and collate all our energy to be focussed on the customers' customer.

I can see our membership grow well beyond tenths of thousands. Every member must be ready to receive and serve our growing membership. Thank you to all our Members, Chairs of Committees, Sections and Centres, Members of Council and to our Chief Executive and the Administration for their selfless and dedicated efforts in serving the Institute and our Membership. This is always appreciated by our all members; as expressed by fellow member, Dr Andrew Erickson, direct from Switzerland. Dr. Erickson grew up in South Africa. He was a leading scientist and engineer at the Council of Science and Industrial Research (CSIR) and later on the Board of ABB.

"Dear Pat,

The postal services to Europe are rather slow and I've only recently received the ***watt****now of May, and so also could only now read your inspiring SAIEE presidential address.*

Congratulations both on your important (and well deserved) new role as SAIEE President and on this very thoughtful and thought provoking message! You have indeed exciting work ahead! And I hope that your message and challenges will be heard by many and energetically taken up.

Best wishes for a fulfilling and successful year in office.

Kind regards"

Thank You.

Dr Pat Naidoo | Pr. Eng | FSAIEE
2014 SAIEE President

WATTSUP

SAIEE Charity Golf Day

The annual SAIEE Charity Golf Day took place at Glenvista Golf & Country Club in the South of Johannesburg, recently. The SAIEE President opted to stay with last year's benefactor of the charity golf day, Girls & Boys Town of South Africa.

Albeit a chilly day, it was thoroughly enjoyed by everyone. The Fourball alliance tournament was a great success. A big thank you to Glenvista Golf Club for hosting the event, as well as the sponsors and players for their participation and support. The sponsors were, in no particular order: Diesel Electric, WPI, IPI, Powertech, Actom, Zest Electric Motors, Wade Walker, Malaysian Switchgear, City Power, Endress + Hauser, Impact Energy, Eberhardt Martin, Liblink, Steelcor, ARB and QUANTA Services.

Patrick O'Halloran with Immediate Past President, Paul van Niekerk.

Paul van Niekerk with Jaco Erasmus.

Paul van Niekerk with C. Lundasami.

Paul van Niekerk with Clive Watson.

Marius Lombard, winner of the generator sponsored by Diesel Electric.

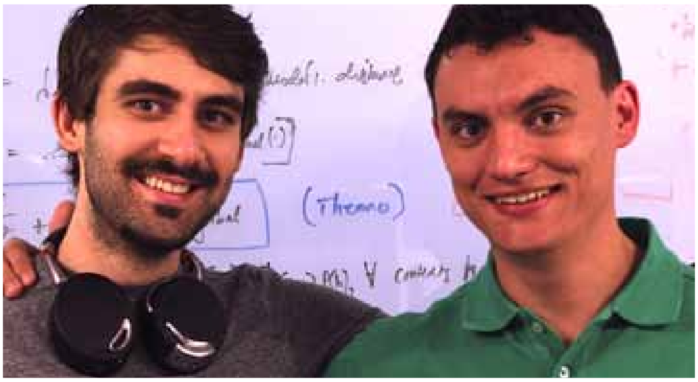
Team: QUANTA Services Group

Quinton Labuschagne with Paul van Niekerk.

Team: Kainos Group.

Team Powertech.

Maties' WorkMode app wins big time



Maties computer science students Jacques Marais and Rijnard van Tonder just earned themselves 25 000 Euros in the Ericsson apps for working life competition.

Two computer science students from Stellenbosch University won €25 000 (about R355 000) for the WorkMode app they developed for Ericsson's applications 2014 competition.

Rijnard van Tonder and Jacques Marais, both MSc students in Computer Science at SU, competed against 158 entries from 142 teams in the student category. They developed an app that helps workers collaborate by allowing them to see the real-time work context and tasks of colleagues.

In a media release, Ericsson says the jury was impressed by the strong business potential of the WorkMode app. Their focus on design and usability also helped when it came to innovation and addressing the theme of Apps for working life.

Rijnard, who is in the third week of an internship at Microsoft in Seattle in the USA, says he's really honoured that they received first prize. *"Africa as a whole also did very well. I think this competition goes a long way to promote our potential here in South Africa and Africa."* Earlier this year Rijnard earned second place in IBM's Master the Mainframe contest, described as the largest competition of its kind in the world.

Jacques says: *"The award will help us to build our business and allow us to develop not only this app but also some ideas we have around education in South Africa. It will also enable us to purchase hardware so we can expand to different platforms. It's a real boost."*

The winner in the company category was Team SOP from Nigeria, who created an app that analyses the availability of electricity in a given area. The Technology for Good Recognition also went to South Africa, with Sowertech's Afta Robot app receiving the award for their smart solution for public transportation.

Southern Cape Centre hosted SAIEE President

An important event on the calender of the SA Institute of Electrical Engineers, is the annual Presidential Address, which is open to other voluntary associations and the public. The Southern Cape Centre hosted this event in George at the end of May, when the newly-elected president, Dr Pat Naidoo, presented *"Engineering Engineers for a World Class South Africa"*.

Dr Naidoo outlined his vision for the way forward, stressing the way in which Engineers contribute to the success of the country, and indeed of the continent. It is up to engineers to plan, commission and maintain infrastructure, create jobs, stimulate the economy, and ultimately to improve the lives of all.

There was strong emphasis on providing services which will thrill not only the customer, but also the customer's customer. Only through World Class engineering services will we achieve a World Class South Africa.

One major shortcoming has been a lack of engineering leadership. New initiatives will strive to place engineers in leadership roles in public utilities and enterprises, and so improve the efficiency and efffectiveness of service delivery.

A 5-step approach was outlined by Dr Naidoo, with each step being discussed in some detail, and those present were left with a feeling of positive resolve to make a difference. After all, the purpose is to improve the lives of all South Africans.

L – R: Mario Barbolini (Honorary Vice President), Dr Pat Naidoo (SAIEE President) and Robbie Evans (Southern Cape Chairman).

FUTURE SOUTHERN CAPE CENTRE EVENTS

There are a number of events being planned for the remainder of the year, including some interesting new possibilities:

- Wind Farm visit
- Quality of Supply presentation
- Annual Bernard Price Memorial Lecture
- Presentation on Google
- Energy Efficient Lighting
- SALT Telescope tour at Sutherland

MEMORANDUM - STATE ENTERPRISE ESKOM

DR JACOB ZUMA
MAY 2014

I was part of the Eskom team who delivered bulk electrical energy at world's lowest cost. Yesterday, we had afternoon tea and an open "Eskom Conversation" with Dr. Ian McRae, my first Chief Executive at Eskom. Dr. McRae is of good health and of unlimited passion to serve South Africa. He sends his regards and best wishes on your inauguration and leadership of South Africa.

We spoke of the challenges of yesterday and the challenges of today. The challenges are similar.

Eskom holds multiple keys to our national challenges of the economy, of jobs, of industrialization, of small business development, of water and sanitation; the list is endless.

Eskom is struggling.

We must help and get Eskom back to its world class performance. Eskom is the "economic pump" of the nation.

We table three ideas for your consideration.

We can work with our members and develop all the ideas for immediate launch towards project construction and commissioning. Our Institute voluntary efforts will be in addition to Government's normal efforts and processes to help Eskom back to its full and original capability.

IDEA 1
REFURBISHMENT OF ESKOM'S THERMAL FLEET OF POWER STATIONS

We have at any hour, on any day, in any month thousands of MW unavailable for duty. This is no fault of Eskom or any individual. The thermal parts of the power station have aged by time causing the unavailability of the total production unit. These parts can be easily refurbished by the people, materials and factories of South Africa. Imagine the new artisan, technician and engineer jobs that we can immediately create. We have so many students at our colleges and universities that are calling upon us for in service vacation work and experiential training; we can do so much together.

IDEA 2
THIRD NUCLEAR UNIT AT SOUTH AFRICA'S KOEBERG NUCLEAR POWER STATION

South Africa's Koeberg Nuclear Power Station is now 30 years old. The fire has burnt continuously in the concrete and steel reactor enclosure for 30 years. We should be building the third nuclear unit at Koeberg so as to allow us the flexibility to refurbish and prepare the existing two units for another three decades of service. Koeberg delivers to the national grid both electrical energy and electrical strength; the latter is more valuable than the former. The third unit at Koeberg will afford us a lower risk opportunity to grow and strengthen our expertise in nuclear technology and nuclear power station operations and maintenance.

IDEA 3
IMPORT OF SADC HYDRO ELECTRIC ENERGY

SADC offers South Africa much more electrical energy with attributes of lower costs in support of energy affordability and carbon emission savings against thermal coal resources.

We must push forward with the integration onto the South African National Grid the import of natural, renewable energy from the bulk hydro resources of Southern Africa. The opportunities are vast and available from the west, central and eastern corridors of SADC; even as far from the northern corridors of Ethiopia.

During your tenure as Deputy President of South Africa and later as Chairman of the Southern African Development Community, we both met at the World Economic Forum and at SADC and shared our aspirations for the large scale import of natural, renewable energy from Inga to South Africa. You were equally excited. Specifically, we had completed the Intergovernmental Agreements and launched the company to develop, finance, build, operate and maintain the 5000 MW, Inga 3 Hydro Electric Power Station and the associated transmission infrastructure to form the Western Power Corridor of the Southern African Power Pool.

The 8 billion USD project was prepared for launch but disturbed by factors that were beyond our control at that time. With your Presidency in South Africa and with your great respect at SADC and the African Union, this project can go back on the launch pad and be commissioned within the next five years. Every minute, the free energy of the Congo River goes into the Atlantic Ocean as we stand by helplessly and challenged by poverty, jobs and a better quality of life for all in Africa.

We must lead.

CONCLUSION

China now has technology that can move 10,000 MW over 3000 km using 1100 kV ultra high voltage direct current technology. Twenty years ago, Eskom was the consultant to both China and India on High Voltage Transmission. Our plan was to bring 3000 MW from Inga 3 to Eskom Beta situated just outside Bloemfontein. We can now do 10,000 MW into South Africa. The Inga – Assam (Cairo, Egypt) can also be achieved. Cape to Cairo is achievable. A full 80,000 MW at Inga is in sight. African Economic Renaissance will have commenced.

Thank you.

DR. PAT NAIDOO I FSAIEE

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Innovative Power Quality Solutions

Schneider Electric's first Xperience Efficiency event in South Africa to spark energy dialogue

In new economies, the need for more electricity is driven by population growth, industrialisation and urbanisation. These unprecedented levels of energy demand have made it possible for Schneider Electric, a global leader in energy management, to showcase the future of energy efficiency at its Xperience Efficiency event, taking place at the Birchwood Conference Centre from 26-27 August 2014.

Xperience Efficiency is a FREE event that tackles the demand drivers that are forcing change: economic and government rebalancing, urbanisation, digitisation, and sustainable resources. By looking at the latest integrated energy trends and sustainability solutions that will transform how we all work, learn and play, Schneider Electric's event creates the ideal platform to discuss and demonstrate efficient energy opportunities.

The prestigious event will bring together industry- and government leaders, international and local delegates, as well as academics, partners and customers, to share knowledge about how to solve critical energy and sustainability challenges. The discussion will, in particular, be tailored to the southern African energy landscape, and focus will be given to energy strategies, challenges and solutions.

Discussions will focus on topics such as the "smart grid" and research papers that have shown that electricity networks in South Africa, and worldwide, require smart solutions if power supply and demand is to be balanced efficiently.

"The answer lies in connecting power customers to smart grids, to each other and with other players, so as to make it all work and to balance supply and demand efficiently. In the existing grid, power providers have to visit consumers and regularly check meters. In the future, consumption data may transfer automatically, giving consumers and utilities a real time estimate of electricity consumption."

At present most people might not know how much electricity they consume until they receive their electricity bill, but in the future they will be able to adjust their energy demand to moments when prices and demand are at their lowest. They will be able to use this information to decide when to switch on household appliances such as washing machines and tumble dryers or to charge other devices, perhaps even, electric cars.

"Resolving and managing energy and sustainability challenges is a responsibility shared by the entire population. Xperience Efficiency South Africa 2014 will therefore offer a unique platform from which to address key drivers of change, including economic and government rebalancing, urbanisation, digitisation and sustainable resources," says Legér.

The event will also provide a line of sight into the future of efficiency by examining the latest integrated "green" energy trends and sustainability solutions that promise to transform how the world works, learns, and plays. *"To fight climate change, we need to reduce CO_2 emissions. This will come mostly from energy efficiency on the one hand, and the development of renewable energy sources on the other, which we'll thoroughly delve into at the event,"* says Leger.

In addition, delegates will experience Schneider Electric's actual solutions first-hand.

Xperience Efficiency South Africa 2014 will take place at the Birchwood Conference centre, Boksburg. For more information please visit www.schneider-electric.co.za.

Harnessing M2M technology for smart utility metering in the commercial sector

Reducing water and energy consumption has become a top priority in green business practices today. XLink, together with industry leading and reputable partners including water engineering specialists WRP and energy specialists KT Utility Forensics, has developed smart metering solutions for the monitoring and management of both water and energy consumption.

The solutions comprise sophisticated machine-to-machine (M2M) technology that effectively addresses the skills shortage barrier by providing clients with immediate access to daily monitoring and control of their water and / or energy consumption.

Smart water metering solutions allow for the identification of system malfunctions, leaks, pressure fluctuations or unauthorised water use as they happen and send early alarm notifications allowing for immediate action. Furthermore, they remove the need for monthly manual meter readings and ensure that accurate readings are provided to local councils for billing. The benefits of smart metering solutions are often underestimated and even a small leak of only $2m^3$ / hour can result in an additional R27 000 each month to the customer's water bill.

WRP partnered with XLink Communications to provide the M2M platform, product installation, on-going portal support and maintenance services that enable WRP to transmit the data from the reader logger attached to the client's water meter through to a base station, and ultimately to XLink's Insight for m2mconneXion™, an internet-based data acquisition and display facility.

"Without this form of 'real-time' monitoring a leakage of this kind is often overlooked and can run for months if not years. As water becomes more expensive and scarce throughout South Africa, the need to implement continuous monitoring and evaluation will increase", comments Grant McGlashan of XLink Communications.

Electricity consumption is no different for businesses and smart energy metering allows businesses to turn data into strategic intelligence that also positively impacts bottom line.

An analysis of the data collected in 2013 revealed that 77 percent of KT Utility Forensics' 800 customers discovered discrepancies in their electricity billing. Smart electricity metering resolves concerns around current local council billing and ensures that clients are only billed for their actual consumption at the legislated tariffs as set by the National Energy Regulator of South Africa (NERSA).

The web-based online management system uses the latest in online metering technology, enabling internet connected customers to remotely monitor their utility meters through access to up to date billing and usage diagrams. Each meter is fitted with a SIM card that sends the relevant data via the GSM network to the online portal where the data is captured in various reporting and graphical formats.

End-users have accurate and real-time readings of energy consumption (KWH), demand (KVA), reactive power (KVar), voltage (V), amps (A), frequency and power factor. This information provides the client access to accurate carbon footprint reporting, outage monitoring, bill comparison, meter estate management, usage optimisation as well as tariff comparison.

In addition to reducing carbon footprints and benefiting from the associated cost savings, there is also a government incentive linked to smart utility monitoring. The energy efficiency tax incentive Section 12L of the Income Tax Act (deduction in respect of energy efficiency savings) came into effect on 1 November 2013, which allows taxpayers to claim deductions of 45 cents per kilowatt hour, or kilowatt hour equivalent, of energy efficiency savings before the year 2020.

Quality guaranteed with unique load test bed

Specialist drive engineering company SEW-EURODRIVE offers customers the peace-of-mind that all of its gearboxes meet the necessary quality standards and requirements, thanks to the load test bed which is currently only found at the company's Durban branch.

SEW-EURODRIVE general manager of operations Raymond Obermeyer notes that the load test bed consists of a motor, generator, test bed and a control system. *"This allows the company to check gear mesh and bearing frequencies, vibration, temperature and thermal levels, as well as general noise levels,"* he explains.

Two gearboxes that need to be load tested are connected together at their output shafts. The motor is then connected to the one gearbox's input shaft and the generator is connected to the other gearbox's input shaft. The motor drives through the gearboxes to turn the generator.

The load on the gearboxes is controlled by the amount of resistance that the generator applies. The generator's resistance can be adjusted within the control system, which recovers the energy from the generator and feeds it back to the motor to reduce overall energy consumption.

The test bed acts as a load that is driven by the prime mover, which is equipped to measure torque and speed. The load tester must be able to operate at any speed and load the prime mover to a recommended level of torque that the gear unit test requires.

According to Obermeyer, the load test bed is largely used to test new equipment, in order to ensure that it meets specified criteria. *"As part of the repair process, gearboxes are also tested to verify that the repairs are up to standard and meet the required specifications."*

The load test bed is currently a unique feature of the SEW-EURODRIVE Durban branch, however, Obermeyer reveals that there are plans to introduce these test beds at other branches across South Africa.

"The load test bed in Durban forms part of the company's continuous improvement plans to develop the infrastructure of its assembly plants nationally. Durban is the newest factory, which is why the load test bed was installed there. This is part of our plan to show that we are committed to expanding our capabilities nationally," he adds.

Obermeyer points out that the load test bed has been well received since the service was established. *"We have had customers using our facility from the first day. By making use of the load test bed, our customers are ensured of a standard of quality that is expected from SEW-EURODRIVE. In addition, our customers increasingly require load testing, and by having these facilities available, we are able to meet our customer and market requirements,"* he concludes.

SAIEE CPD Training Expands into Africa

The SAIEE presented a Continuing Professional Development (CPD) training course in the Republic of the Congo.

BY | GAVIN STRELEC | MSAIEE

During 2013, DAFRO Engineering Consultants approached the SAIEE on behalf of the Kamoto Copper Mine in the Democratic Republic of the Congo (DRC), to present an in-house Continuing Professional Development (CPD) accredited training course on the *"Design of Economical Earthing Systems for Utility Electrical Installations"*.

This CPD course is accredited by the SAIEE and is one of a host of courses that serve to assist SA and beyond in addressing the skills shortage. (Validation SAIEE-1125-V).

Whilst the SAIEE holds regular training courses in South Africa's major centres, this training intervention is significant, in that it was the first time the SAIEE has ventured across the SA borders into Africa.

One of the difficulties in Africa is the relative isolation of industrial, mining and utility companies, compared to those in more developed countries. Without established avenues for interaction such as professional bodies like the Engineering Council of South Africa (ECSA) and the SAIEE, as well as, in many cases, the lack of local standards bodies such as South African National Standards (SANS) or National Regulation Standards (NRS), the trend is to continue past perhaps outdated practices in resolving operational challenges with little potential for improvement.

Alternatively, consultants are appointed to handle designs and project management, with the client being largely isolated and blind to the process. This tends to inhibit the development of internal expertise, and leads to increased dependency on external contractors. In some cases the clients are unable to properly review designs, due to deficiencies in resource expertise.

DAFRO envisions an opportunity for expanding electrical engineering knowledge bases and lifting technical expertise levels, initially in the DRC, with other African countries to follow. As it was believed that companies in Africa might in some cases be unaware that a training need even exists within their companies, DAFRO through their extensive outreach into Africa, set about the arduous task of sensitising clients to the potential benefits of training. Sensitising companies involved expounding anecdotal cases where deficiencies led to incidents and highlighting risks in specific environments. Also, detailing possible technical improvements and cost savings through optimisation as well as the importance of benchmarking against international best-practice.

The collaboration with the SAIEE and DAFRO to facilitate this training under the auspices of the SAIEE is the beginning of this partnership and would further facilitate the upliftment of technical standards in other African countries, thereby ensuring professionalism and integrity. The SAIEE validation of course material and presenters ensure that high standards and quality of presentations are maintained.

This joint venture of the SAIEE and DAFRO will enlarge the SAIEE footprint in Africa. This will be of significant benefit of those participating countries where increased international interaction opens channels for further training and information sharing.

TRAINING EXPERIENCE IN THE DRC

The Kamoto mine identified challenges in meeting existing design limits as well as uncertainty around existing practices and standards, some of which may be antiquated, or even inherited Belgian norms.

The Kamoto Mine is an underground copper and cobalt mine in the Katanga province in the south of the Democratic Republic of the Congo, close to the town

Satisfied customers with Gavin Strelec.

Kolwezi just north of the border with Zambia.

The DRC is the second largest country in Africa and the second largest economy in Africa, relying heavily on mining.

The world's longest HVDC link transfers energy some 1900km from "Inga" Hydro power station on the Congo River the north to "Shaba" converter station close to the Shaba 500kV HVDC converter station.

The mine is run by the Kamoto Copper Company (KCC), a joint venture between Katanga Mining (75%) and the government-owned Gécamines (25%).

The mine is part of a major complex with the potential of becoming Africa's largest copper producer and the world's largest cobalt producer. The mine has a maximum demand of 120MW.

The mine receives power at a nominal voltage of 120kV at two step-down substations where after distribution is effected at 15kV. These, as well all internal MV and LV infrastructure is maintained by the mine. The training was conducted at the mine in two groups of 20, with the smaller groups facilitating delegate interaction. There was a high degree of interaction after the initial ice was broken, with delegates asking questions and seeking clarity to problems and practices that they had encountered. Several in-depth discussions were held around this topic and also where improvements of cost optimisation could be effected.

The DRC is a French speaking country, but despite the training course being presented in English, there were competent and helpful translators within the group who assisted in getting the message across. Since most of the delegates did understand English to at minimum a moderate extent, important points and concepts seemed to be carried across well, and the information was emphasized by the repetition.The presentation was made with the aid of frequent sketches, calculations and pictorial explanations which emphasized the content and important concepts.

The delegates showed avid interest in the course material and an eagerness to absorb and benefit from the intervention. The delegates were always appreciative of the information and most were consistently taking notes.

Of the challenges experienced by the mine, the theft of earthing copper is not a significant threat at present. Within the mine premises relatively good security inhibits opportunistic theft. Consistent with many other African countries, the underdeveloped recycling industry has place a restriction on theft, however this is changing. Therefore, it is recommended to institute theft-deterrent measures in a pre-emptive fashion.

Due to frequent heavy downpours, the soil is leached out resulting in relatively poor soil conditions, and difficulty in achieving the required electrode resistances according to standards. It is therefore necessary to appreciate the requirements in relation to local parameters in order to optimise designs, and not to apply generic approached that may result in unnecessarily high costs.

Mine managers are always interested to investigate ways to save up-front costs due to optimised use of material, and reduced operating costs by instituting low maintenance solutions. Crucial to this is the correct coordination of conductors and connections to improve material utilisation and the use of connections that don't require verification and ongoing maintenance.

By comparing practices between different users and in different environments, an appreciation of the design factors is engendered in the delegates allowing them to start questioning standards and make their own modifications where necessary. This type of interaction not only improves staff competency but also job satisfaction, when knowledge is applied in a constructive way. wn

Africa Boosts Local Manufacturing Base

The Zest WEG Group's 2013 acquisition of a transformer manufacturing operation has increased its local manufacturing base and substantially increased its staff complement in South Africa to over 700 people.

Wadeville-based WEG Transformers Africa, formerly Hawker Siddeley Electric Africa, is one of the largest manufacturers of mini substations, unit substations and distribution transformers in the country, with the capability to design and manufacture the complete range presently in use in the country's industrial sector.

"The acquisition last year of this leading transformer operation is in line with the WEG Group's 2020 vision to grow the business on this continent both organically and through acquisitions," Gary Daines, Zest WEG Group's group sales and marketing director, says. *"WEG has a strategic plan to increase its sales by at least 17% year on year until 2020, when it aims to arrive at a turnover of US$10-billion. However, WEG is very aware that in order to participate in the African market, it needs to contribute to the local economy. As a growing local employer, the Zest WEG Group is on board to support our government's localisation drive and we're achieving this by continuing to expand our production facilities and developing a robust technical skills base."*

"From a group perspective, adding the transformer product range to the Zest WEG Group's offering is very strategic as it complements all our activities and slots in perfectly with our aggressive Africa growth initiative. We have a phenomenally strong national sales team, as well as a network of branches, which are already starting to sell and support the range."

"An important success factor is that the transformer products are 'Africanised' and suitable for local conditions."

"In their manufacture we ensure suitability for operation and for logistical movement in Africa. This has resulted in a very conservative design that will also place us in a strong position when we export these products into first world markets."

Since last year's takeover, WEG Transformers Africa has on embarked a significant upgrade initiative to enhance its equipment, processes and design packages. The initiative includes major improvements to its office buildings and staff amenities.

Danford Mugadza, managing director of WEG Transformers Africa, says the upgrades will bring the company in line with WEG's technology platform and enable it to compete on the world market. At the same time, the cutting edge technologies being introduced will create significant employment opportunities and increase the rate of skills transfer from WEG's technical teams in Brazil to the local workforce.

"We're finding it very rewarding to supplement our operation with all levels of skills and to develop our people through a combination of training them to operate the new equipment and with general skills through the regular Zest WEG Group training programmes," says Mugadza. *"We have a current target to increase our workforce by about 40 people over the next 18 months - nearly a 50% increase in capacity - that will position us for future growth and expansion."*

"We've set our sights on expanding supply not only within South Africa and to other African countries, but also into the

Some of the first WEG transformers to leave Wadeville-based WEG Transformers Africa.

Australasian, Middle Eastern and European markets where WEG has established customer bases. This requires a strong focus on achieving and maintaining world class quality levels and we've currently working on standardising our quality in line with other companies in the WEG Group. WEG Transformers Africa is ISO 9001 accredited, but as we grow and develop the business we need to ensure that our quality systems stay abreast of these advances. We're also improving our environmental standards and investing heavily in making our facility ISO 14000 compliant."

WEG Transformers Africa mini substations and unit substations have a range from 100 kVA to 1000 kVA in voltages up to 22 kV. The company specialises in Type 'B' mini substations, fabricated in mild steel or 3CR12 corrosion resistant steel as recommended in SABS 1029, 1030 and NRS004, with the transformer section complying with SABS 780 and NRS005. The standard size mini substations consist of 100 kVA, 160 kVA, 200 kVA, 315 kVA, 500 kVA, 630 kVA, 800 kVA and 1000 kVA units. HT and LT switchgear can be provided to suit individual requirements with advice and recommendations on the most appropriate switchgear provided by the company's experienced engineers.

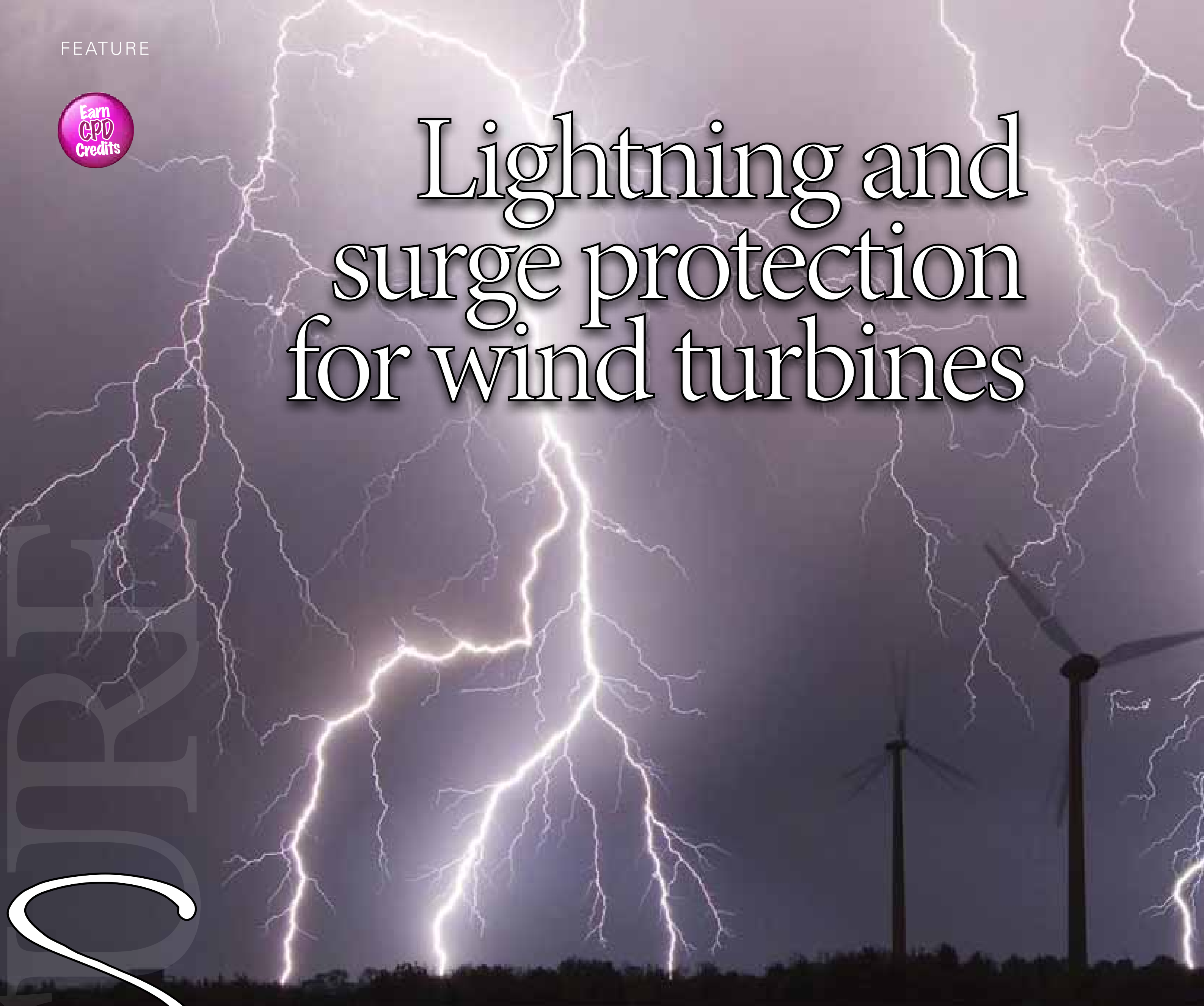
WEG Transformers Africa's standard distribution, power and special application transformers range from 50 kVA to 10 000 kVA in voltages up to 66 kV with off-load tap-switch or on- load tap-changers. In addition, the company manufactures special application units for mining, industrial, rectifier/traction, converter and thyristor drive applications. Dimensions are always within SABS recommendations.

Each unit is fully tested in accordance with SABS and other standard specifications and test certificates are available on request. In addition, distribution transformers carry the SABS mark of approval corroborating that the company's manufacturing facilities are subject to regular routine visits by SABS inspectors. wn

WEG transformers are manufactured under stringent quality control processes in WEG Transformers Africa's ISO accredited facility.

Earn CPD Credits

Lightning and surge protection for wind turbines



Since the risk of lightning striking a wind turbine increases quadratically with its height, it can be estimated that a multi-megawatt wind turbine is hit by a direct lightning strike roughly every 12 months. The feed-in compensation must amortise the high investment costs within a few years, meaning that downtime as a result of lightning and surge damage and associated repair costs must be avoided. For this reason, comprehensive lightning and surge protection measures are essential.

When planning a lightning protection system for wind turbines, not only cloud-to-earth flashes, but also earth-to-cloud flashes, so-called upward leaders, must be considered for objects with a height of more than 60m in exposed locations.

The high electrical charge of these upward leaders must be particularly taken into account for the protection of the rotor blades and selecting suitable lightning current arresters.

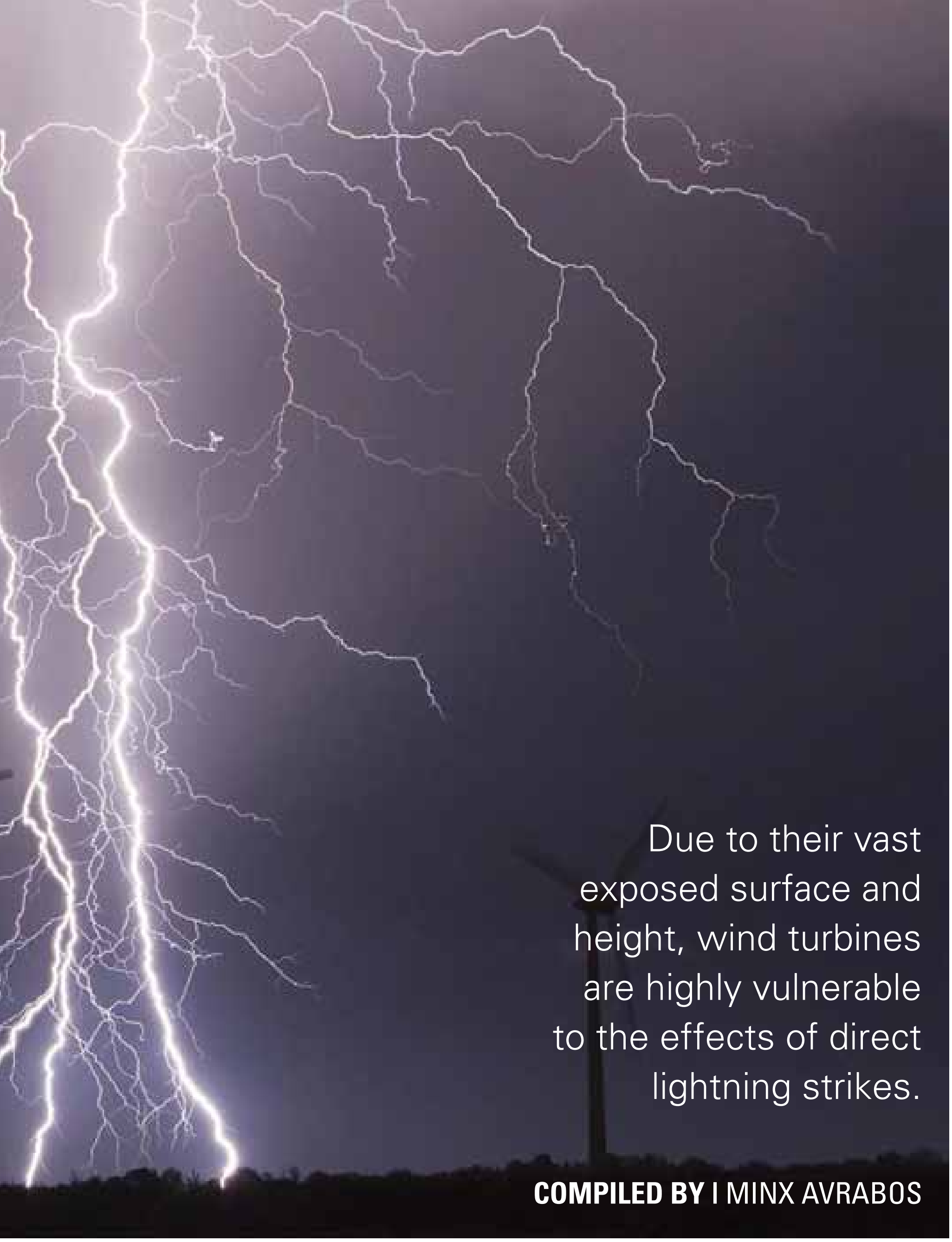
STANDARDISATION

The protection concept should be based on the international standards IEC 61400-24:2010 and IEC 62305 standard series and the guidelines of Germanischer Lloyd (e.g. GL 2010 IV – Part 1: Guideline for the certification of wind turbines).

PROTECTION MEASURES

The IEC 61400-24 standard recommends to select all sub-components of the lightning protection system of a wind turbine according to Lightning Protection Level (LPL) I unless a risk analysis demonstrates that a lower LPL is sufficient. A risk analysis may also reveal that different sub-components have different LPLs. The IEC 61400-24 standard recommends that the lightning protection system is based on a comprehensive lightning protection concept.

The lightning protection system of a wind turbine consists of an external Lightning



Protection System (LPS) and Surge Protection Measures (SPM) to protect electrical and electronic equipment. In order to plan protection measures, it is advisable to subdivide the wind turbine into Lightning Protection Zones (LPZ).

The Lightning ProtectionSystem of wind turbines protects two sub-systems which can only be found in wind turbines, namely the rotor blades and the mechanical power train. The IEC 61400-24 standard describes in detail how to protect these special parts of a wind turbine and how to prove the effectiveness of the lightning protection measures. According to this standard, it is advisable to carry out high-voltage tests to verify the lightning current withstand capability of the relevant systems with the first stroke and the long stroke, if possible, in a common discharge.

This article mainly describes the implementation of lightning and surge protection measures for electrical and electronic devices/systems of a wind turbine.

The complex problems with regard to the protection of the rotor blades and rotably mounted parts/bearings must be examined in detail and depend on the component manufacturer and type. The IEC 61400-24 standard provides important information in this respect.

LIGHTNING PROTECTION ZONE CONCEPT

The lightning protection zone concept is a structuring measure to create a defined EMC environment in an object. The defined EMC environment is specified by the immunity of the electrical equipment used. The lightning protection zone concept allows to reduce conducted and radiated interference at the boundaries to defined values. For this reason, the object to be protected is subdivided into protection zones.

The rolling sphere method may be used to determine LPZ 0_A, namely the parts of a wind turbine which may be subjected to direct lightning strikes, and LPZ 0_B, namely the parts of a wind turbine which are protected from direct lightning strikes by external air-termination systems or airtermination systems integrated in parts of a wind turbine (for example in the rotor blade). According to the IEC 61400-24 standard, the rolling sphere method must not be used for rotor blades themself. For this reason, the design of the air-termination system should be tested according to chapter 8.2.3 of the IEC 61400-24 standard. Figure 1 shows a typical application of the rolling sphere method, Figure 4 the possible division of a wind turbine into different lightning protection zones. The division into lightning protection zones depends on the design of the wind turbine. Therefore, the structure of the wind turbine should be observed. However, it is decisive that the lightning parameters injected from outside of the wind turbine into LPZ 0_A are reduced by suitable shielding measures and surge protective devices at all zone boundaries so that the electrical and electronic devices and systems inside a wind turbine can be operated safely.

SHIELDING MEASURES

The nacelle should be designed as an encapsulated metal shield. Thus, a volume with an electromagnetic field that is considerably lower than the field outside of the wind turbine is achived in the nacelle.

Lightning and surge protection for wind turbines

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In accordance with IEC 61400-24, a tubular steel tower as predominantly used for large wind turbines can be considered an almost perfect Faraday cage, best suitable for electromagnetic shielding. The switchgear and control cabinets in the nacelle and, if any, in the operation building should also be made of metal. The connecting cables should feature an external shield that is capable of carrying lightning currents. Shielded cables are only resistant to EMC interference if the shields are connected to the equipotential bonding on both ends. The shields must be contacted by means of fully (360 °) contacting terminals without installing EMC- incompatible long connecting cables on the wind turbine.

Magnetic shielding and cable routeing should be performed as per section 4 of IEC 62305-4. For this reason, the general guidelines for an EMC-compatible installation practice according to IEC/TR 61000-5-2 should be used.

Shielding measures include for example:

- Installation of a metal braid on GRP-coated nacelles
- Metal tower
- Metal switchgear cabinets
- Metal control cabinets
- Lightning current carrying shielded connecting cables (metal cable duct, shielded pipe or the like)
- Cable shielding

External lightning protection measures
These include:

- Air-termination and down-conductor systems in the rotor blades
- Air-termination systems for protecting nacelle superstructures, the nacelle and the hub
- Using the tower as air-termination system and down con- ductor
- Earth-termination system consisting of a foundation earth electrode and a ring earth electrode

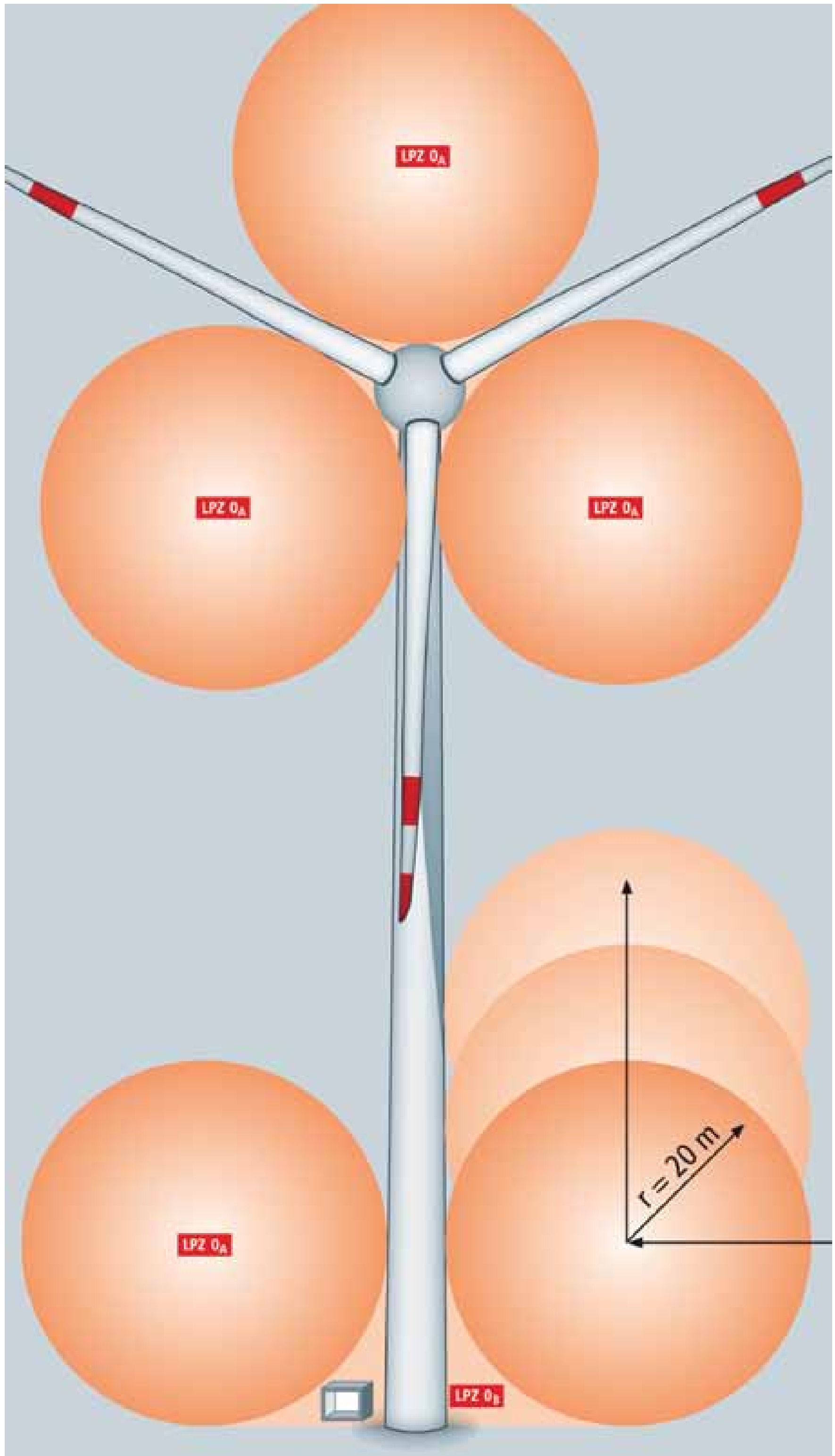

Figure 1 - Rolling sphere method

The function of the external Lightning Protection System (LPS) is to intercept direct lightning strikes including lightning strikes into the tower of the wind turbine and to discharge the lightning current from the point of strike to the ground. It is also used to distribute the lightning current in the ground without thermal or mechanical damage or dangerous sparking which may cause fire or explosion and endanger persons.

The potential points of strike for a wind turbine (except the rotor blades) can be determined by means of the rolling sphere method (see Figure 1). For wind turbines, it is advisable to use class of LPS I. Therefore, a rolling sphere with a radius r = 20 m is rolled over the wind turbine to determine the points of strike. Air-termination systems are required where the sphere contacts the wind turbine.

The nacelle construction should be integrated in the lightning protection system to ensure that lightning strikes in the nacelle hit either natural metal parts that are capable of withstanding this load or an air-termination system designed for this purpose. Nacelles with GRP coating or the like should be fitted with an air-termination system and down conductors forming a cage around the nacelle (metal braid).

The air-termination system including the bare conductors in this cage should be capable of withstanding lightning strikes according to the lightning protection level selected. Further conductors in the Faraday cage should be designed in such a way that they withstand the share of lightning current to which they may be subjected. In compliance with IEC 61400-24, air-termination systems for protecting measurement equipment and the like mounted outside of the nacelle should be designed in compliance with the general requirements of IEC 62305-3 and down conductors should be connected to the cage described above. "Natural components" made of conductive materials which are permanently installed in/on a wind turbine and remain unchanged (e.g. lightning protection system of the rotor blades, bearings, mainframes, hybrid tower, etc.) may be integrated in the LPS. If wind turbines are a metal construction, it can be assumed that they fulfil the requirements for an external lightning protection system of class of LPS I according to IEC 62305.

This requires that the lightning strike is safely intercepted by the lightning protection system of the rotor blades so that it can be discharged to the earth-termination system via natural components such as bearings, mainframes, the tower and/or bypass systems (e.g. open spark gaps, carbon brushes).

AIR-TERMINATION SYSTEM/ DOWN CONDUCTOR

As can be seen in Figure 1, the

- Rotor blades,
- Nacelle including superstructures (Figure 2, Table 1),
- Rotor hub and
- The tower of the wind turbine

may be hit by lightning. If they are capable of safely intercepting the maximum lightning impulse current of 200 kA and to discharge it to the earth-termination system, they can be used as "natural components" of the air-termination system of the wind turbine's external lightning protection system.

Metallic receptors, which represent defined points of strike for lightning strikes, are frequently installed along the GRP blade to protect the rotor blades against damage due to lightning. A down conductor is routed from the receptor to the blade root. In case of a lightning strike, it can be assumed that the lightning strike hits the blade tip (receptor) and is then dis- charged via the down conductor inside the blade to the earth- termination system via the nacelle and the tower.

EARTH-TERMINATION SYSTEM

The earth-termination system of a wind turbine must perform several functions such as personal protection, EMC protection and lightning protection.

An effective earth-termination system (Figure 3) is essential to distribute lightning currents and to prevent that the wind turbine is destroyed. Moreover, the earth-termination system must protect humans and animals against electric shock. In case of a lightning strike, the earth-termination system must discharge high lightning currents to the ground and distribute them in the ground without dangerous thermal and/or electro- dynamic effects.

In general, it is important to establish an earth-termination system for a wind turbine which is used to protect the wind turbine against lightning strikes and to earth the power supply system.

Note: Electrical high-voltage regulations such as CENELEC HO 637 S1 or applicable national standards specify how to design an earth-termination system to prevent high touch and step voltages caused by short-circuits in high or medium-voltage systems. With regard to the protection of persons, the IEC 61400-24 standard refers to IEC//TS 60479-1 and IEC 60479-4.

Lightning and surge protection for wind turbines

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ARRANGEMENT OF EARTH ELECTRODES

The IEC 62305-3 standard describes two basic types of earth electrode arrangements for wind turbines:

Type A: According to the informative Annex I of IEC 61400-24, this arrangement must not be used for wind turbines, however, it can be used for annexes (for example, buildings containing measurement equipment or office sheds in connection to a wind farm). Type A earth electrode arrangements consist of horizontal or vertical earth electrodes connected by at least two down conductors on the building.

Type B: According to the informative Annex I of IEC 61400-24, this arrangement must be used for wind turbines. It either consists of an external ring earth electrode installed in the ground or a foundation earth electrode. Ring earth electrodes and metal parts in the foundation must be connected to the tower construction.

In any case, the reinforcement of the tower foundation should be integrated in the earthing concept of a wind turbine. The earth-termination system of the tower base and the operation building should be connected by means of a meshed network of earth electrodes to gain an earth-termination system ranging over as large an area as possible. To prevent excessive step voltages as a result of a lightning strike, potential controlling and corrosion-resistant ring earth electrodes (made of stainless steel, e.g. material AISI/ASTM 316 TI) must be installed around the tower base to ensure protection of persons (Figure 3).

FOUNDATION EARTH ELECTRODES

Foundation earth electrodes make technical and economic sense and are e.g. required in the German Technical Connection Conditions (TAB) of power supply companies. Foundation earth electrodes are part of the electrical installation and fulfil essential safety functions. For this reason, they must be installed by electrically skilled persons or under supervision of an electrically skilled person.

Figure 2 - Example of an air-termination system for the weather station (anemometer) and the aircraft warning light

Metals used for earth electrodes must comply with the materials listed in Table 7 of IEC 62305-3. The corrosion behaviour of metal in the ground must always be observed.

Foundation earth electrodes must be made of galvanised or non-galvanised steel (round or strip steel). Round steel must have a minimum diameter of 10 mm. Strip steel must have minimum dimensions of 30 mm x 3.5 mm. It must be observed that this material must be covered with at least 5 cm concrete (corrosion protection).

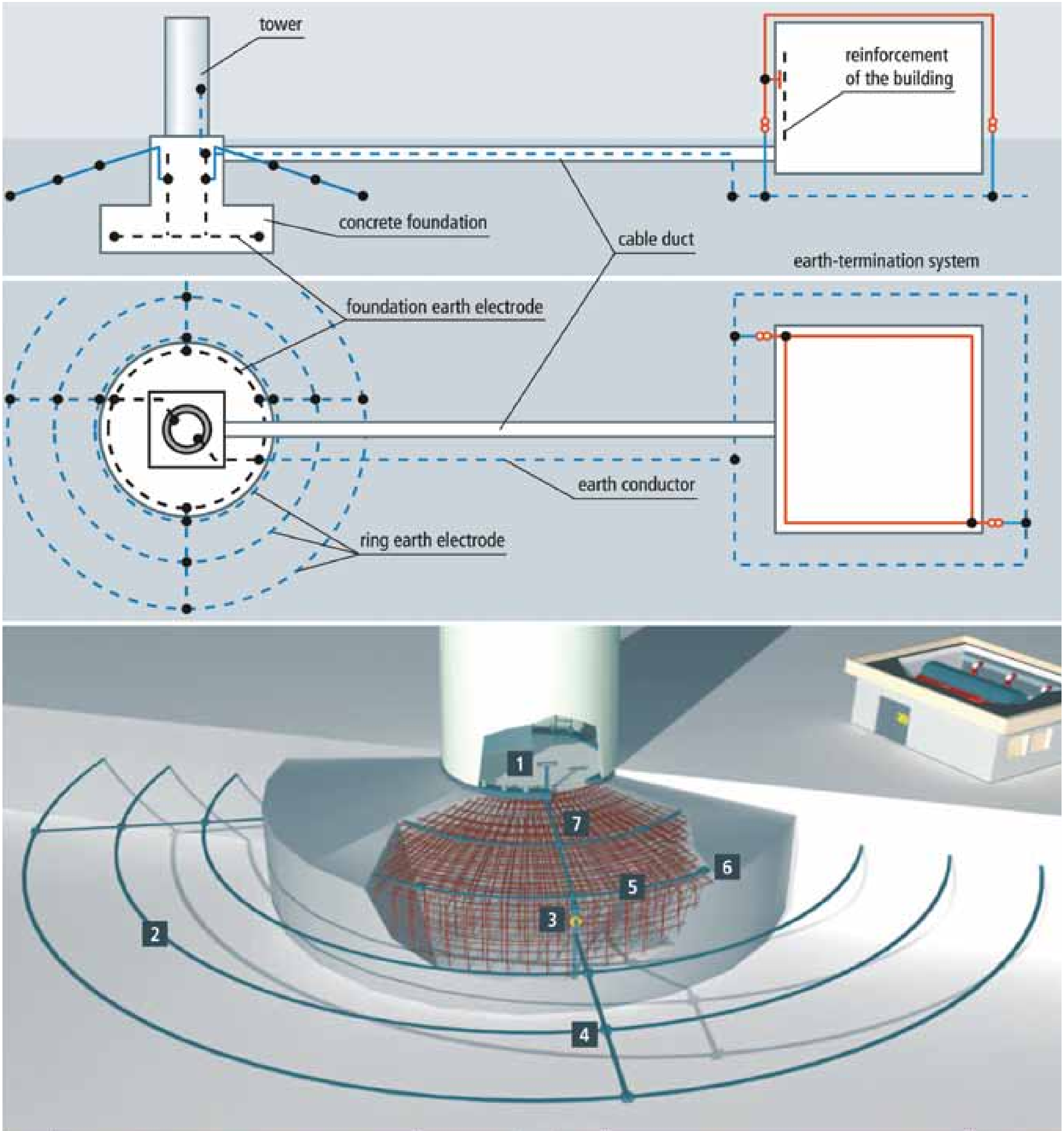
The foundation earth electrode must be connected with the main equipotential bonding bar in the wind turbine. Corrosion-resistant connections must be established via fixed earthing points of terminal lugs made of stainless steel (AISI/ASTM 316 TI). Moreover, a ring earth electrode made of stainless steel (AISI/ASTM 316 TI) must be installed in the ground.

Internal lightning protection measures

- Earthing and equipotential bonding measures
- Spatial shielding and separation distance
- Cable routing and cable shielding
- Installation of coordinated surge protective devices

PROTECTION OF THE LINES AT THE TRANSITION FROM LPZ 0_A TO LPZ 1 AND HIGHER

To ensure safe operation of electrical and electronic devices, the boundaries of the lightning protection zones (LPZ) must be



No.		Part No.
1	Equipotential bonding bar for industrial use	472 209
2	Wire, stainless steel (AISI/ASTM 316 Tl)	860 010
3	Fixed earthing terminal, stainless steel (AISI/ASTM 316 Tl)	478 011
4	Cross unit, stainless steel (AISI/ASTM 316 Tl)	319 209
5	Tape, 30 mm x 3.5 mm (St/tZn)	810 335
6	Pressure U-clamp	308 031
7	MAXI MV clamp, UL467B-approved	308 040

Figure 3 - Earth-termination system of a wind turbine

Lightning and surge protection for wind turbines

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No. in Fig. 4	Area to be protected	Surge protective device	Part No.
1	Voltage supply of the hub Signal lines between the nacelle and the hub	DEHNguard TN 275 FM BLITZDUCTOR XT BE 24 * DENHpatch DPA M CAT6 RJ45S48	952 205 920 324 929 121
2	Protection of the aircraft warning light	DEHNguard M TN 275 FM	952 205
3	Signal line of the weather station	BLITZDUCTOR XT ML4 BE 24 * BLITZDUCTOR XT ML2 BE S 24 *	920 324 920 224
4	Control cabinet in the nacelle 230/400 V voltage supply	DEHNguard M TNC 275 FM DEHNguard M TNC CI 275 FM	952 305 952 309
5	Protection of the stator side	DEHNguard M WE 600 FM	952 307
6	Protection of the rotor	"Neptune" arrester combination: 3+1 (DG 1000 FM 3x, TFS SN1638 1x)	989 405/ SN 1673
7	Voltage supply of the control cabinet in the tower base, 230/400 V TN-C system	DEHNguard M TNC 275 FM DEHNguard M TNC CI 275 FM	952 305 952 309
8	Main incoming supply, 400/690 V TN system	3x DEHNbloc M 1 440 FM	961 145
9	Protection of the inverter	DEHNguard M WE 600 FM	952 307
10	Protection of the signal lines in the control cabinet of the tower base	BLITZDUCTOR XT ML4 BE 24 * BLITZDUCTOR XT ML2 BE S 24 *	920 324 920 224
11	Protection of the nacelle superstructures	Air-termination rods Pipe clamp for air-termination rods	103 449 540 105

Table 1: Protection of a wind turbine (Lightning Protection Zone concept according to Figure 4)

shielded against radiated interference and protected against conducted interference (Figures 4 and 5). Surge protective devices that are capable of discharging high lightning currents without destruction must be installed at the transition from LPZ 0_A to LPZ 1 (also referred to as lightning equipotential bonding). These surge protective devices are referred to as class I lightning current arresters and are tested by means of impulse currents of 10/350 µs waveform. At the transition from LPZ 0_B to LPZ 1 and LPZ 1 and higher only low-energy impulse currents caused by voltages induced outside the system or surges generated in the system must be coped with. These surge protective devices are referred to as class II surge arresters and are tested by means of impulse currents of 8/20 µs waveform.

According to the lightning protection zone concept, all incoming cables and lines must be integrated in the lightning equipotential bonding without exception by means of class I lightning current arresters at the boundary from LPZ 0_A to LPZ 1 or from LPZ 0_A to LPZ 2. Another local equipotential bonding, in which all cables and lines entering this boundary must be integrated, must be installed for every further zone boundary within the volume to be protected. Type 2 surge arresters must be installed at the transition from LPZ 0_B to LPZ 1 and from LPZ 1 to LPZ 2, whereas class III surge arresters must be installed at the transition from LPZ 2 to LPZ 3. The function of class II and class III surge arresters is to reduce the residual interference of the upstream protection stages and to limit the surges induced or generated within the wind turbine.

SELECTION OF SPDS BASED ON THE VOLTAGE PROTECTION LEVEL (U_P) AND THE IMMUNITY OF THE EQUIPMENT

To describe the required voltage protection level U_p in an LPZ, the immunity levels of the equipment within an LPZ must be defined, e.g. for power lines and connections of equipment according to IEC 61000-4-5 and IEC 60664-1, for telecom- munication lines and connections of equipment according to IEC 61000-4-5, ITU-T K.20 and ITU-T K.21 and for other lines and connections of equipment according to manufacturer's instructions. Manufacturers of electrical and electronic components or devices should be able to provide the required information on the immunity level according to the EMC standards. Otherwise the wind turbine manufacturer should perform tests to determine the immunity level. The defined immunity level of components in an LPZ directly defines the required voltage protection level for the LPZ boundaries. The immunity of a sys- tem must be proven, where applicable, with all SPDs installed and the equipment to be protected.

PROTECTION OF POWER SUPPLY SYSTEMS

The transformer of a wind turbine may be installed at different locations (in a separate distribution station, in the tower base, in the tower, in the nacelle). In case of large wind turbines, for example, the unshielded 20 kV cable in the tower base is routed to the medium-voltage switchgear installations consisting of vacuum circuit breaker, mechanically locked selector switch disconnector, outgoing earthing switch and protective relay.

The medium voltage cables are routed from the medium voltage switchgear installation in the tower of the wind turbine to the transformer situated in the nacelle. The transformer feeds the control cabinet in the tower base, the switchgear cabinet in the nacelle and the pitch system in the hub by means of a TN-C system (L1, L2, L3, PEN conductor; 3PhY, 3W+G). The switchgear

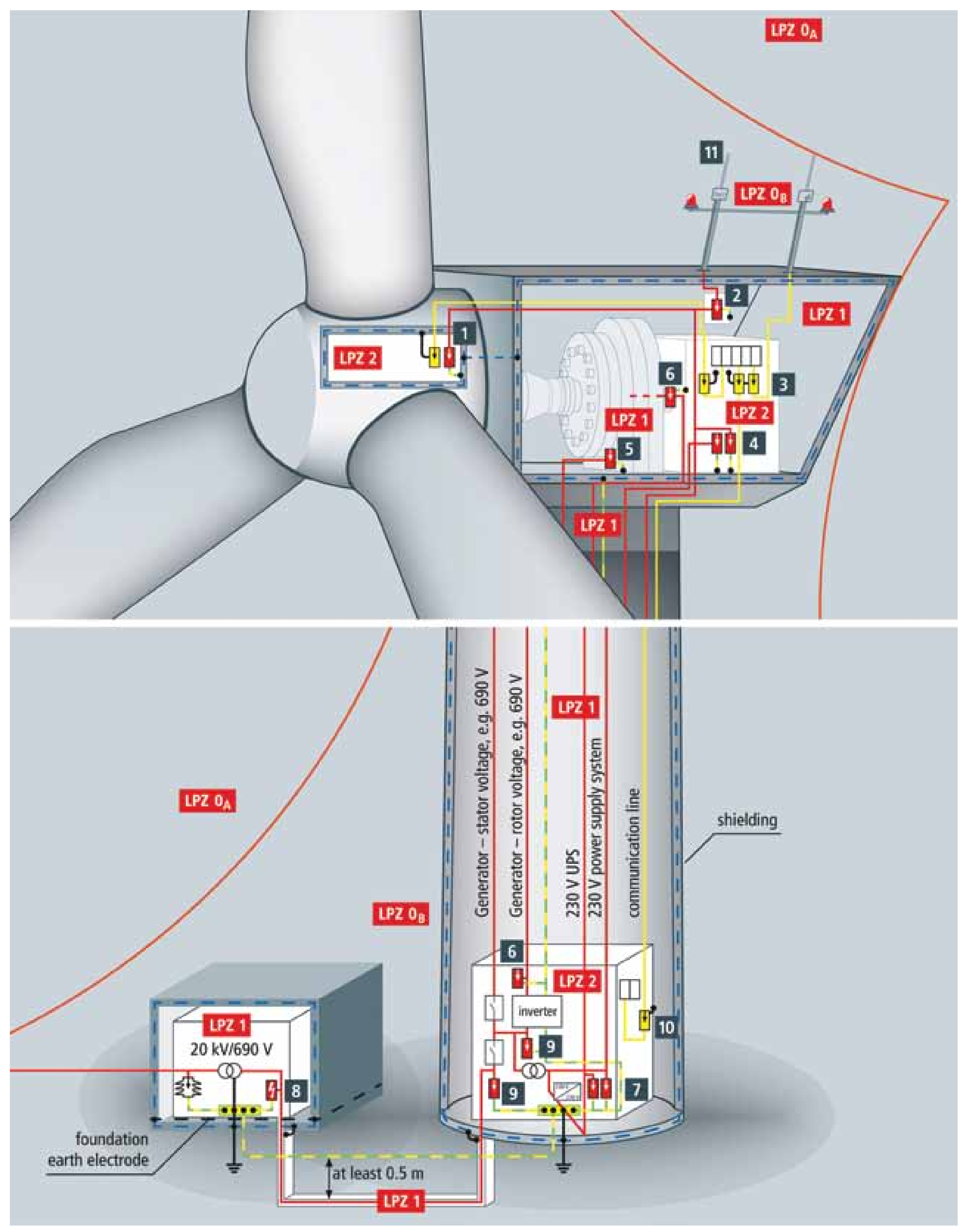

Figure 4: Lightning and surge protection for a wind turbine

Lightning and surge protection for wind turbines

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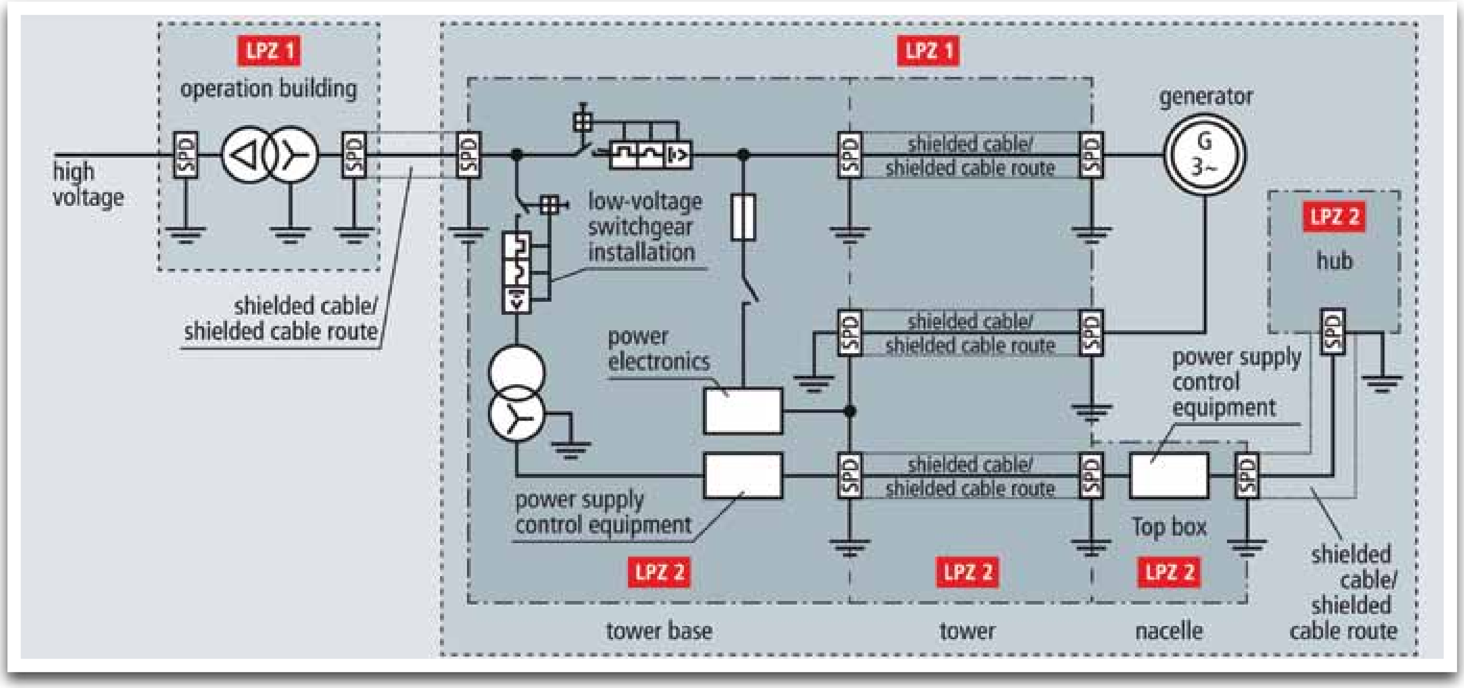

Figure 5: Example of arresters installed at the zone boundaries of a wind turbine according to IEC 61400-24

cabinet in the nacelle supplies the electrical equipment in the nacelle with an a.c. voltage of 230/400 V.

According to IEC 60364-4-44, all pieces of electrical equipment installed in a wind turbine must have a specific rated impulse withstand voltage according to the nominal voltage of the wind turbine (see IEC 60664-1: Table 1, insulation coordination). This means that the surge arresters to be installed must have at least the specified voltage protection level depending on the nominal voltage of the system.

Surge arresters used to protect 400/690 V power supply systems must have a minimum voltage protection level $U_p \leq 2.5$ kV, whereas surge arrester used to protect 230/400V power supply systems must have a voltage protection level Up ≤ 1.5 kV to ensure protection of sensitive electrical/ electronic equipment. To fulfil this requirement, surge protective devices for 400/690 V power supply systems which are capable of conducting lightning currents of 10/350 µs waveform without destruction and ensure a voltage protection level Up ≤ 2.5 kV must be installed.

230/400 V POWER SUPPLY SYSTEMS

The voltage supply of the control cabinet in the tower base, the switchgear cabinet in the nacelle and the pitch system in the hub by means of a 230/400 V TN-C system (3PhY, 3W+G) should be protected by class II surge arresters.

PROTECTION OF THE AIRCRAFT WARNING LIGHT

The aircraft warning light on the sensor mast in LPZ 0_B should be protected by means of a class II surge arrester at the relevant zone transitions (LPZ 0_B → 1, LPZ 1 → 2) (Table 1).

400/690V POWER SUPPLY SYSTEMS

Coordinated single-pole lightning current arresters with a high follow current limitation for 400/690 V power supply systems, must be installed to protect the 400/690 V transformer, inverters, mains filters and measurement equipment.

PROTECTION OF THE GENERATOR LINES

Considering high voltage tolerances, class II surge arresters for nominal voltages up to 1000 V must be installed to protect the rotor winding of the generator and the supply line of the inverter. An additional spark-gap-based arrester with a rated power frequency withstand voltage UN/ AC = 2.2 kV (50 Hz) is used for potential isolation and to prevent that the varistor-based arresters operate prematurely due to voltage fluctuations which may occur during the operation of the inverter. A

modular three-pole class II surge arrester, with an increased rated voltage of the varistor for 690 V systems is installed on each side of the stator of the generator.

Modular three-pole class II surge arresters are specifically designed for wind turbines. They have a rated voltage of the varistor Umov of 750 V a.c., thus considering voltage fluctuations which may occur during operation.

SURGE ARRESTERS FOR INFORMATION TECHNOLOGY SYSTEMS

Surge arresters for protecting electronic equipment in telecommunication and signalling networks against the indirect and direct effects of lightning strikes and other transient surges are described in IEC 61643-21 and are installed at the zone boundaries in conformity with the lightning protection zone concept (Figure 4, Table 1).

Multi-stage arresters must be designed without blind spots. This means that it must be ensured that the different protection stages are coordinated with one another. Otherwise not all protection stages will be activated, thus causing faults in the surge protective device. In the majority of cases, glass fibre cables are used for routeing information technology lines into a wind turbine and for connecting the control cabinets from the tower base to the nacelle. The cabling between the actuators and sensors and the control cabinets is implemented by shielded copper cables.

Since interference by an electromagnetic environment is excluded, the glass fibre cables do not have to be protected by surge arresters unless the glass fibre cable has a metallic sheath which must be directly integrated into the equipotential bonding or by means of surge protective devices.

In general, the following shielded signal lines connecting the actuators and sensors with the control cabinets must be protected by surge protective devices:

- Signal lines of the weather station on the sensor mast
- Signal lines routed between the nacelle and the pitch system in the hub
- Signal lines for the pitch system

SIGNAL LINES OF THE WEATHER STATION

The signal lines (4–20 mA interfaces) between the sensors of the weather station and the switchgear cabinet are routed from LPZ 0_B to LPZ 2 and can be protected by means of combined arresters. These space-saving combined arresters protect two or four single lines with common reference potential as well as unbalanced interfaces and are available with direct or indirect shield earthing. Two flexible spring terminals for permanent low-impedance shield contact with the protected and unprotected side of the arrester are used for shield earthing.

SIGNAL LINES FOR THE PITCH SYSTEM

If information between the nacelle and the pitch system is exchanged via Industrial Ethernet data lines, a universal arrester can be used.

Alternatively, an arrester can be installed to protect the 100MB Ethernet data lines. This surge protective device is a prewired standard patch cable with integrated surge arrester.

The connection of the signal lines for the pitch system depends on the sensors used which may have different parameters depending on the manufacturer.

CONDITION MONITORING

Availability of wind turbines, especially of offshore wind turbines, increasingly gains importance. This requires to monitor lightning current and surge arresters for signs of pre-damage (condition monitoring).

The specific use of condition monitoring allows to plan service work, thus reducing costs. wn

Earn CPD Credits

Power supply of 4th generation mobile radio systems

Mobile data traffic has increased sharply in recent years, and will continue to grow exponentially. Mobile network operators are faced with major challenges as expectations regarding mobile network transmission systems grow and change the system architecture. This also has consequences for reliable lightning and surge protection

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Given the increasing need for ranges and capacities mobile network transmission stations have been continuously further developed. Initially, all electronic components were protected inside a room or an outdoor shelter. Only antennas and coaxial connection cables (coaxial feeders and coaxial jumpers) between the transmitter/receiver unit and antenna were exposed to environmental conditions. In order to compensate for the high power loss on long coaxial cables, the Tower Mounted Amplifier (TMA) and the Low Noise Amplifier (LNA) were subsequently placed as close to the antennas as possible.

After that, the range and coverage of the antenna had to be optimized; antennas were equipped with the Remote Electrical Tilt (RET) for this purpose. This allows for the tilt of the antenna's vertical electrical boresight to be modified without touching the antenna. The latest 3G (Universal Mobile Telecommunications System, UMTS) and 4G (Long Term Evolution, LTE) system architectures are increasingly based on Remote Radio Head (RRH) technology.

It is placed close to the antenna and include all transmitter and receiver components, including any required amplifiers. The actual mobile network transmission station becomes smaller, more compact, and likewise more efficient. The space saved, as well as the need for fewer individual components, help mobile radio operators to reduce operating costs with regard to power supply, air conditioning, spare part logistics, and rental space.

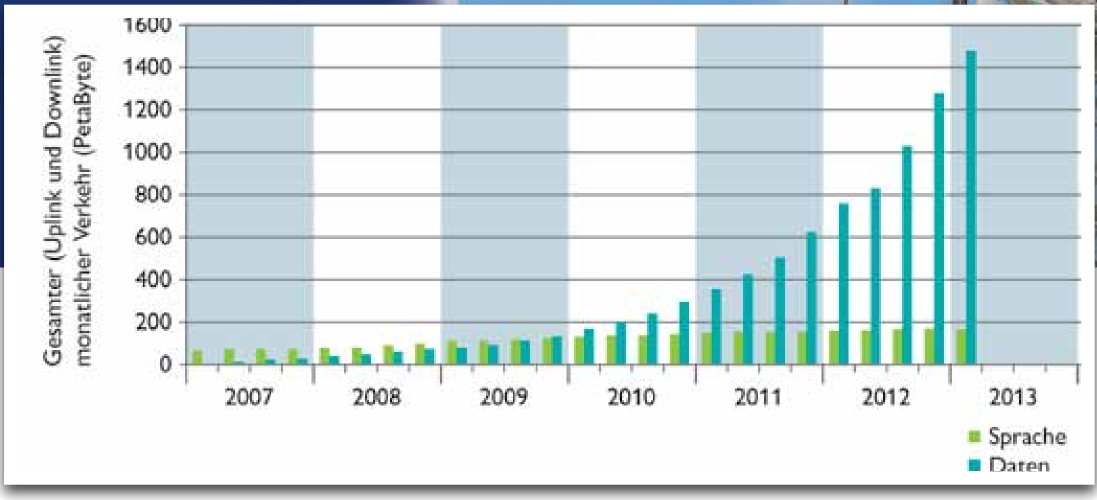

Figure 1: Global trend in mobile communication networks: while voice traffic stagnates, data traffic grows exponentially.

Communication between the RRHs and the Base Band Unit (BBU) usually occurs via fiber optics; this architecture is referred to as Fiber To The Antenna (FTTA). These fiber optic cables replace copper-based coaxial cables. They allow for a higher bandwidth and higher data transmission speeds. Only in this way can the massive data volumes made available via the radio interface securely and reliably reach the BBU and subsequently the core network.

The fiber optic cables do not require any special measures to protect against electromagnetic interference in the sense of lightning and surge protection, given that couplings on these cables can be ruled out following a lightning strike or power surge. The precondition for this is that the fiber optic cables do not have metal sheaths or other metal components. The power supply of remote radio heads is typically 24 V DC or 48 V DC via the corresponding power supply system. Power supply cables, if possible with screened sheath, must be routed from the power supply to the RRH for this purpose.

LIGHTNING AND SURGE PROTECTION MUST KEEP PACE

For safe, uninterrupted operation, the copper-based cables of the low-voltage supply must continue to be integrated, with the help of suitable lightning and

Power supply of 4th generation mobile radio systems

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surge protection devices, into the on-site equipotential bonding system. The new system architecture with RRH technology defines additional requirements for the lightning and surge concept of the overall system. A lightning protection zone concept that divides the entire system into Lightning Protection Zones (LPZs) is therefore recommended. Thus, outer and inner zones are defined based on lightning hazard parameters.

On the boundary to the next protection zone, with its higher requirements regarding environmental conditions, the cable-conducted disturbance variables are reduced via Lightning and Surge Protective Devices (SPD). This zone concept is described, among others, in IEC 62305-1 (2010-12), in DIN EN 623505-1 (2011-10), as well as in the German lightning protection standard VDE 0185-305 (Part 4).

The following outer zones are defined here:

- **LPZ 0_A** - Risk of direct lightning strikes, of impulse currents up to full lightning current, and of the full electro-magnetic field of the lightning.
- **LPZ 0_B** - Protection against direct lightning strike. Risk of impulse currents up to partial lightning currents and of the full field of the lightning.

The inner zones include:

- **LPZ 1** - Impulse currents are limited by way of current sharing and SPDs at the zone boundaries. The lightning field can be reduced by spatial shielding.
- **LPZ 2** - Impulse currents are further limited by way of current sharing and SPDs at the zone boundaries. The lightning field can be further reduced by additional spatial shielding.

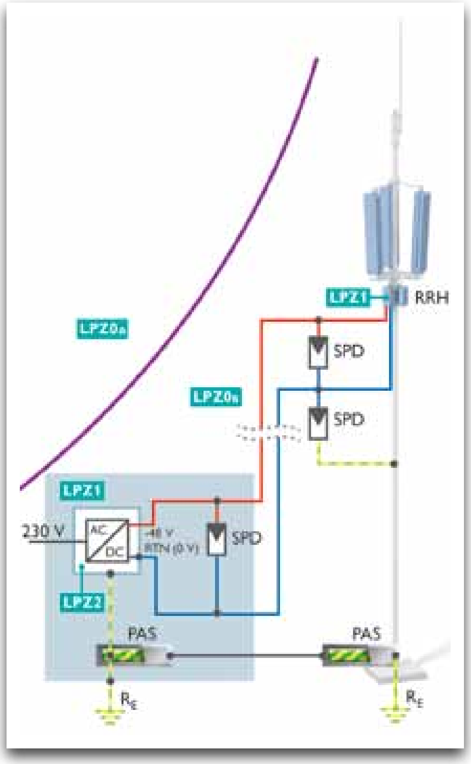

Figure 2: When setting up a mobile network transmission station with remote radio head technology, the division into multiple lightning protection zones has become even more important.

A protective device on the output side of the power supply – at the transition LPZ 0_B to LPZ 1 – protects sensitive components of the power supply from surges that couple into the current-conducting supply lines of the RRH following a power surge or after lightning strikes.

Depending on grounding conditions, these protective devices are frequently sufficient as single-pole version between the grounded plus pole and minus pole.

A suitable protective device must also be selected for the input of the voltage supply of the RRHs. That is because these supply lines may be 30 m or longer based on the configuration of the components in the base station, i.e., building or mast installations.

When lightning strikes, major differences in voltage occur at such line lengths, which negatively impact the level of protection offered by the protective device at the output of the power supply and exceed the dielectric strength of the RRH components. In order to reduce voltages induced on the conductor loop, an additional protective device should be placed in front of the RRH power supply starting at a line length of 10 m. This protective device is installed as 1+1 circuit: a protective element between the grounded plus pole and the minus pole, as well as a protective element between the plus pole and the general ground potential – cable shielding, mast, ground, etc. (Figure 2). This connection option prevents corrosion currents through the ground and parasitic fault currents through the ground cable.

SELECTING SUITABLE PROTECTIVE DEVICES

Depending on the philosophy behind the protection concept for the overall system, different versions of protective devices are conceivable. The best protection against lightning currents and the electro-magnetic field of the lightning is offered by a solution based on type 1 surge protectors, which protect system components in the case of direct lightning strikes. Pure type 1 surge protectors are usually based on spark gaps technology according to IEC 61643-11 (2011-03) and DIN EN 61643-11 (2013-04). In the case of this operating principle, it must be ensured that the selected protective system is also suitable for DC applications and can extinguish a DC lightning arc if it occurs. Furthermore, the protection level offered by this protective system (typically < 1.5 kV) must be coordinated with the dielectric strength of the components to be protected.

The combination of spark gap-based type 1 and varistor-based type 2 surge protectors reduces the level of the residual voltage, lowers the protection level, and provides a high degree of protection. If the protection concept is created, with reference to Figure 2, and all system components are in the protected LPZ 0_B zone, direct lightning strikes in the protected individual components can be ruled out. However, partial lightning currents are still to be expected in many areas of the system. For this reason, the protection system should securely discharge these partial lightning currents and offer an optimal protection level for individual components.

In comparison with surge protectors based on spark gaps, varistor-based lightning and surge voltage protectors deliver an improved response characteristic. Due to the low protection level, they offer optimal protection for the sensitive electronic components of the RRH or the power supply. When selecting protective systems, it is important to pay attention to the coordinated operation of individual components. This concerns not only the components of the lightning and surge protection, but also electronic equipment. Accordingly, the maximum voltage limit of the protection device must be lower than the dielectric strength of the components to be protected. In the case of compact modules, there are often flashovers in the area of elements placed close to each other. Internal insulation as well as air and creepage paths inside the total module must be taken into account here and, if necessary, reconsidered.

CONCLUSION

The increasing use of mobile communication devices, such as smartphone or tablet PCs, leads to more data traffic and hence higher loads on mobile radio networks. Network operators must respond to this with modern technology and new infrastructure. Restructuring always serve the purpose of reducing service and operating costs and increasing availability and reliability. A well-planned surge protection concept with appropriate protective systems comes closer to this goal. wn

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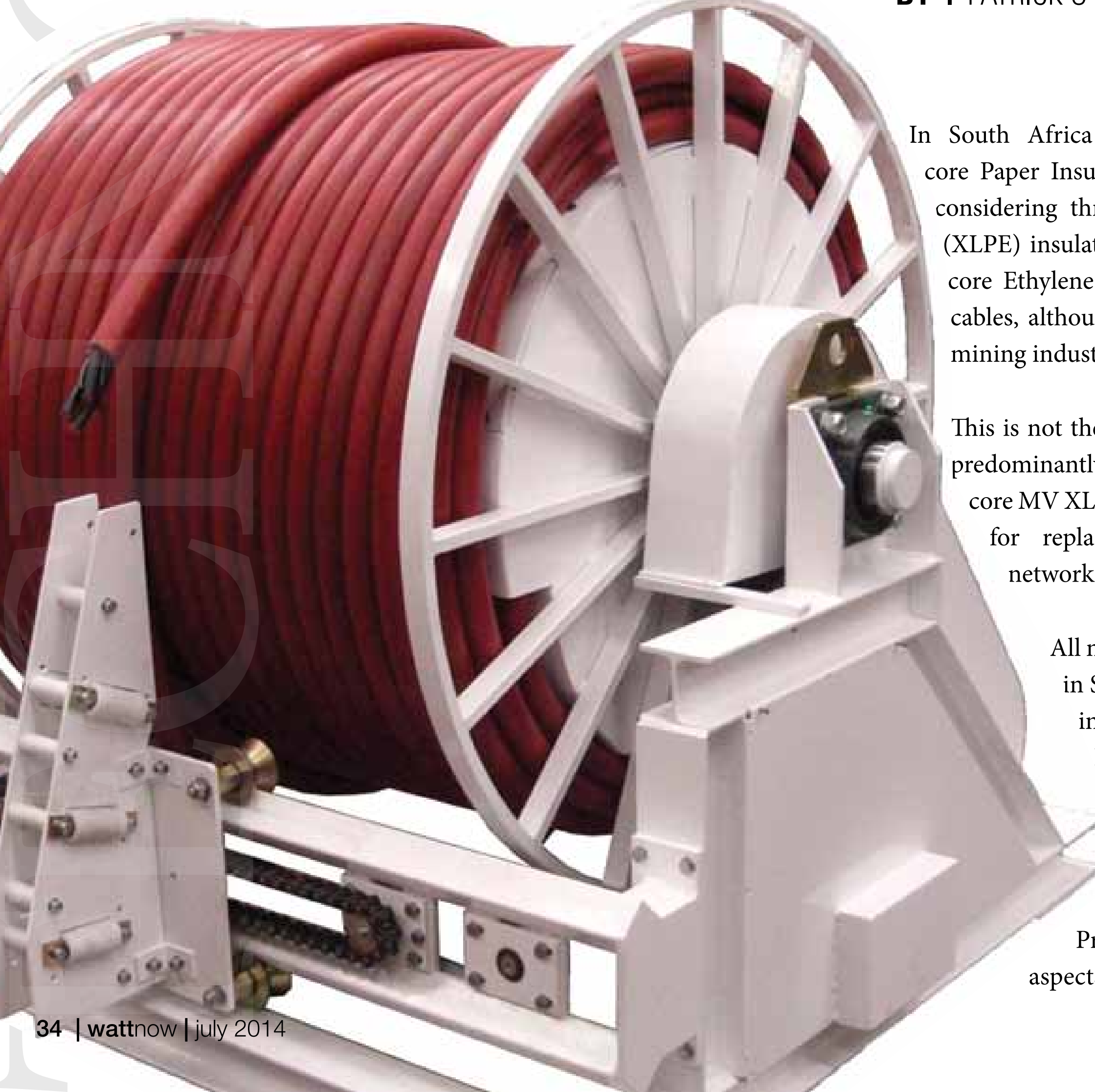
The Evolution of Medium Voltage Power Cables up to 36kV

This paper covers the evolution of MV power cables over the last century, and considers some pros and cons of all the different types of insulation materials used for MV power cables.

BY | PATRICK O'HALLORAN | BTECH | SMSAIEE



In South Africa most Utilities still install three-core Paper Insulated Lead covered (PILC) and are considering three-core Cross-Linked Polyethylene (XLPE) insulated cables. No Utilities install three-core Ethylene Propylene Rubber (EPR) insulated cables, although these are extensively used in the mining industries.

This is not the case internationally, where utilities predominantly only install either single, or three-core MV XLPE or EPR cables, and have programs for replacing their existing PILC cables networks.

All new High Voltage (HV) cable projects in South Africa are all single-core XLPE insulated. The old existing fluid-filled HV power insulated cables are being replaced because of the intensive maintenance requirements of these oil pressurized systems.

Product evolution has affected all aspects of our lives. Who still uses a typewriter or a pager? These days we have email and smart phones. Technology is changing our lives faster than we could ever have thought possible.

BACKGROUND

Ever since electricity was first transmitted over MV power cables more than a century ago, their insulation materials and designs have evolved. MV power cable networks make up the biggest asset, which most utilities have to operate and maintain. These MV power cable networks are buried and out of sight, unless they become unreliable and faults are experienced. In many cases these networks are run to failure, with very little maintenance or expected life diagnostic testing being conducted.

Utilities need to ensure reliability of supply, and hence MV cables designs have also evolved. MV power cable insulation ages as a result of the electrical stress and operating conditions to which they are exposed. Cable experts will also remind end users how critical it is not to overload their MV power cables, since increased temperature is the quickest aging mechanism for reducing the remaining life of MV power cables. When MV power cable faults occur, they contribute to large area interruptions of supply, and the fault may take considerable time to be located. This fault can be very costly to repair. Depending on the MV network design, some faulty cable sections could be quickly isolated, and power restored to the healthy parts of the MV network.

MV power cable design changes have also been driven by changes in switchgear design, higher voltages, and the loads which are required to be transmitted to provide the increased power demands which utilities are required to supply.

The remaining life of an existing MV power cable network is difficult to predict. However by performing regular condition assessment tests on the existing cables, the degrading results will give utilities a good indication as to when the cable insulation system is reaching the end of its life, and repeated failures can be expected.

On-line and off-line diagnostic testing can be applied to try to predict the remaining life of our existing installed MV power cable networks.

The impact of theft on MV power cables is now starting to affect the performance of MV networks, and the repeated faults are causing stress on upstream power transformers and associated MV equipment, which is also reducing their remaining life.

Another big concern is the lack of jointer skills needed for repairing all the cable faults that utilities experience. Experienced jointers are being lost by utilities, either as a result of retirement, or to other industries. As a result, utilities now are forced to make use of contractors to perform the critical joints and terminations. The standard to which jointers should be trained, and who is competent to provide the required training, remain thorny issues.

INTRODUCTION

The first power distribution system was developed by Thomas Edison in the early 1880's in New York City. This used a cable constructed from copper rods, wrapped in jute and placed in rigid pipes filled with a bituminous compound.

Although vulcanized rubber had been patented by Charles Goodyear in 1844, it was not applied to cable insulation until the 1880s, when it was used for lighting circuits. Rubber-insulated power cable was first used for 11000 volt circuits in 1897 when it was installed in the Niagara Falls power project. Mass-impregnated paper-insulated, lead-covered, medium voltage cables only became commercially practical by 1895.

During World War II, several varieties of synthetic rubber and polyethylene insulation started being used in MV power cables.

By the late 1960's Cross-Linked Polyethylene (XLPE) insulation was introduces for MV power cable insulation, and this technology significantly changed MV power cable systems. However, like any new technology, this had many teething problems. Manufacturers spent a great deal of time and money in resolving the problems which were experienced in the industry with the first generation XLPE insulated cables.

The MV power cables currently available in South Africa are all manufactured and tested to stringent standards published by the South African Bureau of Standards (SABS).

These standards are reviewed periodically, and the following SABS South African National Standards (SANS) are compulsory

The Evolution of Medium Voltage Power Cables

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for MV Power Cables in South Africa according to VC 8077;

- SANS 97: Electric cables - Impregnated paper-insulated metal-sheathed cables for rated voltages 3,3/3,3 kVto 19/33 kV (excluding pressure assisted cables);
- SANS 1339: Electric cables - Cross-linked polyethylene (XLPE) insulated cables for rated voltages 3.8/6.6 kV to 19/33 kV;
- VC 8077 - Compulsory specification for the safety of medium voltage electric cables.

In addition to the above standards, the Electricity Suppliers Liaison Committee (ESLC) has published the NRS 013 specification for Medium-voltage cables. This specification makes recommended rationalized options for PILC and XLPE MV power cables used by utilities.

MV POWER CABLE CONSTRUCTION

The construction of the above compulsory MV power cable standards need to be clearly understood to be able to grasp the major technical differences between the two different technologies. Both technologies are available in single or three-core, and as unarmoured or armoured. The conductors are either stranded Copper or Aluminium, depending on the end users preference or power needs. The Copper conductor has been preferred over Aluminium for many good reasons, but not cost. The extruded outer sheaths vary depending on the final applications. Polyvinyl chloride (PVC) is typically flame retardant but can also be low-halogen for mining applications.

Cables intended for underground use, or direct burial in the ground, will have heavy plastic or metal, most often lead sheaths, or may require special direct-buried construction. When cables must run where they could be exposed to mechanical impact damage, they may be protected with flexible steel tape or wire armour. A water resistant polyethylene outer sheath covers new XLPE cables.

PILC MV power cables are insulated with mass impregnated paper insulation, and XLPE MV power cables are insulated with cross-linked polyethylene insulation. These two insulation materials are very different in many ways.

PILC MV power cables have been around for more than a 100 years, and subsequently make up the prominent installation base in South Africa, as well as internationally. These cables have had many design changes over the last 100 years. Many of these cable improvements introduced were to make the cables performance more reliable at higher voltages. When PILC MV power cables were first utilized they were only used on 6.6 kV or 11 kV voltages.

Typical three-core PILC MV power cable

Paper insulation on its own does not provide a good enough insulation for power cables for the following reasons;

- absorbs atmospheric moisture,
- susceptible to cracking with ageing, and
- when continuously subjected to local ionisation (partial discharge) during load cycling can result in irreparable damage during cable handling.

The paper insulation is currently impregnated with a non-draining compound. They are now referred to as Mass Impregnated Non-Draining (MIND) cables. In the past the oil-based compounds used were susceptible to draining (e.g. rosin oil). When the compound drained as a result of gravity and temperature, the paper insulation would dry out, and many failures at terminations were experienced. There are two types of "non-draining" compounds used by various manufacturers;

- Compound processed from a mineral based amorphous crystalline wax, and
- Recently a synthetic compound better known as Polyisobutylene (PIB) compound.

However, three-core cables have sector shaped conductor and initially had a "Belted" construction design, and one of the first improvements was to introduce an "individually screened" construction. This design equalizes electrical stress on the cable insulation. Martin Hochstadter patented this technique in 1916; the Screen is sometimes called a Hochstadter screen. The individual conductor screens of a cable are connected to earth potential at the ends of the cable, and at locations along the length if voltage rise during faults would be dangerous. When a cable is screened, it can be touched safely without the risk of a potential build up occurring.

Unscreened Belted design is a three-core cable, in which additional insulation (the belt insulation) is applied over the laid-up core assembly. If air is introduced in a belted designed cable, the potential for partial discharge (PD) to be initiated is

increased. This is typically what happens at dry type terminations. If the air is removed, such as in a compound-filled cable box or in joints, no PD should occur, and therefore no crutch failure.

Screened cables are cables in which, in order to ensure that the radial electric field surrounding the conductor in each core is individually screened and contained in the core insulation, (by a non-magnetic conducting tape that is in electrical contact with the metal sheath). In the case of three-core cables, in direct contact with the screens of the other two cores.

The risk of a crutch failure is reduced with this type of screened cable design. Special steps must be taken to ensure that the electrical stress at the ends of the core screens are graded to prevent PD. Typically, stress relieving mastic or stress control tubes are used.

Belt papers are removed when jointing and terminating. This reduces the phase voltage to earth to 5.5kV at all accessories. Screened designed cables are therefore more reliable when being jointed or terminated and only earth faults, rather than symmetrical faults, can be expected (i.e. lower fault currents).

In the illustrative figure No.1 the electric field lines in belted unscreened and individually screened three core cables can be seen.

Unscreened cable (belted design) insulation comprised of core paper insulation and belt paper insulation.

- Only "collectively" screened
- Reduced core insulation when compared to screened cables
- Only up to 11 kV

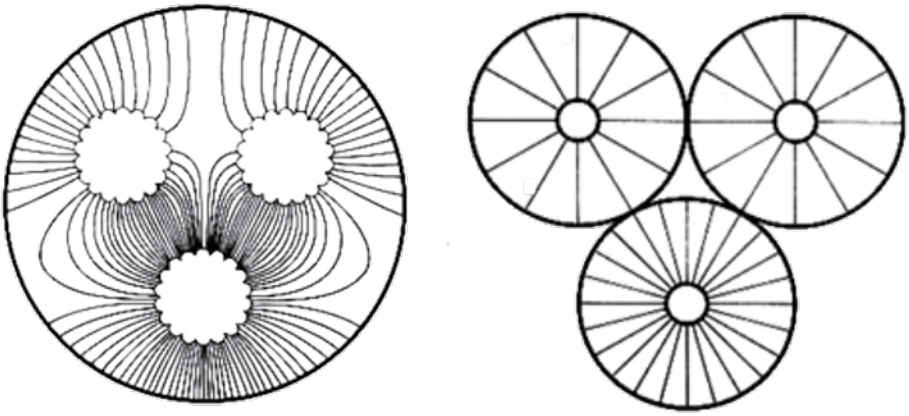

Figure 1: Unscreened (belted) cable and Screened cable PILC MV power cable

Many of these cable improvements were developed to make the PILC cable performance more reliable at higher voltages. When PILC MV power cables were first used, it was at 6.6 kV or 11 kV voltages only. For voltages above 11 kV only screened designed cables are available.

All single-core PILC cables have round conductors and an individually screened design. PILC MV power cables are highly susceptible to moisture ingress. Once moisture has penetrated through the lead sheath, the paper insulation is rapidly affected, leading to insulation failure. This moisture then quickly travels down the cores, and eventually affects a larger section of the PILC MV power cable.

It is therefore critical to prevent moisture from entering the cable at all costs. It is also then very important to perform a moisture crackle test on the paper insulation prior to any joint or termination being installed. If moisture is detected, the cable with moisture ingress should be replaced to prevent further failures. It is therefore also critical that the PILC MV power cables are sealed at all times with the appropriate sealing caps. The sloppy use of a plastic bag or a plastic half litre cold drink bottle is not acceptable and will lead to moisture ingress.

XLPE insulated MV power cables have not been available for as long as PILC MV power cables. When XLPE insulated power cables were first manufacture in the late 1960's, they experienced many premature failures in the field. These failures were due to incorrect manufacturing processes, leading to the presence of impurities and contaminants within the XLPE insulation. These failures gave XLPE insulated MV power cables a poor reputation in the industry. In South Africa most utilities rapidly changed back to PILC MV power cables.

Typical single and three-core XLPE insulated MV power cables

Subsequently the XLPE insulation cleanliness, designs and manufacturing

The Evolution of Medium Voltage Power Cables

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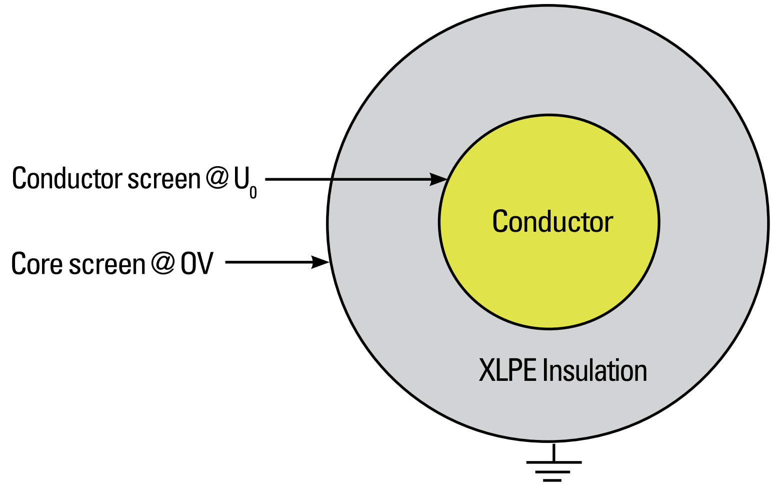

Figure 2: The three critical layers in a XLPE insulated MV power cables, which are applied as a triple extrusion

production process technologies have evolved considerably. The manufacturers began to understand what was important when it came to making XLPE cables more reliable, with extended life expectancy. The three critical layers in a XLPE insulated MV power cables are now applied at the same time and is referred to as triple extruded. These three critical layers are;

- The conductor screen which is at Uo phase voltage,
- The XLPE insulation, and
- The core screen which is at 0V (needs to be kept at earth potential)

The conductor and the core screen are both made of semi-conductive materials and the XLPE insulation is the pure insulating material. XLPE insulated cables are always have a screened design and are round to ensure the equal stress distribution in the XLPE insulation.

Further improvements have now been made with regards to the XLPE insulation materials and for MV power cables tree retardant (TR) XLPE compounds (TR-XLPE) are now utilized to successfully pass the wet aging type test and required breakdown strength criteria, which are specified in SANS 1339.

The quality of XLPE insulated cables is so high that it is becoming the preferred insulation at 500kV since XLPE insulation has lower dielectric losses and higher operating temperatures. This means higher ampacities and lower environmental impact. Un-aged XLPE insulation for MV power cable has typical breakdown strength of 50kV/mm. City Power has changed their MV power cable specifications to longitudinally water blocked XLPE insulated cables as a standard. The concept is like a baby's nappy, where water swell-able compounds and tapes are included in the areas where water could flow in the cable once it has entered in the cable for whichever reason. (Damage Sheath, lugs, existing cables, storage, etc.)

The water penetration type test, as per SANS 1339, shall be conducted to prove the design. This design will extend the life of the cable since when water enters; it is stopped at that point. This then also prevents the old problem of XLPE cables becoming water pipes.

Areas in a three-core XLPE cable, which have to be water blocked, are;

- Conductors
- Core(s) and metallic screening
- Laid up cores for 3 core designs
- Armouring

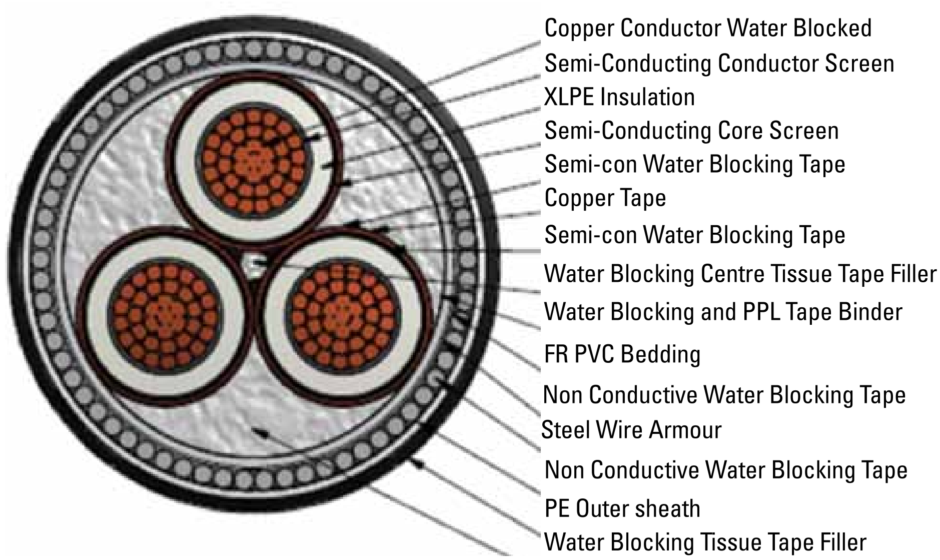

Figure 3: CBi Electric African Cables longitudinal water blocked XLPE MV power cable design

The international trend is to use single core cables rather than three core cables. This is because it is simple and easy to longitudinally block a single core cable, and since it does not have the large fillers between the cores. The risk of moisture entering all three phases is also reduced when three single core cables are utilized, as compared to a three-core design.

The first 400 kV Extra High Voltage (EHV) XLPE insulated cable will be installed in South Africa early in 2014. The cables and the accessories will all be imported for this project. Our local market leading HV cable company has invested in a new EHV XLPE production line to be able to manufacture cable up to 275 kV. This is really exciting for future projects and we will no longer have to import 275 kV EHV cable, since it can now be made locally. We will also be able to purchase HV cables with conductor sizes up to 2500 mm^2.

The risk of DC pressure testing is also better understood these days, and it is no longer recommended to use DC pressure test equipment on XLPE insulated MV power cables. DC pressure testing has been proven only to test the resistive properties of the cable, and at the end of the day is not really effective. DC pressure testing has been around for many years, like PILC cables, but is slowly being replaced by AC, DAC and VLF source test equipment. AC source test equipment tests the permittivity properties of the cable systems.
DC source equipment is required for fault-finding, but this is different from voltage withstand testing.

To prevent theft of cables in South Africa, suppliers are now putting in special markers with serial numbers. With the inclusion of these serial numbers, end users are able to identify cable ownership. Furthermore, end-users are also utilizing these serial numbers for their asset register.

The table summarizes the key differences between PILC and XLPE insulated MV power cables.

OTHER FACTORS INFLUENCING CABLE TECHNOLOGIES

With the improvements in insulation media and cable terminations, MV switchgear has drastically reduced in actual size. This means that the sizes of cable boxes have been reduced and special bushings have been introduced to accommodate the new cable terminations.

Things get really exciting on site if the wrong equipment has been specified and purchased. Typically, most equipment has long lead times, and instead of stopping the project, people make plans onsite to terminate the cable in to the switchgear that is supplied on site.From day one therefore, the installation is wrong, and premature failures can be expected. These failures can be costly to repair, could also involve replacement of the switchgear, and in

CABLE CONSTRUCTION	PILC-INSULATED CABLE	XLPE-INSULATED CABLE
Conductors (Either Copper or Aluminium)	Usually shaped conductor, but may be circular / oval	Only circular
Insulation	Wrapped Impregnated paper insulation	'Solid' extruded dielectric XLPE insulation
Screen	Belted collectively or individually screened (Wrapped metallised paper tapes)	Always Individually screened (Extruded semi-conductive semicon with copper tapes or copper wires)
Metallic sheath	Essential, typically lead	Optional, either lead or Al
Bedding layer	Extruded or Fibrous (if armoured)	Extruded bedding (if armoured)
Armouring	DSTA / SWA / AWA (optional)	SWA / AWA (optional)
Outer sheath	Extruded (PVC/PE) / Fibrous	Extruded (PVC/PE)
Continuous operating temperatures	70°C	90°C
Short Circuit temperatures	160°C	250°C
Longitudinally water blocked	No, normally only radially due to metallic layer	Yes, if specified, since this is a special requirement in SANS 1339
PD free design	No	Yes
Diagnostic testing possible	• Tan Delta diagnostic, which is a measurement of the overall circuit condition. • Pre-failure faults can't be located without breaking down the insulation system by applying a high voltage source	• Tan Delta and Partial discharge diagnostic possible. • Pre-failure faults can be located without breaking down the insulation system • Jointer errors can be identified before energizing the cable

Table 1: Comparison between PILC and XLPE MV power cables

The Evolution of Medium Voltage Power Cables

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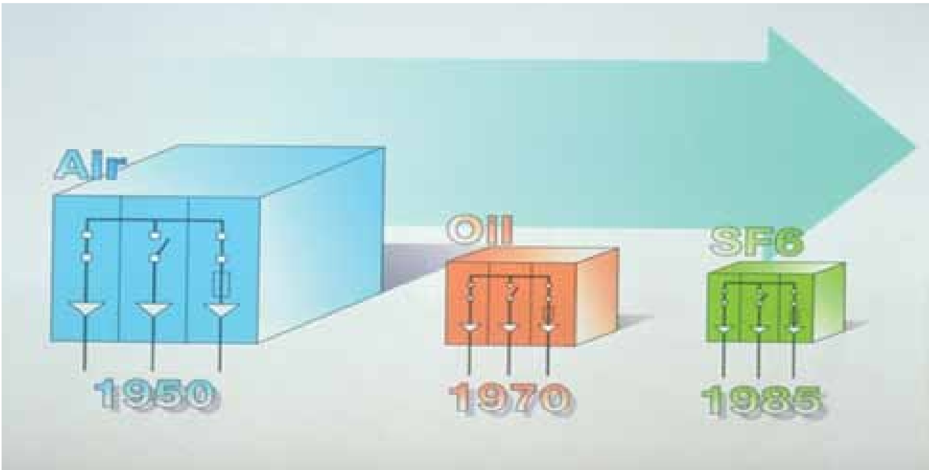

MV switchgear trend as insulation mediums evolved

addition staff or the public could be injured or killed from any resulting explosion.

Compound filled cable boxes

The picture shown above is of very old compound filled cable boxes. These were designed for PILC belted, unscrewed MV power cable, and they were filled with hot pouring compound. This ensured that there was no PD in the critical crutch of a PILC belted unscrewed MV power cable as all air was removed in the critical areas.

Due to a variety of reasons these compound filled terminations are no longer preferred and most end users prefer to install convention dry type terminations. These are referred to as either Heat Shrink, or cold applied products.

CABLE TERMINATION BEGINNINGS (EARLY 1900 – 1950S)

In the early days, electrical equipment, such as switchgear and transformers were designed to have compound filled metal cable boxes. This way of terminating cables was technically good, except it was very difficult and hazardous to field staff. The MV paper insulated (PILC) cables at that time had a belted construction and used wiped earth connections.

Compound filled cable boxes are designed to exclude air, so that creepage was not a major consideration when designing the cable bushing. This explains why the bushings of compound filled cable boxes are small when compared with the air filled cable box bushings found in metal clad switchgear, and outdoor transformers.

Compound boxes were filled with many different compounds, but a hot pouring compound was mainly used. This hot pouring compound was difficult to manage and gave off harmful fumes when being heated up, prior to pouring. Compound filled boxes were made of metal housing, with porcelain bushings where the cables exited the compound box.

Some drawbacks of compound filled cable boxes are;

- Compound top-up is required to ensure proper insulation (no air voids),
- Long installation times, and
- Cable box failures cause major damage when they ruptured (hot burning compound could be expelled).

New technology cold pouring compounds are now available. These are environmentally friendly and safe to install.

AIR INSULATED MV CABLE TERMINATIONS (1950 – 2000S)

With the introduction of tapes, heat shrink, and later cold shrink terminations, compound filled boxes have over time been replaced with air-insulated terminations. This type of MV cable termination is used by 95% of our South African market.

Screened paper insulated cables were introduced to control the electrical stresses within the cable designs, especially where increased voltage cable ratings were required. Belted design paper insulated cables are currently limited to 12 kV. Screened paper insulated cables are normally rated up to, and including 36 kV, as per SANS 97. The screened cable design provides improved MV cable termination performance, especially in the crutch where, in belted cables the crutch is a high stress area.

The belted design of paper-insulated cable is more likely to have crutch failures than the improved screen design paper insulated cable, where the complete crutch area is screened. This is because of the permittivity properties of the materials, and the introduction of air between the unscreened insulated conductors.

International market trends (which are mainly 24 kV rated systems) produces smaller and smaller switchgear. This in turn leads to reduced busbar clearances and cable boxes.

Air was the first insulating medium for busbars. It was replaced with oil, and then with the introduction of SF6 insulation, busbar clearances could be reduced tremendously. This allowed the cable box sizes to be reduced. Figure 4 shows how switchgear sizes have reduced with the introduction of new insulating technologies. Along with the reduced sizes of cables boxes, came the reduced clearances between phases and phase to earth. This reduction in of clearances required new designs of MV cable terminations.

When switchgear manufacturers designed smaller air-filled cable boxes, with reduced clearances, MV cable accessory manufactures then had to redesign the bushings and MV cable terminations, in order to make the cable box and cable termination compatible with these reduced clearance requirements.

In South Africa we have standardized on a ‘Type C’ 630A bushing with M16 thread. This ‘Type C’ bushing is found on all the news SF6 insulated switchgear, which currently is only used by City Power, Eskom and similar utilities and industries.

The ‘Type C’ bushing allowed end users to move away from traditional putty and tape shrouds to factory made fully insulated shrouds. These shrouds are installed the same way every time, and in addition ensure that cables are terminated correctly on Type C bushings. This is a product which is designed to be used on our South African PILC cable systems.

PILC cables, which are susceptible to moisture ingress causes insulation breakdown. Hence users are being forced to find alternative new cable designs. With the introduction of screened XLPE cables, MV terminations have also evolved.

It was decided internationally to standardize the cable interface, and also introduced screened cable terminations. Screened MV cable terminations should preferably only be used on MV XLPE cables, and when installed, this eliminated the problems of creepage, tracking and erosion, and clearances experienced by most air insulated MV cable terminations. The terminology ‘Screened’ means earthed. Once a cable termination is completely screened it can be completely submerged in water without any flashover.

Screened connectors are required when connecting to new 24 and 36 kV compact switchgear.

International utilities have moved away from 3 core cables, and now utilize single core XLPE insulated cables. This is not an easy change to make, as all electrical aspects of the network must be reviewed and staff need to be trained on how to install and terminate single core XLPE insulated cables. Our South African market mainly uses 3 core cable designs for a number of reasons.

The design of the screened connector controls the electrical stress from the XLPE cable through the ‘Type C’ bushing, and into the switchgear. Because the surface of the cable and the screened connector is screened, there is no leakage current along the surface of the screened connectors. With these screened connectors installed in the cable box, the size of the cable box and all electrical clearances can be drastically reduced. The life expectancy of screened MV cable terminations is double the expected life expectancy of unscreened cable terminations, especially with reduced clearances inside new reduced cable boxes. In an effort to eliminate failures from occurring in the MV cable compartment, the following two national standards have been published;

- NRS 012 / SANS 876 - Cable terminations and live conductors within air-filled enclosures (insulation co-ordination) for rated ac voltages from 7.2 kV and up to and including 36 kV
- NRS 053 / SANS 1332 - Accessories for medium-voltage power cables (3.8/6.6 kV to 19/33 kV)

These two standards are not yet compulsory, so it is up to the end-user to specify them when purchasing any MV switchgear and MV cable accessories.

All MV cable accessories should comply with the requirements of NRS 053 / SANS 1332.

With the introduction of air in the cable boxes, we now have to consider the following;

- Creepage distances,
- Tracking and Erosion, and
- Clearances (Phase to Phase and Phase to Earth)

The Evolution of Medium Voltage Power Cables

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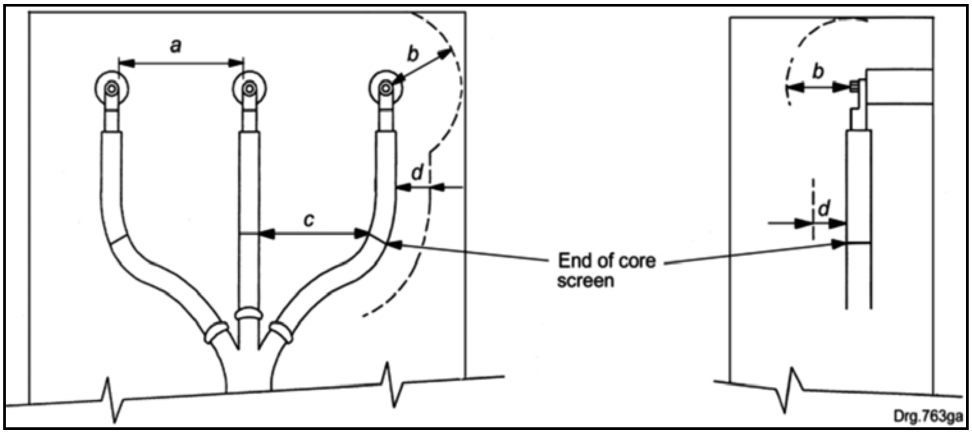

Figure 4: Bare termination Air-insulated (type 1)

The above three technical considerations must be correct if an air filled termination is to last in excess of 30 years. If adequate creepage, tracking and erosion properties, and air clearances are not provided, then the MV cable termination will fail prematurely. Failure of MV cable terminations is dangerous and can lead to long power interruptions.

NRS 012/SANS 876 has been developed to address the challenges which have been identified. This standard is critical to understanding and also to correctly specifying when ordering new switchgear in order to accommodate the cable technology that will be installed.

In NRS 012 / SANS 876 the following type of terminations are specified;

- Type 1 termination - lugs connected onto bushings or post insulators, uninsulated at the terminal fixing point, figure 4.
- Type 2 termination - lugs connected onto bushings or post insulators with a shrouded (unscreened) insulation termination, figure 5.
- Type 3 termination - unscreened separable connector terminations, figure 6.
- Type 4 termination - screened separable connector terminations – outside cone, figure 7 and;
- Type 5 termination - screened separable connector terminations – inside cone, figure 8.

All critical dimensions and definitions are given in NRS 012/SANS 876.

TYPE 1 BARE TERMINATION (AIR INSULATED)

In a Type 1 termination, the interfaces are bare and;

- Cable cores terminated with stress control appropriate to the cable design and voltage.
- Air being the sole insulation medium for the terminal connections.
- The minimum distance from any live bare metal (e.g. bushing, post insulator, live conductor, lug, fitting etc.) to an adjacent phase or to earth determined by the impulse withstand voltage requirement.

TYPE 2 SHROUDED TERMINATION

In a Type 2 termination, the interfaces are shrouded with unscreened interfaces are;

- Cable cores terminated with stress control appropriate to the cable design & voltage.
- Unscreened local insulation enhancement at the terminal connections.
- The minimum distance from any unscreened, shrouded, live metal (e.g. shrouds, cable cores etc.) to an adjacent phase or to earth determined by power frequency (e.g. corona inception and extinction) and impulse withstand voltage considerations.

TYPE 3: UNSCREENED SEPARABLE CONNECTOR TERMINATION (USC)

In a Type 3 termination, the interfaces are unscreened but utilize specially design USC and;

- Cable cores terminated by stress control appropriate to the cable design & voltage
- USC at terminal connections.
- The minimum distance from any unscreened, live metal (e.g. USC, cable cores etc.) to an adjacent phase or to

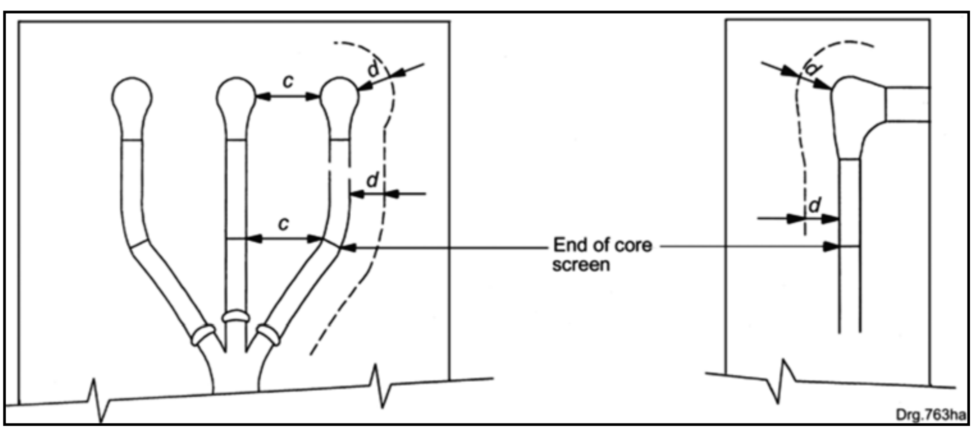

Figure 5: Shrouded termination (type 2)

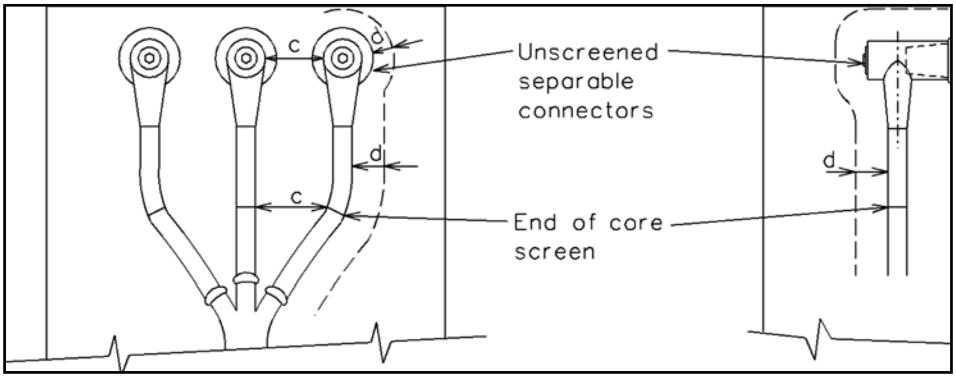

Figure 6: Unscreened separable connector termination (type 3)

earth determined by power frequency and impulse withstand voltage considerations.

- Leakage current limited by quality of the interface between USC and bushing – interference fit.

TYPE 4 AND 5 SCREENED SEPARABLE CONNECTOR INTERFACES (SSC) – INSIDE OR OUTSIDE CONE

In a Type 4 and 5 terminations, the interfaces screened and utilize special designed SSC and;

- Clearances determined by the mechanical clearance required to fit the SSC's within the cable box.
- Safe to touch due to surface being earthed.
- Leakage current limited by quality of the interface between SSC and bushing (interference fit).
- NOTE –traditionally PILC cables could not use SSC especially above 11 kV because;
  - sector shape cores, and
  - loose core screen.

CABLE BOX SIZES (HEIGHTS)

It is also important to ensure that the correct size cable boxes are supplied, as nearly all MV power cables installed are three cores, so extra space is required.

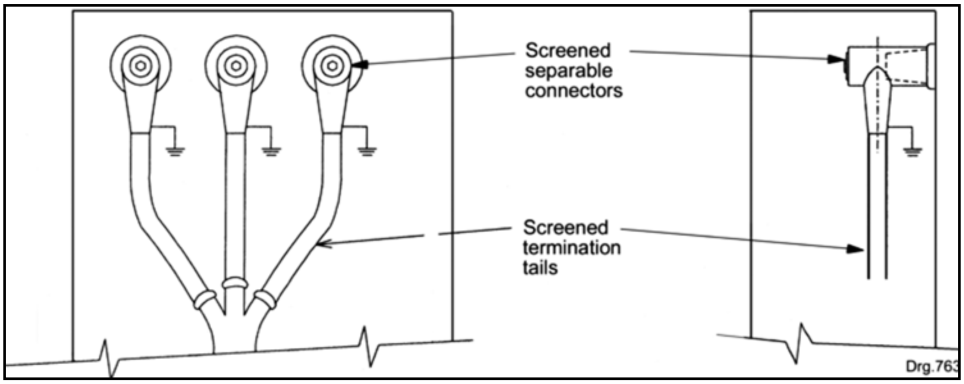

Figure 7: Screened separable connector termination – outside cone (type 4)

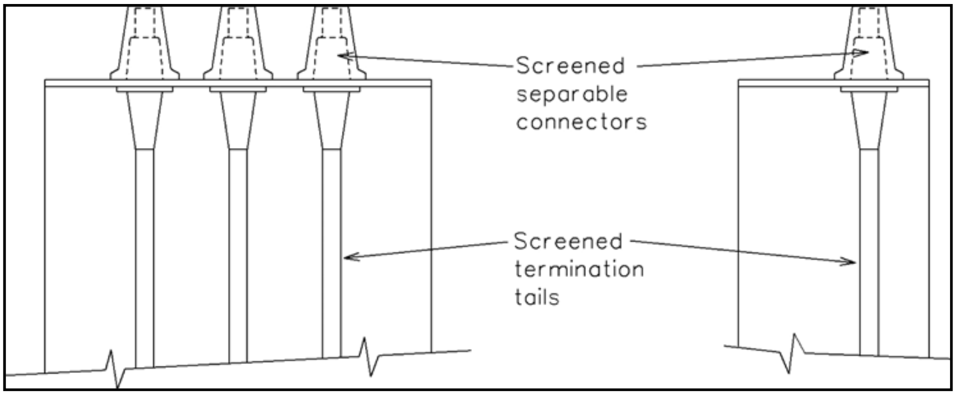

Figure 8: Screened separable connector termination – inside cone (type 5)

LOW VOLTAGE CURRENT TRANSFORMERS IN MV CABLE BOXES

As technologies have improved with the use of screened cables, the use of low voltage current transformers in MV cable boxes for metering and protection applications has been incorporated.

It is essential that these low voltage current transformers be installed in a screened area; otherwise discharge may occur if the air clearances are not adequate. The dimensions in the type 2 and 3 terminations cover the dimensions from the top of the low voltage current transformer to the screen cut.

CORE CROSSING FOR PHASING WITHIN MV CABLE BOXES

Core crossing for correct phasing within MV cable boxes is not recommended, however many crossed terminations exist in our networks. The risk with crossed cores in side unscreened type terminations is that adequate clearances become reduced, and this leads to increased electrical stress and partial discharge.

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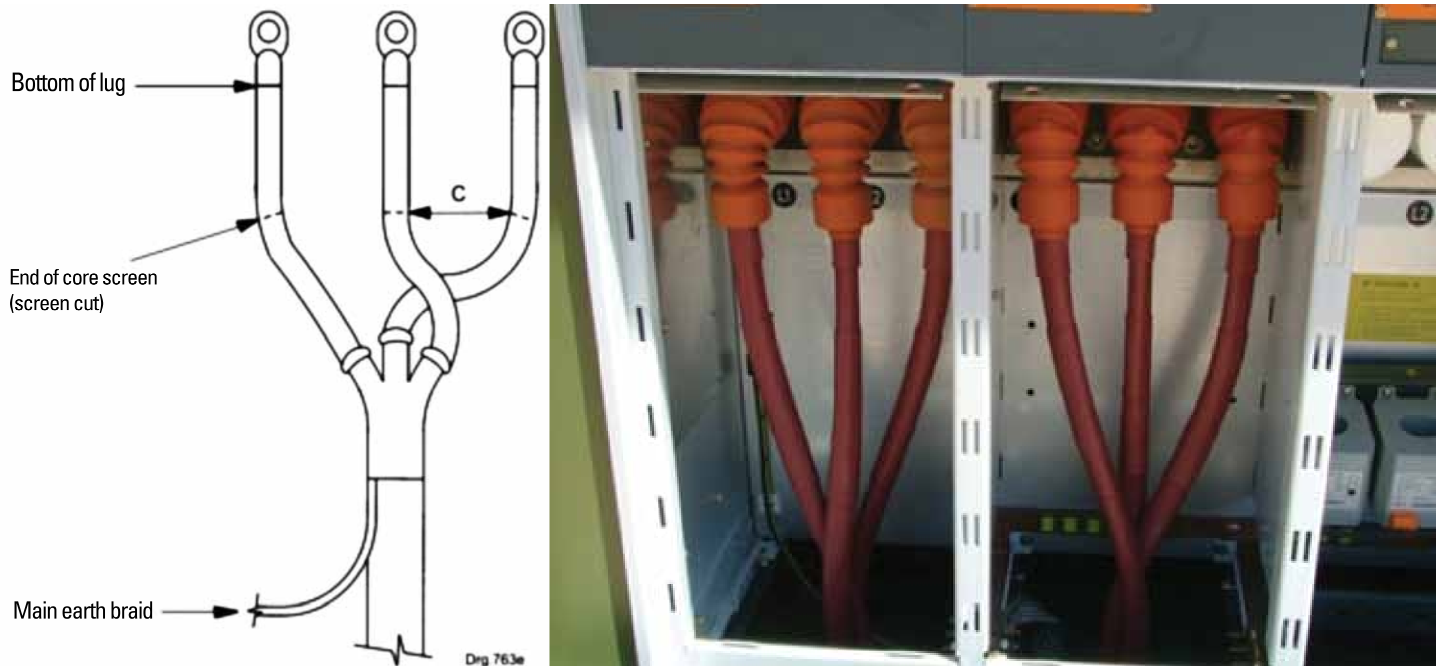


Figure 9: Example of a cable termination where the core crossing is made below the end of the core screen

NRS 053 requires all terminations be done with a top down principle. In Fig 10 the strip back dimensions can be seen. If the top down principle is followed, the screened metallic area is increased and core crossing can be done easily without any risk of partial discharge. However with a belted design cable, there is no metallic screen and core crossing is very risky.

The below clearly shows the extra base which needs to be supplied with compact switchgear in order to ensure that the correct three core cable height is attained. This would not be the case for three single core cables. The whole evolution of MV Power cables, switchgear and cable accessories has made it possible to considerably reduce the size of cable boxes.

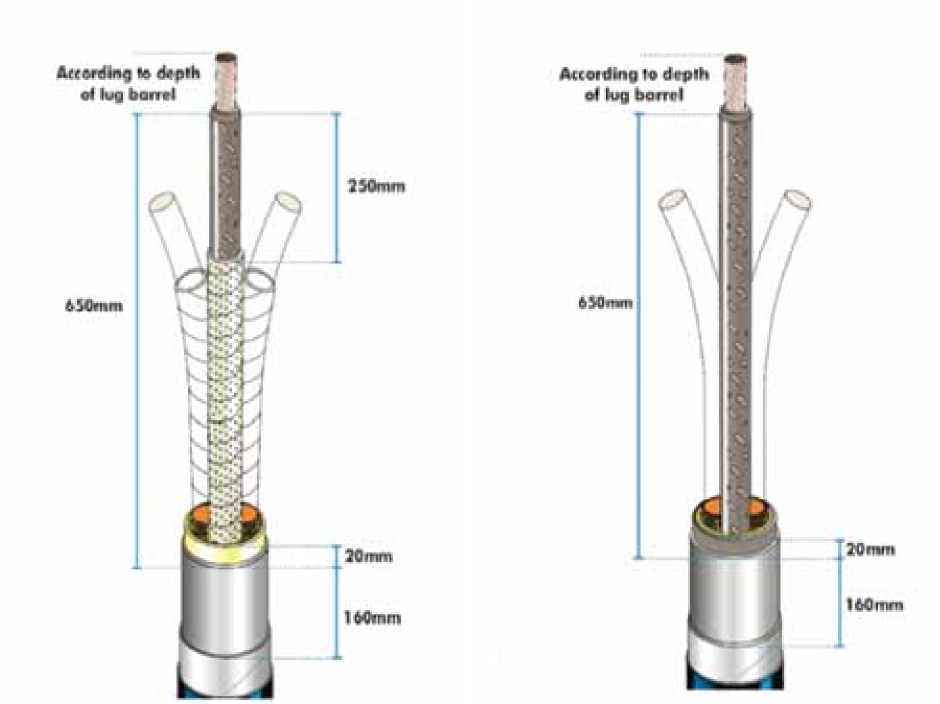


Figure 10: Example of screened and belted PILC cable termination prepared from the top down principle

The bending radius of three core cables also has to be considered and in the picture below special removable front covers of the RMU and plinth have been designed to make the jointers life easier. Implementing this will hopefully reduce jointer errors.

The picture below shows a clever way of terminating there core XLPE MV power

Example of SF6 RMU with an additional raising plinth and removable front sections

cables into small, compact switchgear. By performing a tri-furcating termination in the duct or ground, three single core cables are achieved. Terminating single core terminations in such small cable boxes is recommended. This small cable box has two cables terminated in it and there is no risk that a failure could occur. Core crossing is done under the cable box in the duct or ground. Special attention should be paid to using the right single cable clamps and gland plate material.

Below is a good example of where things have gone wrong in the past. The SF6 insulated ring main unit pictured below was installed with additional metering, low voltage and protection current transformers (CT). This often happens and it is all because the wrong products were ordered or because end users have not understood the new technologies, or wanted to stay with old technologies.

We were able to locate this problem before a failure occurred, by using the EA Technologies handle held UltraTev Plus detectors. These tests are non intrusive and should be done on line. No interuptions of supply are required.

The installation should have been done with type 4 terminations and single core XLPE cables. Instead a type 3 termination was installed and the CTs were installed over the unscreened areas of the termination.

This installation would have failed if nothing had been done. PD takes a long time to cause a failure in terminations, but it is guaranteed to fail eventually.

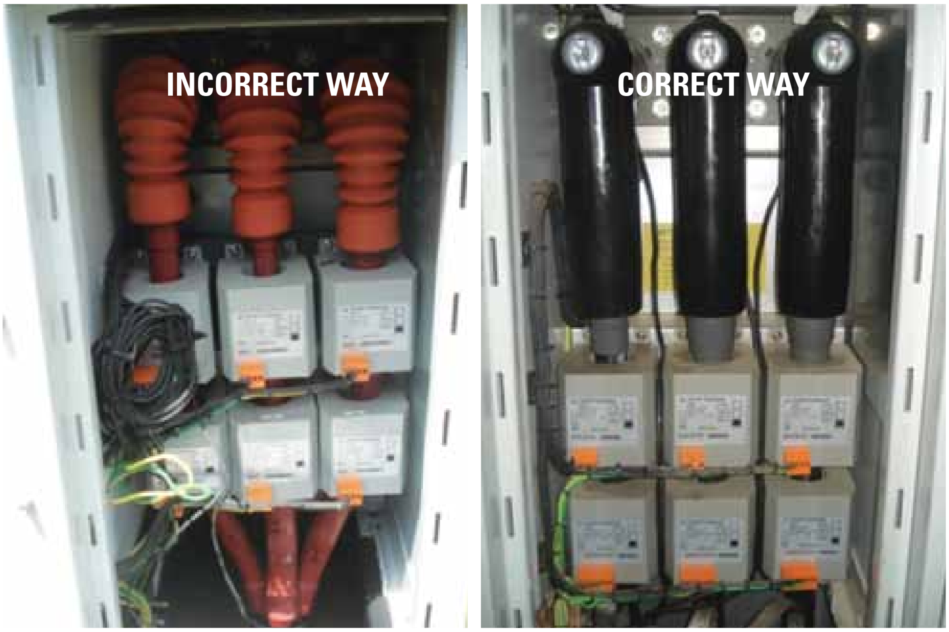
TESTING TO ENSURE RELIABILITY

Most end-users still use direct current (dc) cable pressure test equipment, which gives no diagnostic results. This type of equipment has been available for many years, is portable and is affordable. The test method involves applying a high dc voltage on the cable cores for a predefined period. If nothing trips during the test, the cable is declared healthy to energize.

This is referred to as "Go or No-go" testing. Why then do failures of the cable, joint or terminations still occur after energizing?

The answer is well documented: dc testing only tests the resistivity properties of the cable system. However, when energized with alternating current (ac) at 50 Hz, the

Example of tri-furcating termination into compact MV switchgear



Example of incorrect and correct termination into compact MV switchgear with LV CTs

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cable system permittivity properties of the components are stressed.

To ensure that future cable system failures are avoided, and to make an informed decision on the remaining life with regard to possible replacement of the faulted or aged MV power cable, we need to do our testing differently.

With the improved technologies available in testing voltage sources, we are able to test the permittivity properties of the cable system, and simulate the same stresses as in service with ac system conditions. The following alternative test waveforms exist;

- Very Low Frequency (VLF),
- Damped Oscillating Waveform Test Voltage (DOWTS), and
- Alternating Current @ power frequency.

A diagnostic test should also be conducted before energizing a new cable, or after a repair has been made to a failed cable system.

Off-line Tan Delta (TD) and Partial Discharge (PD) results can be taken during the pressure test. The results are available on site, and an informed decision can be taken with regard to the health of the MV Power Cable system.

TD test results will give an overall cable system condition result. It will not isolate the problem area.

PD test results will give the distance to the source of the PD (potential failure point). Because new XLPE insulated MV power cable is PD free, if PD is detected it is typically in the joints or terminations where jointers have made errors. This now means that these joints need to be identified and corrected, prior to energizing. We all know that PD will never go away and it will just intensify and eventually lead to a failure.

These results provide us with a fingerprint of the current condition of the MV power cable system, and when future diagnostic tests are conducted, the results can be compared, and the cabling aging rate confirmed.

The proposed revised SANS 10198-13 code of practice for MV power cable testing, now recommends integrated voltage withstand and diagnostic testing. These tests do not take any longer to perform, since they are now all integrated in the available new test equipment.

CONCLUSION

MV Power cables have significantly evolved over the years. The new third generation XLPE-insulated MV power cables are now far more reliable, and make it possible to connect into the new compact switchgear, which is currently being installed.

The following recommendations need to be considered in the future to ensure improved reliability of MV cable systems:-

- Install screened rather than belted designed PILC cables;
- Select and specify the correct termination types up-front, since it makes no sense to install the wrong terminations from day one;
- If three core cables are installed, ensure that the switchgear is suitably designed as per NRS 012/SANS 876;
- If three single cores are installed, there is reduced risk of termination failures. Tri-furcating terminations are perfect for converting three core cables to three single core cables;
- It is also possible to install a tri-furcating transition joint from three core PILC to three single core XLPE;
- Ensure clearances are kept as a priority if screened terminations are not installed;
- Ensure jointers are well trained in installing the MV power cables and accessories, so as to prevent unnecessary failures;
- If PILC insulated cable are installed, always test for the presence of moisture, and cut out affected sections;
- If XLPE insulated cable is installed, utilise the correct screen removing tool;
- Consider using single core cables instead of large 3 core cables, and lastly;
- Always perform combined voltage with stand and diagnostic testing, so that the actual condition of the cable system is known, and future faults can be avoided.

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MEMORIES

It was with great interest that I read the article in **watt**now, Feb 2014. I apologize for the delay in writing this, but my copy only arrived in the US a few days ago.

BY | ANTON P. SCHMIDT
P.E. | MIEEE | SMSAIMEE | MSAIEE | MDP (UNISA) | NTD | GCC (ELEC. & MECH. FACTORIES)

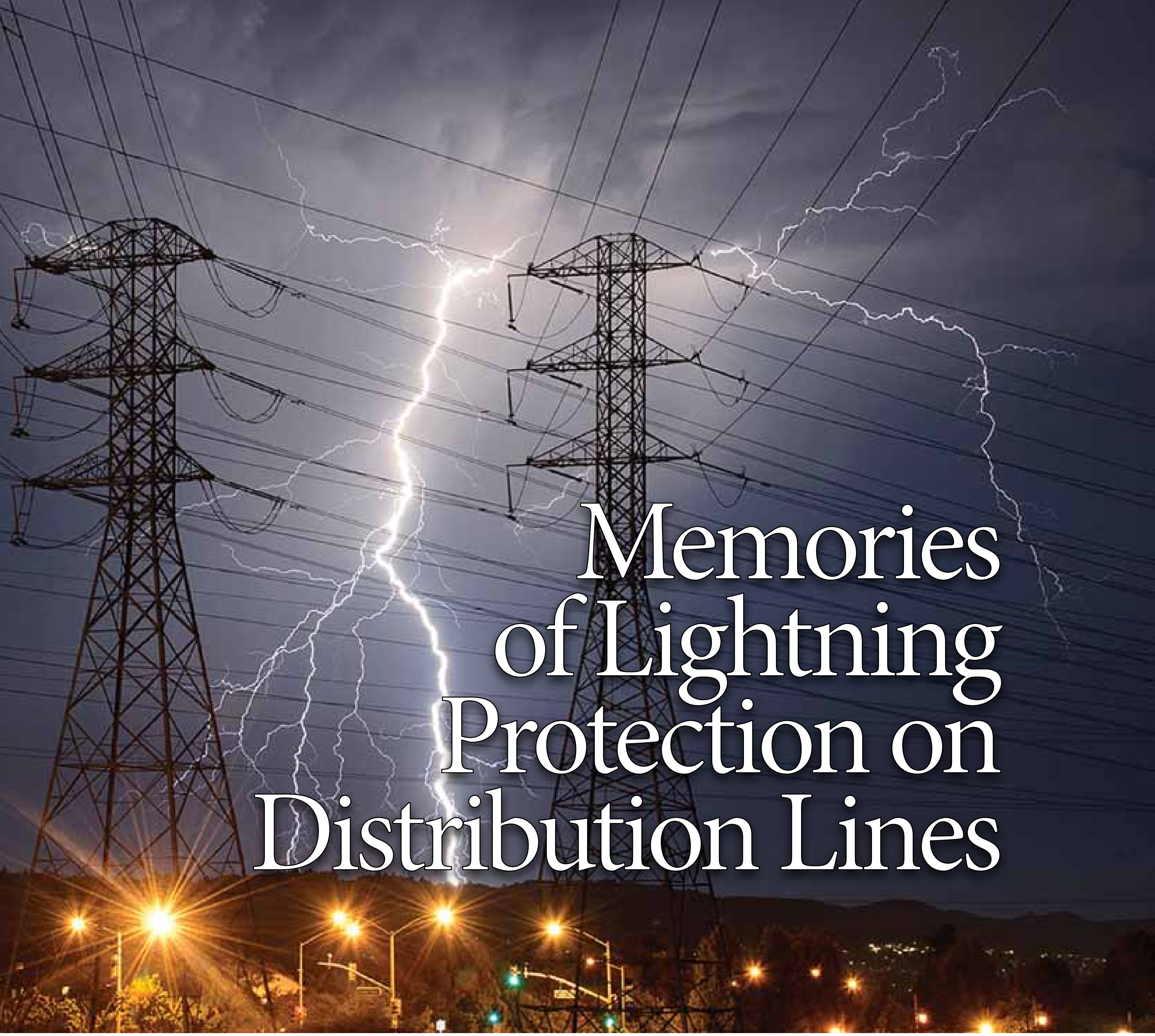
I was employed by ESKOM in the late 80's early 90's as the Operations and Maintenance Superintendent for the Margate District. Lightning was our nemesis, especially in the Kokstad, Cedarville areas where very high strike rates were recorded. Anything up to 15 or 20 transformer would fail after a severe storm, some completely exploded, poles were shattered and consumer equipment damaged.

Outages would last for 36 hours or more due to the extent of the damage. The late Stuart Almond and his staff, based in Kokstad, did a magnificent job getting all the repairs done in record time under very difficult situations.

The Engineering team based in Margate attended a conference at the CSIR in Pretoria, presented by Hendri Geldenhuys, Tony Britten, Chris van der Merwe and others in 1992. Lightning was a grey area for many of us and the presenters did a fantastic job educating us. Subsequent to the conference we started implementing some of the recommendations suggested.

The first project was to install additional sets of Arrestors on the Kokstad/Cedarville 33 kV line where we had experienced regular damage and substation trips on "Restricted Earth Fault" (REF). In order for the responding person to reset an REF flag, I had to be woken up, in Margate, by Control in Georgedale to approve re-energization.

In consultation with Chris van der Merwe, two sets of Surge Arrestors (SA's) were installed on towers, three spans and 5 spans respectively, away from the Substation. We also placed several sets on the power



Memories of Lightning Protection on Distribution Lines

line which ran along a ridge. The effect was a significant decrease in faults on the 33 kV line. The theory being that the additional SA's would attenuate the lightning strike wave front before reaching the substation. The line SA's would also reduce the wave front and prevent flashovers.

The Engineering team then changed their design policies and started installing SA's on the lateral's coming off rural 22 kV Backbone lines. Over time, due to the cost, many sets of SA's were retrofitted to troublesome lines. This had a big impact over time on transformer failures and flashovers throughout the district.
Pat Naidoo (ESKOM Transmission) also had us install SA's on the 132 kV line feeding Kokstad and its performance improved significantly as well.

The same principal was applied to some areas where cable was installed (mostly 11 kV). SA's were retrofitted at least one span before the cable termination. The result was outstanding with no further failures where the SA's had been retrofitted, even several years after I had moved on in my career.

These small changes not only saved the cost of damaged equipment, it saved on Line patrols, overtime, and reduced customer complaints.

I must stress however that any SA will only work as a function of the resistance of the earthing it is attached to. It is critical to ensure a good earth preferably <5 Ω and have good bonding for a well-protected line. I still have the manual we were given at the conference ,and have referred to it many times over the years, helping colleagues and customers solve tricky power quality problems as a result of what I learned so long ago. wn

Earn CPD Credits

Faraday and Maxwell

Faraday and Maxwell stand as giants in the annals of science and engineering. The Encyclopaedia Britannica described Faraday as: *"Possibly the greatest experimental genius that the world has ever known"*. Max Planck said of Maxwell's theory of light, on the occasion of the centenary of Maxwell's birth: *"… remains for all time one of the greatest triumphs of human intellectual endeavour"*.

BY I DUDLEY BASSON

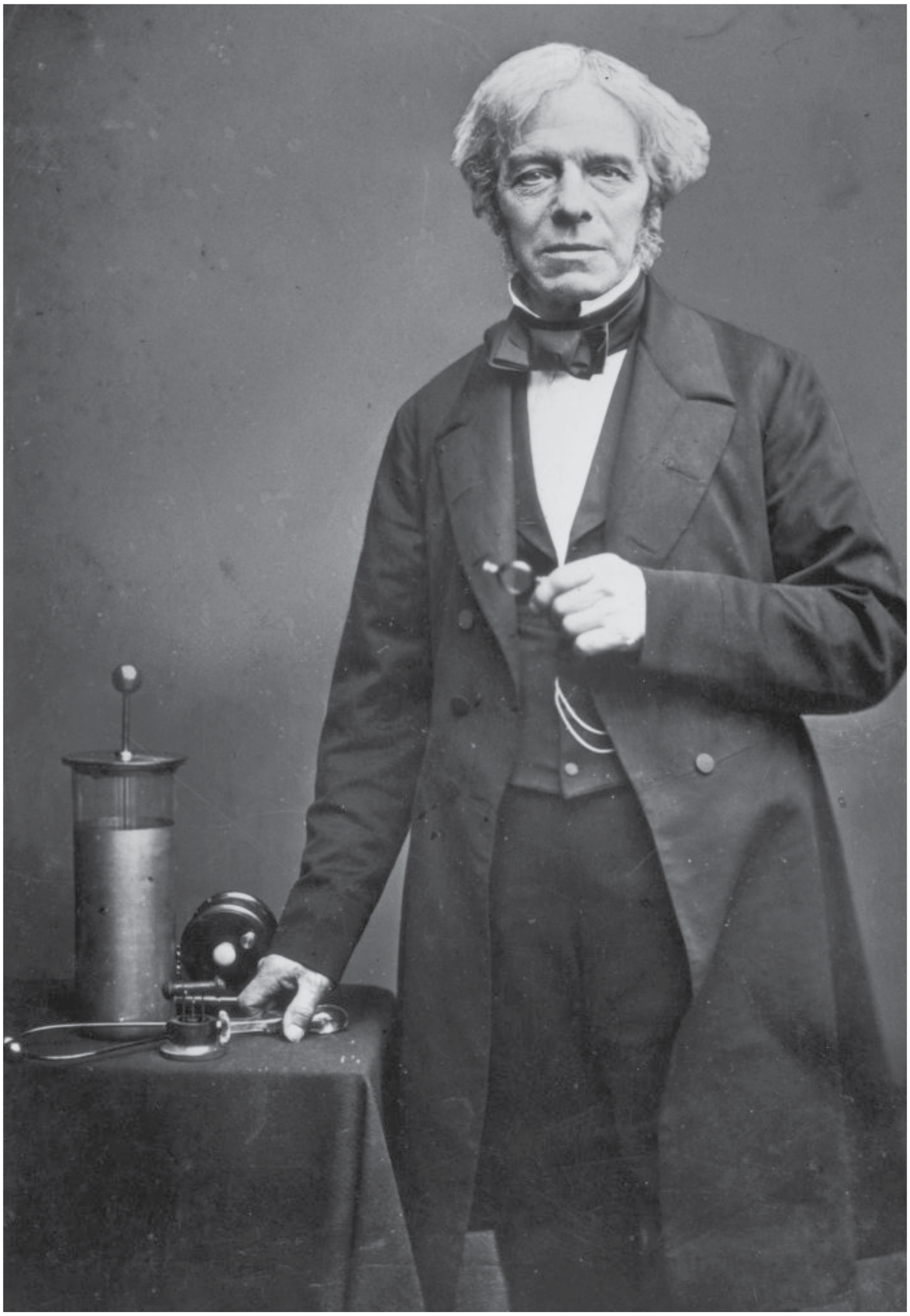
Michael Faraday was born in London on 22 September 1791, the son of a blacksmith, one of four children born to James Faraday and Margaret (née Hastwell). At that time there were many thousands of horses in the streets of London and there would have been much business for furriers, saddlers, blacksmiths and wheelwrights. Bookseller and stationer, George Riebau, employed the 13-year old Michael as a messenger. He needed to supplement the family income as his father was in poor health at the time. Riebau, noticing Michael's intelligence, indentured him as an apprentice bookbinder. Michael was health conscious and never drank anything other than water – something that was most unusual in an apprentice. Michael had an insatiable desire to learn and went to lectures, museums, studied natural phenomena and would read every book that struck his fancy. He also read the electrical treatises in the Encyclopaedia Britannica. He took notes at lectures and bound them for future use.

A customer of Riebau, William Dance, one of the founders of the Royal Philharmonic Society and a member of the Royal Institution, gave Michael tickets to attend a course of lectures by Professor of Chemistry, Sir Humphrey Davy. Michael, as usual, took notes (300 pages) and bound them. This eventually led to Davy employing Michael as an assistant after Davy had injured his eyes in a laboratory accident.

In October 1813, Davy set off on an 18-month tour of scientific enquiry to Europe, and took Michael along as assistant and secretary. This was a wonderful travel opportunity for Michael but which was somewhat marred by Davy's snobbish wife who treated Michael as a servant. Michael would have to ride outside the carriage and take his meals with the servants – the man who would one day be offered a knighthood by the Queen of England.

They met with many famous European scientists, including Ampere and Volta, travelling to Paris, Nice, Turin, Rome and Naples. On the long trip Michael's youthful ebullience, sense of humour, and humility in the face of nature's marvels endeared him to Davy. On learning of Napoleon's escape from Elba in February 1815, they abandoned further travel and hurried home.

Faraday plunged into chemical experiments, liquefying a number of gases



and isolating benzene. He prepared new chemical compounds and made time-consuming efforts to produce new alloys of steel. With a group of friends he set up a 'mutual improvement plan' to study English grammar and syntax as well as oratory. He also joined the City Philosophical Society where in 1816 he delivered the first of many scientific lectures. He also helped Sir Humphrey to develop the miners' safety lamp, which brought a wonderful improvement to coal mine safety. Michael discovered that coal dust blown into air suspension by a gas explosion, could be a far greater explosion hazard than the gas. This important discovery, vital to coal mine safety went, at first, tragically unheeded. Michael developed an early version of the laboratory Bunsen burner.

In 1809 Davy was responsible for a brilliant invention – the first incandescent electric light, using a charcoal filament. Without a commercially available power source and a durable material for the filament, it would have to wait many years before commercial development was possible. Remarkably, Davy was the first to isolate the nine chemical elements: potassium, sodium, barium, boron, calcium, chlorine, magnesium, strontium and iodine.

Michael did not seem to bother much with girls as a teenager and wrote verses beginning with:

What is the pest and plague of human life?
And what the curse that often brings a wife?
'tis Love.

When these lines came to the notice of 22-year-old Sarah Barnard at Michael's church group, she decided to capture him. Michael fell madly in love and they married soon after in June 1821. Sarah proved to be the ideal wife for Michael, supporting him in his work but without actually understanding what he was doing.

A scientific breakthrough came in 1820 when Danish professor Oersted of Copenhagen showed that an electric current deflected a magnetic compass. The only source of an electric current at the time was the voltaic pile developed by Italian nobleman Alessandro Volta in 1800. Faraday was quick to follow up on the link between electricity and magnetism.

By ingenious means he was able to show that a magnetic needle would spin around a current carrying wire and conversely a current carrying wire would spin around a magnet – the first monopole DC motor. He even showed that the wire would spin under the influence of the Earth's magnetic field alone. Faraday was wild with excitement.

Faraday became a member of the Royal Society and a Director of the Laboratory at the Royal Institution. He became a well-known lecturer, particularly effective with young audiences.

In 1831, after lengthy experiments to improve forms of optical glass, he resumed his work on electromagnetism. Faraday was appointed as Fullerian Professor of Chemistry at the Royal Institution.

Faraday and Maxwell

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On 29 August 1831 Faraday set up his now famous induction experiment. He ordered a six-inch ring of iron, one inch thick, from a blacksmith. He wound two coils of insulated wire through the torus and connected the one coil to a voltaic pile and the other to a galvanometer. When a current was started or stopped in the one coil, a current would be induced in the other – the world's first transformer. He also discovered that this could work, albeit less effectively, without the iron core.

Soon after, he showed that moving a magnet inside a coil with reciprocating motion would induce a reciprocating current – the first AC alternator. The next step was to produce a constant flow of electric current.

This he achieved on 28 October 1831with a copper disc mounted on a shaft. Spinning the disc between the poles of a magnet would produce a current between brushes on the shaft and the periphery of the disc – the first DC generator.

Faraday also developed the basic laws of electrolysis introducing the terms anode, cathode, ion and electrode. The Faraday cup (for capturing beams of charged particles) found application in mass spectrometry.

Faraday's theory of lines of force and transmission of electromagnetism through space would be taken up by Maxwell and raised to new mathematical heights of theoretical physics. Faraday was intrigued by Maxwell's work, writing to him in November 1857:
"When a mathematician investigating physical actions and results has arrived at his conclusions, may they not be expressed in common language as fully, clearly and definitely as in mathematical formulae?"

In 1844, Ada Lovelace (of Babbage machine fame) wrote to the 53 year old Faraday in the hope of arranging science tuition for herself, but the happily married Faraday declined, having no intention of getting into any entanglement with a flirtatious enchantress.

A brief extract of the correspondence between Faraday and Lovelace:

Dear Mr Faraday,
I am exceedingly tickled with your comparison of yourself to a tortoise. It has excited all my fun (& I assure you I have no little of that in me). I am also struck with the forcible truth of your designation of my character of mind: "elasticity of intellect". It is indeed the very truth, most happily put into language.

Faraday replied:
"You have excited in my mind a ridiculous, but not ungraceful, allegorical picture, viz: that of a quiet demure plodding tortoise, with a beautiful fairy gamboling round it in a thousand radiant & varying hues; the tortoise crying out, "Fairy, fairy, I am not like you. I cannot at pleasure assume a thousand aerial shapes & expand myself over the face of the universe. Fairy, fairy, have mercy on me, & remember I am but a tortoise".

Many honours were bestowed on Faraday, including the Legion of Honour from the Emperor of France. He declined the presidency of the Royal Society and a knighthood saying, *"I must remain plain Michael Faraday to the last"*.

He accepted a 'grace and favour' residence at Hampton Court from Queen Victoria in 1859. In accordance with his wishes, he was not interred in Westminster Abbey.

Faraday's fame is enshrined for posterity in thirty brilliant treatises titled 'Experimental Researches in Electricity' deposited with the Royal Society.

Innumerable place names, street names, sculptures, lecture programs and establishments have commemorated Faraday. His likeness was featured on the June 1991 issue of the £20 Bank of England banknote. In 1973 the Royal Institution opened a museum dedicated to Michael Faraday in the main building in Albemarle Street. The museum is Faraday's actual laboratory and not a replica. This magnificent grade 1 listed building has recently been offered for sale.

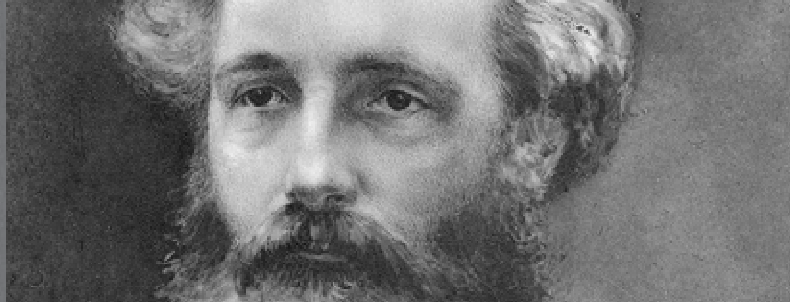
Physicist Ernest Rutherford said of Faraday: *"When we consider the magnitude and extent of his discoveries and their influence on the progress of science and of industry, there is no honour too great to pay to the memory of Faraday, one of the greatest scientific discoverers of all time"*.

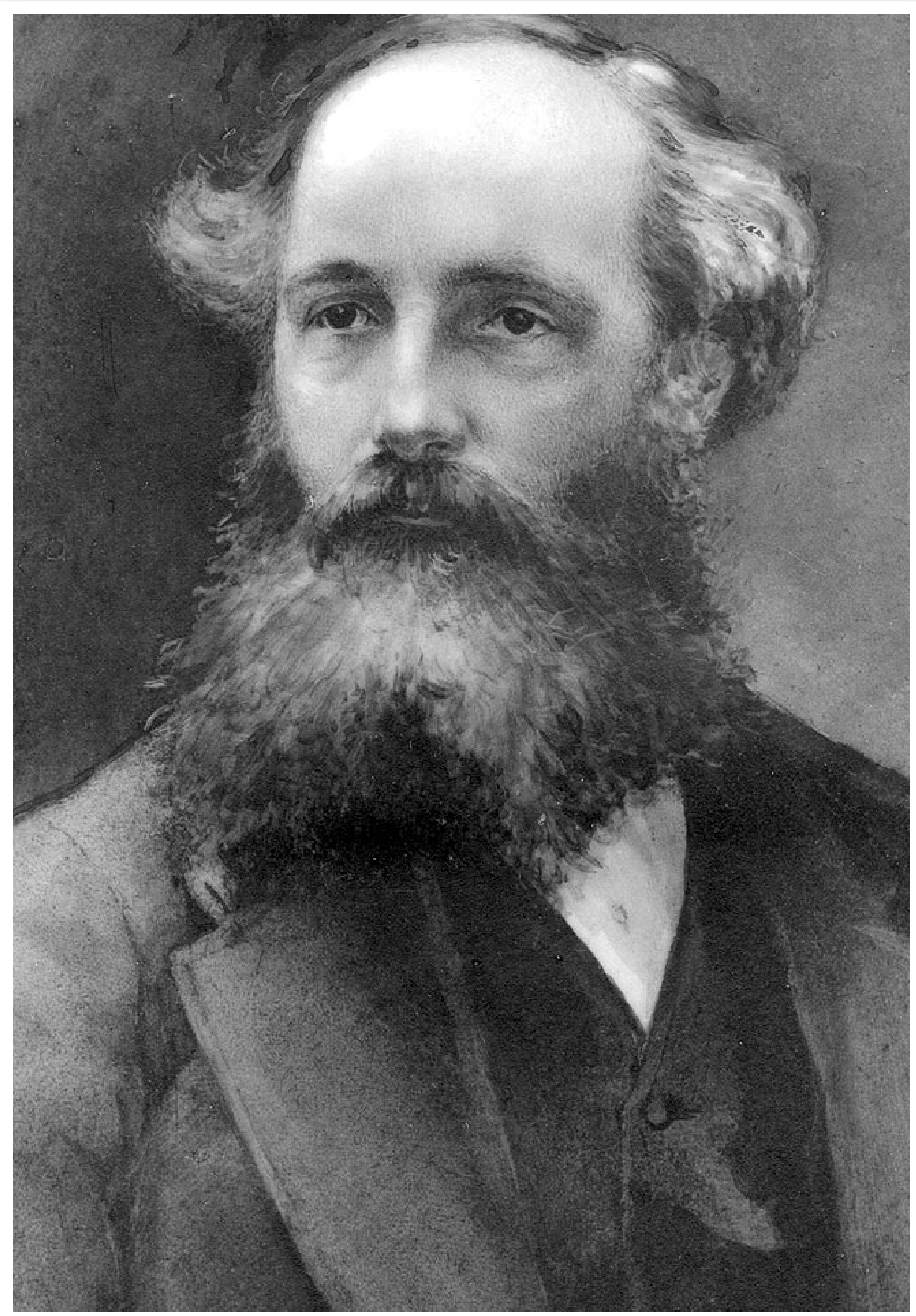
Faraday's religious faith was a great comfort to him during his life as is evidenced by a remark in a letter to a friend, near to the end of his life, when his health was failing:

I am, I hope, very thankful that in the withdrawal of the power and things of this life, the good hope is left with me, which makes the contemplation of death a comfort – not a fear. Such peace is alone in the gift of God and as it is he who gives it, why shall we be afraid?

Michael Faraday died aged 76 on 25 August 1867.

The fundamental experimental work had been done – the engineering world was





now ready for the next giant to walk the stage – Nikola Tesla, who would become the electrical scientist known as: *'The man who switched on the 20th century'*.

JAMES CLERK MAXWELL was born on 13 November 1831, the son of John Clerk Maxwell and Frances (née Cay). His father took the name Maxwell on inheriting the Maxwell estate near Edinburgh. From a very young age he showed an endless curiosity to know how things worked. His father, an advocate, was also a member of the Royal Society in Edinburgh with a keen interest in scientific matters and was able to satisfy his son's curiosity and encourage him further.

James' mother, who sadly died when he was eight years old, gave him his initial schooling. A tutor also taught James before being admitted to the Edinburgh Academy at aged ten. As frequently happens amongst school pupils, an informal group will identify another pupil as the odd-one-out. James was mocked for his country accent and home made clothes and given the nickname 'Daftie'. James met Lewis Campbell and Peter Tait at school who became lifelong friends.

Aged 13 he won the school's mathematics medal and first prize for English and poetry. He took an interest in geometry from an early age rediscovering and making models of the regular polyhedra. He wrote his first scientific paper at the age of 14, which described a method of drawing various mathematical curves with a length of string, and also described the properties of ellipses, Cartesian ovals and other curves with more than two foci.

From the age of sixteen Maxwell attended the University of Edinburgh. In his spare time he experimented with improvised chemical, electric and magnetic apparatuses and made a study of polarized light using blocks of gelatine, discovering photo elasticity. Aged 18 he wrote two papers for the Transactions of the Royal Society of Edinburgh - *'On the Equilibrium of Elastic Solids'* and *'Rolling Curves'*.

In 1850 Maxwell left Scotland for Cambridge where he graduated in 1854 with a degree in mathematics at Trinity College. Soon after obtaining his degree

Faraday and Maxwell

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he read his mathematical paper *'On the Transformation of Surfaces by Bending'* to the Cambridge Philosophical Society. In March 1855 he presented a paper to the Royal Society of Edinburgh on Experiments in Colour, which laid out the principles of colour combination. He showed that additively mixing three primary colours by spinning a disc with the colours in the correct proportion would produce white. Not like the subtractive mixing of paints, which would produce black. He did much research on colour and colour vision, as well as research on people with colour blindness.

Maxwell produced the first colour photograph by taking three exposures through red green and blue filters and produced a full colour image by projecting the images through filters. He used a Scottish Tartan ribbon as the photographic subject.

The image was of poor colour accuracy due to the plates having little sensitivity to red. It is thought that the red image obtained was due to the red dye in the ribbon reflecting ultraviolet light, which exposed the plate. Colour photography would become a huge worldwide industry in the 20th Century. A large variety of single image photographic materials were developed giving negative as well as colour-reversal images. The Technicolor three-strip system for cinematography was reminiscent of Maxwell's method.

Maxwell became a fellow of Trinity College in October 1855.

He accepted the Chair of Natural Philosophy at Marischal College, Aberdeen, in November 1856. Here he had a busy schedule, devising the syllabus and lecturing for fifteen hours a week as well as giving pro bono lectures at the workingmen's college. He wrote to a friend: *"No jokes of any kind are understood here. I have not made one for two months and if I feel one coming I shall bite my tongue"*. He worked on an astronomical problem that had eluded scientists for two centuries – the nature of Saturn's rings – which if solid or liquid would be mathematically unstable. He showed that the rings must consist of small particles each orbiting independently – and won the £130 Adams prize for his discovery. Astronomer Royal, George Airy, remarked that it was the most remarkable application of mathematics to physics that he had ever seen.

A most fortunate event of Maxwell's life came about when he met and married Katherine Dewar, daughter of Marischal Principal, the Rev. Daniel Dewar. Maxwell moved with his wife to London in 1856 on being appointed to the Chair of Natural Philosophy at King's College. This period was probably the most productive of his career. He would attend lectures at the Royal Institution where he regularly made contact with the now ageing Michael Faraday. In 1857 Maxwell wrote an elegant paper giving convincing mathematical grounds for accepting Faraday's lines of force and went on to develop his electromagnetic theory in the conditions of space.

Maxwell needed a four dimensional algebra for his electromagnetic theory and was able to use quaternions discovered by Hamilton more than a decade earlier. Quaternions came to Hamilton as he was walking along the Royal Canal on his way to the Irish Academy in Dublin. He was so delighted with his discovery that he scratched the quaternion multiplication identity on a stone of Brougham Bridge. No trace of Hamilton's graffito remains but a plaque has been affixed to the bridge, which reads:

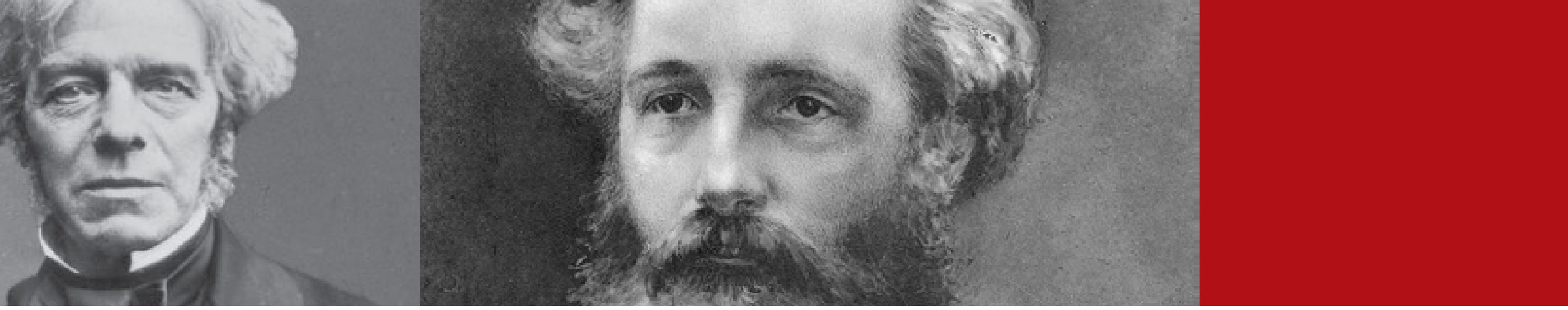
Here as he walked by
on the 16th of October 1843
William Rowan Hamilton
in a flash of genius discovered
the fundamental formula for
quaternion multiplication
$i^2 = j^2 = k^2 = ijk = -1$
and cut it on a stone of this bridge

Maxwell expressed his electromagnetic theory as twenty quaternion equations in twenty variables using:
Gauss's law:- Electric charges produce electric fields.
Ampere's law:- Electric currents produce magnetic fields.
Faraday's law:- Changing magnetic fields produce electric fields.

The Maxwell equations as we know them today were re-formulated by Oliver Heaviside (1850-1925) to four equations in four variables using vector calculus.

Detractors of Heaviside's work claimed that the Maxwell equations were over-simplified by losing the full functionality of quaternions. Heaviside was the nephew of Sir Charles Wheatstone. Maxwell and Willard Gibbs (1839-1903) worked together on thermodynamic studies. Heaviside and Gibbs independently developed vector calculus and introduced the dot and cross product notation to vector algebra.

Hamilton introduced the ∇ (nabla or del) symbol to mathematical notation. The name nabla, on Maxwell's suggestion, comes from the symbol looking similar to an ancient



harp. This convenient and concise notation has found widespread use. Hamilton's work would become of immense value to Dirac's advanced theoretical quantum physics in the following century.

In Maxwell's equations the nabla represents the three-dimensional partial differential equation: $\mathrm{i}\frac{\partial}{\partial x} + \mathrm{j}\frac{\partial}{\partial y} + \mathrm{k}\frac{\partial}{\partial z}$

The i, j and k represent the three complex orthogonal unit vectors of space and the real dimension is used for time. Used with the vector dot and cross products, **∇**. gives gradient and **∇**x gives curl.

I can remember a very practical application of vector algebra when working as an ISCOR apprentice millwright in the civil engineering drawing office, detailing large diameter steel pipes.

The bends and elbows in the pipeline were drawn with precise dimensions and angles, but when two pipes met coming from different angles in the drawing as well as from different angles to the plane of the drawing, calculating the angle between the pipes was considered to be an impossible mathematical problem, and it was left to the boilermaker to cut and weld the pipes on site as best he could.

When I showed the other draughts men that determining the angle between the pipes, using vector multiplication, were a quick and trivial calculation, they looked on in open-mouthed disbelief. (It was only necessary to take the dot product of the unit vectors of the pipes, which yielded the cosine).

Maxwell was an accomplished poet and also enjoyed the poems of Robert Burns, which he would sing to his own guitar accompaniment. Let us take a look at Maxwell's poem written in honour of multi-dimensional geometer Arthur Cayley, which mentions hyper-dimensionality and matrix algebra:

O wretched race of men, to space confined!
What honour can ye pay to him, whose mind
To that which lies beyond hath penetrated?
The symbols he hath formed shall sound his praise,
And lead him on through unimagined ways
To conquests new, in worlds not yet created.

First, ye Determinants! In ordered row
And massive column ranged, before him go,
To form a phalanx for his safe protection.
Ye powers of the n^{th} *roots of -1!*
Around his head in ceaseless cycles run,
As unembodied spirits of direction.

And you, ye undevelopable scrolls!
Above the host wave your emblazoned rolls,
Ruled for the record of his bright inventions.
Ye cubic surfaces! By threes and nines
Draw round his camp your seven-and-twenty lines –
The seal of Solomon in three dimensions.

March on, symbolic host! With steps sublime,
Up to the flaming bounds of Space and Time!
There pause, until by Dickenson depicted,
In two dimensions, we the form may trace
Of him whose soul, too large for vulgar space,
In n dimensions flourished unrestricted.

This is not an epitaph – Maxwell died before Cayley. The Dickenson referred to was a portrait artist of Maxwell's acquaintance.

Arthur Cayley (1821–1895) was one of the most prolific and important mathematicians of the Victorian era. His influence still pervades modern mathematics, in group theory (Cayley's theorem), matrix algebra (the Cayley-Hamilton theorem), and invariant theory, where he made his most significant contributions. Cayley also extended quaternions to an eight-dimensional algebra known as octonions.

Maxwell resigned the Chair at King's College in 1865 and returned with his wife to his home - Glenlair House in Scotland.

Maxwell was invited in 1874 by the University of Cambridge to establish the Cavendish research laboratory. This would become one of the most prestigious research institutions on Earth. Maxwell was appointed as the first Cavendish professor of physics. He died aged 48 on 5 November 1879 suffering from an abdominal cancer.

When discussing Newton's statement that he was able to see further by standing on the shoulder's of giants, Einstein was asked if he stood on the shoulders of Newton - he replied: *"No, on Maxwell's"*. Einstein had such a great admiration for Maxwell, Faraday and Newton that he kept portraits of them on a wall of his study in Princeton. Regarding Maxwell's equations, Einstein commented:

The precise formulation of the time-space laws was the work of Maxwell. Imagine his feelings when the differential equations he had formulated proved to him that electromagnetic fields spread in the form of polarized waves, and at the speed of light! To few in the world has such an experience been vouchsafed … it took physicists some decades to grasp the full significance of

Faraday and Maxwell

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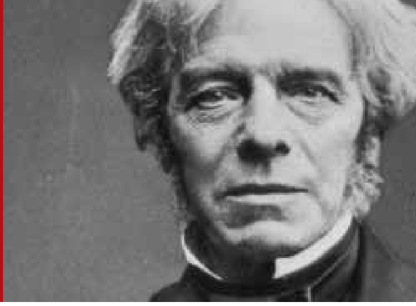


Maxwell's discovery, so bold was the leap that his genius forced upon the conceptions of his fellow workers.

At the time of Maxwell's discovery the only known part of the electromagnetic spectrum was the narrow band of wavelengths known as visible light and near infrared, visible light spanning less than a single musical octave of frequencies. There was however no reason for the spectrum not to extend much further in both directions. It was only some years later that Hertz discovered a longer wavelength part of the spectrum.

An electric field is a zone where electric charges attract or repel each other, a magnetic field is a zone where moving charges influence each other, but it was not known if these fields had any actual substance.

In Maxwell's theory it was assumed that waves were formed in the '*aluminiferous ether*' and propagated themselves by the magnetic and electric fields oscillating at right angles to each other without the presence of any electric charges.

This model of transverse waves perfectly described the wavelength, frequency and polarization properties of light. In 1887 Michelson and Morley performed their famous interferometer experiment to prove the existence of the ether. They would measure differences in the speed of light due to the Earth moving through space at different times of day, different times of the year and in different directions. They were expecting a fringe shift of one third of a fringe but the interferometer was sensitive enough to detect a shift of one hundredth of a fringe.

They based their estimate on the speed of the Earth in its orbit around the Sun, but the entire Solar System moves at a very much greater speed about the galactic centre and the entire galaxy moves at an even greater speed through the local galaxy group. To their astonishment, there were no shifts at all, and they had proved that the ether does not exist. Recent experiments have confirmed this result with very much greater accuracy. The speed of light was the same in any direction regardless of the motion of the Earth through space. This result became a forerunner to Einstein's Special Theory of Relativity.

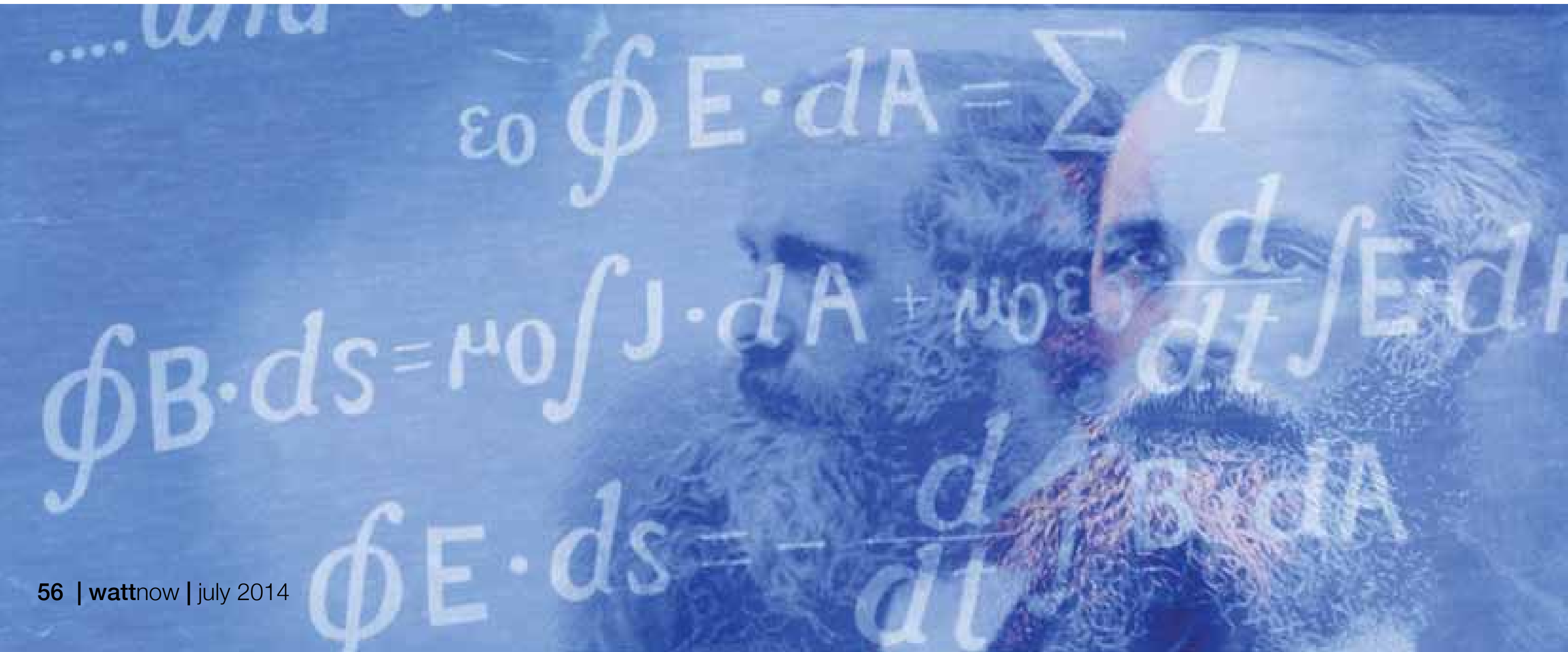
The equation $\varepsilon_0\ \mu_0\ c^2 = 1$ expressing the speed of light in terms of the electric permittivity and magnetic permeability of space must have seemed the ultimate seal of verification of Maxwell's equations.

Consider also Newton's F = m a linking force, mass and acceleration – what could be more fundamental?

These laws seemed to stand stable and foursquare as the pyramids of Giza – as indeed they still do, but when taken to the extreme worlds of atomic particles or interstellar space, things become complicated and paradoxical.

In 1905, Einstein published his four *'annus mirabilis'* papers, which, together with Max Planck's quantum theory, shook the world of physics to its foundations.

The early part of the 20th century ushered in an era of unprecedented developments in theoretical physics. wn



IN MY OPINION : MAX CLARKE

Keeping the Lights on...

In 1879 a showman from overseas visited Cape Town and presented *"a collection of electrical illuminary art never before witnessed in South Africa"*. The next year, the steam powered ship *"Trojan"*, one of the few in the world to have electric lights, arrived in Table Bay and duly impressed the locals with it lights. On 2nd September 1882 the town of Kimberley switched on electric street lights and became the first town in the Southern Hemisphere to use the then novel form of energy.

BY | MAX CLARKE **|** FSAIEE

In a relatively short space of time, other towns followed suite and electricity and lighting became synonymous in the minds of South Africans. Little has changed over the years... "electricity = lights" is imprinted in the minds of most modern-day South Africans.

By the early 1920's, municipalities were beginning to look at ways of increasing their sales of electricity beyond the virtual monopoly of "lights'. A number of cities established "electricity showrooms" to demonstrate the wider use of the commodity and such novel things as heating, refrigeration, cooking and motive power began to creep into use. Consumption began to rise but, in spite of this, to this day, large numbers of users are still greatly surprised when they find that in their homes barely 5% of their useage is taken up by "the lights".

With the increasing consumption patterns and the proliferation of large and small generating stations, it wasn't long before the merits of establishing large centralised generating stations and interconnected transmission grids became apparent. The passing of the Electricity Act in 1922 saw the establishment of the Electricity Supply Commission (ESCOM) and the stage was set for a massive increase in the use of electricity in almost every sphere of the people's lives.

Fast forward to 2008... through a combination of circumstances, which included erroneous high level policy decisions, electricity loads exceeded production capacity and the "lights" went out for varying lengths of time throughout the land. Energy saving quickly became the catch phrase. Amongst other things the CFL (Compact Fluorescent Lamp) emerged like a mythical charger on its white horse to save the day... and *"save electricity, switch to energy-saving CFLs"* went up as the call of the national savoir.

Come 2014 and again the call has gone up... *"SAVE ELECTRICITY, SWITCH OFF ALL UNECESSARY LIGHTS... and the geyser... and the pool pump... and... and..."* So how does the man-in-the-street react when the home is dark and cold, and he/she needs to find a take-away to feed the kids... and their sight is affected by the glare from brightly lit giant advertising hoardings along the road to a non-shed area?

Street lights are understandable - they are safety-related - but illuminated advertising signs? If we need to conserve energy do we really need horrendous objects that, in the final analysis, are

wealth re-distributors NOT wealth creators … never mind being generators of CO_2 ?

And what about the public and commercial buildings that brazenly show-off their architectural glamour with energy-sapping interior and exterior lights and flood lights that are yet another straw on the camel's back? Then there are the innumerable street lights that burn during day-light hours because maintenance programs are inadequate or non-existent?

Maybe the actual wasted energy consumption will not fire up an idle smelter but in the public's mind they have a serious negative connotation which translates to a *"….why should I worry when the authorities don't bother…"*-attitude. Can the nation afford to ignore this?

How can authorities justify the cost of advertising things like *"The power is in your hands… use electricity wisely"* and *"Switch off…. and help to keep the lights burning.."* when they don't lead the way ?

Also, it should come as no surprise that when the highly successful *"electricity for all"* program was started a few years ago the potential consumers all wanted "lights". It is ironical that this triggered what is arguably a poison chalice of gigantic proportions when it was followed by the introduction of "free basic electricity" – a social engineering program that cuts across the fundamental of "user pays" reality of life…

The question must be asked as to why grant money was not handed to deserving cases and the costs of metered energy charged at tariff rates? Has this been a contributing factor to the escalation in electricity theft – and therefore load on the network - that now significantly adds to the estimated 20% + of unaccounted-for electricity in the country? There has always been electricity theft… one can say it is one of the basic sins of mankind… but when it reaches the scale of having an organised industry that re-connects cut-off connections at will, as was the case a while back in Soweto (it may still be going on ….who knows?), then there is something fundamentally wrong in the system and society as a whole.

So what's to be done ? In my book we need inspirational leaders from the highest echelons of government, and society in general, to sort out the blatantly obvious technical issues, ban and vigorously enforce unnecessary illumination, institute effective inspections and follow-up procedures to combat electricity theft (maybe we should re-train all the spin-doctors, who endlessly spew out vocal and printed garbage about our "world class' society, to do this work) and set examples in prudency and efficient energy usage for all to see.

Maybe it would help if the leaders and bureaucrats started acting as the "civil servants" they are supposed to be and switched off their computer games, rolled up their sleeves and switched off a few unnecessary lights around their offices…

Did someone say "pipe-dream…" well, maybe… keep your candle and matches handy, you'll be needing it to read this magazine by - soon enough… **wn**

Watt's your Opinion?
Please submit your comments or your own opinion piece to minx@saiee.org.za.

July

COMPILED BY I JANE BUISSON-STREET
SMSAIEE I PMIITPSA

The month was named by the Roman Senate in honor of the Roman general, Julius Caesar, it being the month of his birth. Prior to that, it was called *Quintilis.*

1 July

1903 First Tour de France bicycle race begins! 50 riders started the Tour and only 21 survived the 2 428km marathon. Maurice Garin of France won in 94h 33m 14s.

2 July

1907 Emil Haefely obtained a patent for a method of wrapping "hard" paper (resin-impregnated) around electrical conductors thereby insulating them.

3 July

1886 Karl Benz officially unveils the Benz Patent-Motorwagen, widely regarded as the first automobile (a vehicle designed to be propelled by an internal combustion engine).

4 July

1951 Bell Labs and primarily William Shockley announced the invention of the junction transistor at a press conference in Murray Hill, NJ, USA.

5 July

1988 The bugs bunny phrase *"What's Up Doc?"* trademark for T-shirts was registered (US Patent #764).

6 July

2012 Andy Murray makes it to the final of the 2012 Wimbledon Championships – Men's Singles, becoming the first Briton to do so in 74 years.

7 July

2003 NASA Opportunity rover, MER-B or Mars Exploration Rover – B, was launched into space aboard a Delta II rocket and landed on Mars on January 25, 2004.

8 July

1895 Delagoa Bay Railway opens in South-Africa.

9 July

1877 The inaugural Wimbledon Championships begins.

10 July

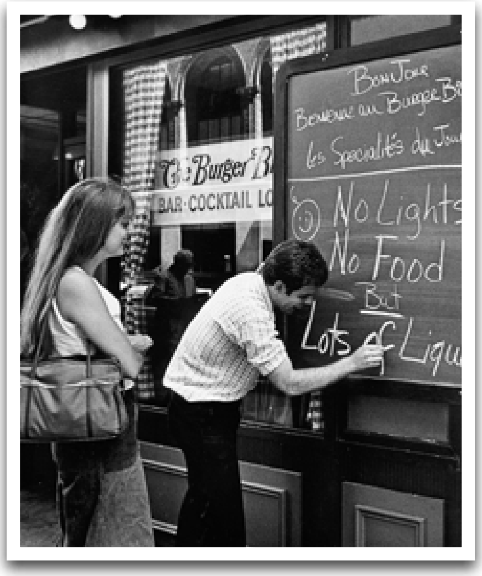
2012 South Africa cricket player Mark Boucher ends his career after sustaining an eye injury during the tour of England.

11 July

1892 The U.S. Patent Office decided that Joseph Wilson Swan in England, not Thomas Edison, was the inventor of the electric light carbon for the incandescent lamp.

12 July

1894 Eight units for the measurement of electrical magnitudes were adopted in U.S. law when President Grover Cleveland signed an Act of Congress *"to define and establish the units of electrical measure"* for the ohm, ampere, volt, coulomb, farad, joule, watt and henry.



13 July

1977 Starting at about 9 pm, four lightning strikes on high-voltage transmission lines within the course of about half-an-hour knocked out electricity and plunged millions of residents of New York City into darkness.

14 July

2011 A rare manuscript of an unfinished Jane Austen novel has sold for £993,250 (US$1.6m) in London. The work, The Watsons, was sold at Sotheby's for three times its estimated price.

15 July

2006 Twitter is launched, becoming one of the largest social media platforms in the world.

16 July

1867 Reinforced concrete was patented by F. Joseph Monier (1823-1906), a Parisan gardener.

17 July

1888 Granville Woods received a patent for the *"tunnel construction for electric railways."*

18 July

1998 Nelson Mandela marries Graca Machel.

19 July

2011 The Space Shuttle Atlantis undocks from the International Space Station for the final time in the history of the space shuttle program.

20 July

1937 Marconi died in Rome at age 63, following a series of heart attacks. Italy held a state funeral for him.

21 July

1984 The first robot-related fatality in the United States occurred.

22 July

1873 Louis Pasteur received a patent for the manufacture of beer and treatment of yeast.

23 July

1903 The Ford Motor Company sells its first car.

24 July

2011 Japanese television switches to digital television.

25 July

2013 The Oxford English Dictionary confirms that it will change the definition of the word "marriage" to include the LGBT (lesbian, gay, bisexual, and transgender) community.

26 July

1951 Walt Disney's 13th animated film, Alice in Wonderland, premieres in London, England, United Kingdom

27 July

1866 Cyrus W. Field finally succeeded, in laying the first underwater telegraph cable 1,686 miles long across the Atlantic Ocean between North America and Europe.

28 July

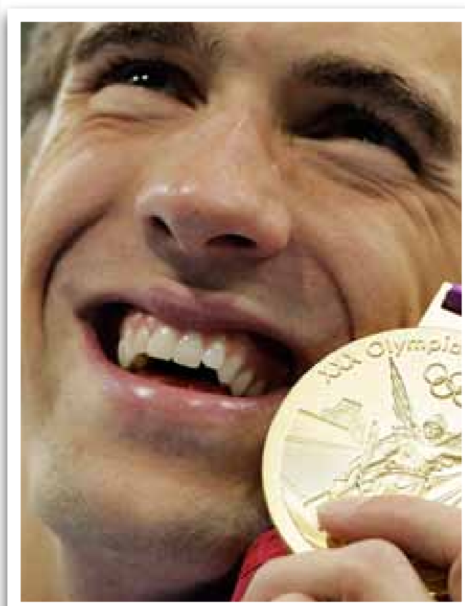
1858 A British colonial magistrate in India starts using fingerprints as a means of identifying people.

29 July

1914 Transcontinental telephone service began with a telephone conversation between Thomas A. Watson in San Francisco and Alexander Graham Bell in New York City.

30 July

1933 The Monopoly board game was copyright registered.



31 July

2012 Michael Phelps breaks the record set in 1964 by Larisa Latynina for the greatest number of medals won at the Olympics. wn

Calendar of events

If you want to see your function or event listed here, please send the details to Minx Avrabos at minx@saiee.org.za

JULY 2014

9-10	Photovoltaic Solar Systems	CPD training Course, Johannesburg	www.saiee.org.za
16-17	Practical Lighting Design Workshop For Commerical & Industrial Applications / SAIEE House		www.saiee.org.za
22-25	Insulating Oil Management	CPD training Course, Johannesburg	www.saiee.org.za
24	Variable Frequency Control	CPD training Course, Johannesburg	www.saiee.org.za

AUGUST 2014

5-6	High Temperature Low Sag Overhead Line Conductors	CPD training Course, Johannesburg	www.saiee.org.za
19-22	Managing Projects Effectively	CPD training Course, Johannesburg	www.saiee.org.za
27-28	Incidents Investigations Management & RCA	CPD training Course, Johannesburg	www.saiee.org.za

SEPTEMBER 2014

11	Bernard Price Memorial Lecture	Wits University, Johannesburg	www.saiee.org.za
12	Bernard Price Memorial Lecture	Bloemfontein	www.saiee.org.za
15	Bernard Price Memorial Lecture	TBC, Cape Town	www.saiee.org.za
16	Bernard Price Memorial Lecture	TBC, George	www.saiee.org.za
17	Bernard Price Memorial Lecture	TBC, Port Elizabeth	www.saiee.org.za
18	Bernard Price Memorial Lecture	TBC, KwaZulu Natal	www.saiee.org.za

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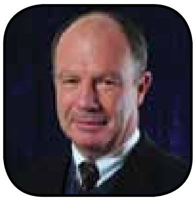

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EQUALIZER-ST

Medium and Low Voltage Motor Startup Solution

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The EQUALIZER-ST is a real-time, dynamic reactive power compensation system that utilizes a proven industrial technology to provide an additional solution for the challenges related to large motor startups. The system itself operates at low voltage and by utilizing a step-up transformer, the EQUALIZER-ST is also able to to compensate for medium voltage networks.

Centralized Motor Startup Compensation

The EQUALIZER-ST is a centralized motor startup solution, that provides fast compensation in real-time. In an environment of many motors, one EQUALIZER-ST system serves any number of motors, assuming that two motors are not started simultaneously. Eliminating the need to use individual soft start devices for each motor, makes the EQUALIZER-ST more cost effective than conventional compensation systems.

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