NUCLEAR NETWORK AFRICA

THE WORLD OF NUCLEAR

SA EXPERIENCED IN NUCLEAR ENERGY NOT ONLY IN AFRICAN TERMS / WORLD TERMS
SISA NJIKELANA

NUCLEAR, WIND AND SOLAR
ANDREW KENNY

AND MORE.....

1ST ISSUE

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1ST ISSUE HIGHLIGHTS

N²A

FROM THE CHAIRMAN

KELVIN KEMM
STRATEK GLOBAL CHAIRMAN

Worldwide, over the last two years, a very visible international move towards nuclear power has become evident. What is more, this move is accelerating, with more and more leaders in politics and business being prepared to stand up and to be counted as amongst nuclear power supporters. This is an exciting development.

Some notable milestones have been; the European Union declaring that nuclear energy is green, and the successful construction of a large four reactor nuclear power station in the UAE. This is the first venture of the UAE into nuclear power, and the project has progressed smoothly according to plan.

Nuclear power has traditionally been seen as the domain of the large first world countries. But now, another new exciting door has been opened. That is the advent of the Small Modular Reactors. The rapid emergence of SMRs has opened nuclear power to any country. The whole concept of SMR's is changing many traditionally held views. For example, there is no need for an SMR to be connected into the National Grid. An SMR could have its own mini grid, which can be as small as two to five kilometers in diameter. So SMR's can be owned by individual companies, such as large mining companies, or provinces, or even individual cities and agricultural clusters.

Another traditional belief has been that nuclear reactors have to be sited on an ocean coastline or next to very large lakes, for the purposes of large-scale water-cooling.. But a country like South Africa has minimal inland water, and in fact is generally quite dry, so the South African nuclear teams decided to develop an SMR, which is helium-cooled and does not need any large water body. In other words; countries really can place such a reactor anywhere they like. The world of nuclear power is opening up dramatically, for everyone.

It is well known that over the last couple of decades the extreme green anti-nuclear lobby have opposed nuclear power of any sort. Sadly, this has frequently been done by distorting the facts and intentionally producing material designed to mislead the public and the authorities. Because the extreme anti-nuclear lobby have been very well funded much of their anti-nuclear campaign has worked to a significant degree, and many decision-makers, and much of the public, have been very misled.

However, the result of much of this has been the installation of inadequate power systems which, particularly in the case of Africa, just do not suit the local conditions. The result has been inadequate and intermittent electricity supplies, coupled with increasing prices. This scenario has been very evident in Europe, where despite huge expenditure, electricity prices have risen dramatically with no evident improvement in the supply. Indeed, even the objective of curtailed atmospheric emissions has not been met. In many cases, the expensive experiment of trying to run any country on intermittent wind and solar power has clearly illustrated the incorrect path to follow.

Nuclear power in various forms is making a significant comeback.

FROM THE EDITOR

It is with great excitement that I edit and co-ordinate this powerful piece of digital publication. It's a privilege of placing into readable digital format, the writings of South Africa's greatest minds, in the world of nuclear energy. Learning their perspectives based on real life experiences and practices, I have the wonderful opportunity to introduce to our reader audiences the insights and highlights in this fast paced and rapidly growing world of nuclear energy.

N^2A is a publication that will feature a diverse mix of opinions and perspectives concerning the development of nuclear power in and around Africa and the rest of the world. The technologies used and also social, environmental and economic factors that both influence, and are influenced by Nuclear power development.

It is my hope that this publication becomes the mouthpiece for positive thinking nuclear engineers, designers, supporters and business minded individuals, to exercise their capacity to propel this industry into the future with the same gusto and excitement we see in the world today.

HEATHER VELDHUIS
EDITOR

SA IS EXPERIENCED IN NUCLEAR ENERGY, NOT ONLY IN AFRICAN TERMS, BUT IN WORLD TERMS

SISA NJIKELANA

The energy sector has received quite intensive attention in South Africa just as is the case globally. Whilst the entry of new technologies and systems - such as renewables, storage, and digitisation of power systems – has gained attention nuclear has been steadfastly advancing in levels of technology as well, thus maintaining interest and growing investment.

South Africa has etched its role into both the participation and the benefit of not only nuclear energy itself but also in the nuclear industry generally. It is worth noting the significance of nuclear energy in the supply of power in South Africa, albeit remaining constant at 5% for a sizeable time. Furthermore, the technology is acknowledged as one of those which will be used deep into future generations as we witness the steadfast growth of the nuclear fusion concept.

Notwithstanding this, before we venture into the future of nuclear energy and its contribution to the socio-economic wellbeing of the country, we need to reflect on the history.
South Africa's entry into the nuclear industry dates as far back as the late forties through the establishment of the Atomic Energy Board whose primary focus was regulation of uranium mining. However, the mandate extended to developing the nuclear industry itself including building a nuclear reactor for research purposes during 1950's. Such plans were also to include nuclear energy and mitigate against the proliferation of nuclear arms.

During the 1950's the construction of two research reactors – the erstwhile Pelinduna-0 and Safari-1 (still operational) was planned and initiated. This was a milestone that firmly ushered South Africa into the nuclear industry. However, the very site of Pelindaba was also used to develop nuclear weapons by the apartheid regime between 1978 and 1990.

Of course, there are a number of other developments worth mentioning starting with Koeberg nuclear power station which was commissioned in 1984, with a capacity of 1860MW, and is still operated by the state-owned power utility ESKOM. It was the first, and still is the only nuclear power plant, in Africa although quite a number of African countries have now joined the nuclear power community by announcing their intention to follow a nuclear power future. In fact, upgrades are currently being executed to extend Koeberg's operational life by another 20 years. In December 2023, government announced plans for development of 2500 MW of new nuclear capacity. We also need to remember the Pebble Bed Modular Reactor program, which got South Africa into the global limelight given the development of the reactor and the fuel which were clearly part of the advanced new Generation IV technology!

An interesting development is the entry of private companies into nuclear development ,of course focusing on Small Modular Reactors. This is another display of capability and confidence.

South Africa has the ability to produce TRISO fuel for Pebble Bed type reactors. In the past, fuel was fabricated for the Koeberg nuclear reactor but that was stopped decades ago for political reasons. However, there has been some consideration given to restarting this activity. proving another attribute that earns the country a seat at the global nuclear table.

South Africa has extended its nuclear capabilities into other fields such as nuclear medicine, as well as a number of industrial applications. Molybdenum-99, a radioisotope which is manufactured by NTP (NECSA subsidiary) for the diagnosis and treatment of cancer, is one of the major international nuclear medicine exporters.South Africa is ably engaging a number of countries as part of the collaboration in the nuclear sector thus enabling us to keep very much abreast of technology advancements. Furthermore, quite a number of universities are intensively engaged in nuclear research and development including NECSA. When we consider the various functions of the of South Africa Nuclear Energy Corporation (NECSA), iThemba Labs, and the National Nuclear Regulator, this is further evidence of the efforts to build, nurture, and advance the capability and capacity that matches leading global standards, but which even leads the competition in a number of areas, for that matter.
When it comes to the disposal of nuclear waste, the state-owned National Radioactive Waste Disposal Institute operates and manages the Vaalputs National Radioactive Waste Disposal Facility. This is a mechanism which provides safety for the country against radioactive waste. Any radioactive waste in the country, from other industries and operations as well, is disposed of at Vaalputs.

There are a number of institutions that are involved in nuclear operations both state-owned and a growing number of private companies as well.

South Africa has not only proven its capability, capacity and prowess in the nuclear sector, throughout its nuclear history but this legacy also displays a bright future that extends across all of the nuclear industry. This reality undoubtedly places us amongst key players in the nuclear industry globally. At this current juncture, our country has been experiencing the excruciating pain of power shortages, skyrocketing electricity tariffs and particularly a lack of baseline power supply that is adequate to enable economic revitalisation and growth! Nuclear energy, with the advent of Small Modular Reactors currently, and Micro Modular Reactors in the near future, is ensuring the feasibility of facing this challenge with confidence.

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WHAT ABOUT THE REGULATIONS RELATED TO POSSIBLE NUCLEAR DAMAGE?

PROF DAVID NICHOLLS

One of the key issues for the operation of nuclear power plants is that of liability for possible damage caused by nuclear accidents. In other industries such as the aviation industry or chemical industry, the normal practice is that within the national regulations, the liability for any damage to the public is attributed to which organisation was at fault. If an airliner crashes, the liability could be with the aircraft designer, the airline itself, the engine manufacturer, and so on.

Due to the creation of the commercial nuclear industry under the shadow of the nuclear weapons programs with the fear of nuclear radiation, the civil nuclear industry has developed a virtually unique system where the operator of the nuclear plant has strict liability for any nuclear damage caused by the plant. There is no defense by the operator against the claims from those affected, and there is no option for an affected party to sue anyone other than the operator. While this may seem to be a straightforward method of resolving a highly controversial issue, it puts a very significant responsibility on the nuclear operator and the related national regulatory body.

International Convention

This approach is specified in international conventions such as the Vienna Convention "no person other than the operator shall be liable for nuclear damage". This is aligned to most national regulations such as the South African one, "a holder of a nuclear installation licence is, whether or not there is intent or negligence on the part of the holder, liable for all nuclear damage caused by, or resulting from, the relevant nuclear installation". Another example is the Swiss Federal Office of Energy "Under the Federal Nuclear Energy Liability Act, operators of nuclear installations bear unlimited liability for nuclear damage arising from the operation of their installations".

This is not just a financial insurance requirement but also requires an engineering competence that license holders must have a full design understanding of the installation, and the knowledge of specifications for all components and systems. This requirement explicitly states that there must be in-house expertise that cannot be contracted out.
In the airline industry which is a similar industry that is perceived as high risk, it is widely accepted that the designer and constructor of the aircraft is liable for the fundamental safety of the aircraft, given that the operator obeys the operating, inspection and maintenance rules laid down by the designer. In terms of the certification of the design, it is accepted that the aviation authorities in the country of origin are seen to be competent to assess the design. This was tested in the case relating to the Boeing 737 Max problems of a couple of years ago. Under these circumstances it is accepted that the "Design Authority" for the aircraft is the original designer, throughout the service life of the aircraft.

With this relationship it is reasonably possible for a small African airline to purchase an airliner without the full set of liability obligations. The airline will have to train the aircrew, in line with the designer regulations, and will have to have the aircraft maintained by an organisation certified as competent by the designer. Similarly, the airline regulator will be limited to confirming that the local airline is following the design requirements. CONTINUE ON PG 7

WHAT ABOUT THE REGULATIONS RELATED TO POSSIBLE NUCLEAR DAMAGE? CONT.... FROM PG 6

PROF DAVID NICHOLLS

This is not the case with a nuclear power station. As all the liability rests on the operator, both they and the national nuclear regulator are required to have a full understanding of the design of the power plant, along with the operation, inspection and maintenance requirements. This results in the operator of the plant being the "Design Authority" of the plant. It is notable that due to national requirements, unlike the aviation industry, virtually every country has variations of the original design with different safety justifications. This also largely applies to the regulator. If one considers the situation of South Africa, with one nuclear power station, Koeberg, of some 2000 MW then the operator, Eskom, has an engineering and licensing team of over 200 skilled people, and the regulator, the National Nuclear Regulator, has a staff of some 170, largely committed to Koeberg power station.

Regulator development

The South African nuclear regulator has taken about fifty years to develop, and was the first Nuclear Regulator in Africa. This process was accompanied by a deep process of human capacity building, essentially over more than two generations.
Egypt is now constructing four nuclear power reactors at El-Dabaa and will be the second country in Africa with a Nuclear Power Station. Egypt went through a similar long process in developing its regulator, the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA) which was established in 2010.

This level of engineering support required for a nuclear power plant is not specifically related to the size of the nuclear fleet, but primarily to the diversity within such a fleet. In relation to a single nuclear plant it can be seen that under the current international approach a base overhead of some 300 skilled personnel can be expected in a country. With a power plant size of some 2000 MW this can be justified as part of the overall advantage of such a plant.

At this stage a large set of reactors, with Koeberg about 2000 MW and El-Dabaa about 5000 MW, is not appropriate for most countries in Africa. Smaller reactors, such as the Small Modular Reactors (SMRs) of around 50 MW – 300 MW would be better matched. They can be deployed in groups, if required. However, in the case of a small SMR project the current regulatory model would be a significant barrier to entry.

The staffing for the 210 MWe HTR-PM SMR operating in Shandong, China, is quoted at 175. In the African context there are many national grids where unit sizes of about 100 MW would be appropriate and therefore the "strict liability" requirement would imply a more than doubling of the human resources to operate the early units. It can be seen that this would be a significant barrier to entry for SMRs in the African market, so something should be done.

Proposal for Africa

The African continent has adequate resources to support the deployment of SMRs into the small grids that would benefit from them. The issue of achieving this is constrained by the infrastructure overheads that are induced by the current international licensing regime. It is proposed that there have to be a number of changes to the way that nuclear power is managed to resolve this:

1. The African Union, in conjunction with the SMR vendor, undertakes the equivalent of the US Design Certification (DC) of SMR designs.
2. This Certification is supported by the existing nuclear regulators in the AU, such as the South African National Nuclear Regulator.
3. It is accepted that the SMR design(s) that obtain a DC are completely standardised.
4. The SMR vendor accepts liability for nuclear damage caused by errors in the design of the SMR.
5. The national regulator in the country of construction accepts the DC as being appropriate and undertakes the QA/QC ensuring that the design is constructed and installed as per the reference design.
6. The operator(s) of the specific SMRs installed across the continent under this scheme have a joint liability for nuclear damage on all the related SMRs. There may, in fact, be a trans-national operating company.

Way forward for Africa

SMRs offer an ideal solution to Africa's chronic electricity shortage in a low carbon world, however there are challenges. The current infrastructural and legal construct offers challenges to the "roll out" of SMRs across African countries. For these to be resolved there needs to be a different approach to SMRs in Africa compared to the developed countries.
For SMRs to effectively assist Africa to meet its needs for industrialisation within a Net Zero Carbon world there needs to be an agreement across the continent to allow supra-national nuclear licensing and liability, in place of the current international practice.

Prof David Nicholls is a nuclear engineer who retired as the Head of Nuclear at Eskom.
He started his career as a nuclear engineering officer in nuclear submarines in the Royal Navy. After emigrating to South Africa he joined Eskom as a nuclear engineer.
He is currently Chairman of the South African Nuclear Energy Corporation. (Necsa)

STRATEK GLOBAL'S HTMR-100 IS A PARADIGM SHIFT IN SUSTAINABLE ENERGY

OLIVIA VAUGHAN

In an era marked by rapid technological advancements and shifting societal norms, the built environment is undergoing a generational transformation. Stratek Global, a pioneering company in the energy sector, has taken a bold step toward sustainability with its innovative Small Modular nuclear Reactor (SMR), the HTMR-100. This groundbreaking development combines aesthetics, eco-friendly architecture, and regional adaptability to create a new paradigm for clean energy infrastructure.

Aesthetic Fusion with Eco-Friendly Design

I spoke to Johann Koch of JKDA Architects, the architectural firm responsible for designing the external structures of Stratek Global's HTMR-100. The designs challenge the conventional perception of energy infrastructure. Gone are the days of drab, utilitarian power stations. Instead, the HTMR-100 integrates seamlessly into its surroundings, drawing inspiration from the natural environment. Here's how:

Harmonious Design: Each HTMR-100 reactor is bespoke, tailored to the specific region where it will be deployed. Stratek's architects collaborate with local communities, incorporating elements that resonate with the landscape. Whether nestled in an African Savannah or perched on a desert escarpment, the reactor becomes a part of the scenery.

Columns and Trusses: Stratek's commitment to eco-friendliness extends beyond functionality. The HTMR-100 features areas filled with native plants, and columns constructed of raw materials, reducing heat absorption and promoting biodiversity. Trusses blend with the environment, using sustainable materials that age gracefully over time.

Natural Scenery Integration: The play of light and shadow creates an inviting atmosphere, dispelling the notion that nuclear facilities must be dark and foreboding. The designs are predicated on the notion that power stations are the lifeblood of a community and as such, should add to the value of the area and the community which they serve.

Johann Koch of JKDA delves into the inspiration behind the Kudu and Oryx designs

The Kudu Design

"The Kudu design aims to blend into natural African Savannah conditions, inspired by the vertical lines found in natural camouflage, such as the stripes on a Kudu, Zebra, or Nyala. The exposed columns and trusses provide depth and add vertical layers to the structure, blending into the surrounding environment seamlessly. The reactor building is inspired by the African drum, a significant part of African culture, symbolic of energy as the heartbeat of the local community."

Other notable features that JKDA have incorporated, are locally available construction materials that are easily accessible in remote areas, materials that age gracefully in local conditions with minimal maintenance and using these materials in a way that incorporate local participants in construction. The Kudu design is an indigenous testament to understanding nature and working with the elements, rather than against them.

Kudu Design is one that takes on the characteristics of the South African Kudu, known for its grace and beauty. While moving at speed, it exhibits great power and elegance. Much the same in spirit, this nuclear reactor presentation invokes the grace and power which lies beneath its elegant structures, especially designed for Savannah conditions.

STRATEK GLOBAL KUDU DESIGN NUCLEAR POWER STATION

CONTINUE ON PG 9

STRATEK GLOBAL'S HTMR-100 IS A PARADIGM SHIFT IN SUSTAINABLE ENERGY

CONT.... FROM PG 8

OLIVIA VAUGHAN

The Oryx Design

"The Oryx design is designed for arid desert regions. This one was a lot of fun, as we could use the movement of the dunes and rock formations to mimic the organic movement of the desert snake, creating a dune like undulating flow. The use of local rocks, raw tinted concrete and Corten Steel create depth and texture within the earthy tones. Angular longer buildings add to the organic layers, depicting dune and rock formations of the region. Corten Steel is designed to naturally weather externally, eliminating the need for painting, while retaining its structural integrity. From an arial view, the Oryx moves from every angle, blending perfectly into the arid region organically."

Other notable features of the Oryx design are the use of materials that do not need maintenance, but rather just weather naturally, Factors in the design are the consideration of the lack of water for cleaning purposes, and the use of natural fauna and rocks within the complex. The Oryx is designed to create the shadows and light of the moving dunes of the desert, while providing sustainable, clean and consistent energy.

The Oryx is a powerful antelope which exists in desert regions of Southern Africa. It is seen as a beautiful and dramatic image far out in desert sands, or in sparse dry scrubland. It always looks majestic, standing amongst massive sand dunes.

More on the Horizon

Future designs include the Sable, designed for Arctic and icy conditions found in the far Northern Hemisphere, There are a few more surprises, as more and more enquiries stream in from regions looking to deploy SMRs.
For urban settings, Johann and team are working on various versions of the design. He confirms that with the advent of small nuclear power the days of drab, utilitarian power stations are gone, "Designs should be inviting and invoke a sense of pride within the community, while adding not just a source of energy, but also aesthetic value to the area."

Environmental Impact: Clean Energy and Reduced Footprint

The HTMR-100's extremely small environmental impact is significant:
Clean Energy: The HTMR-100 produces electricity without greenhouse gas emissions, or any other emissions. It operates efficiently, generating clean consistent power while minimising its carbon footprint.
Compact Footprint: Unlike sprawling conventional power stations and large land areas used by renewable sources, the SMR's compact design reduces land usage. Stratek's commitment to preserving open spaces aligns with global efforts to combat urban sprawl.

Waste Management

The HTMR-100's advanced fuel cycle minimises nuclear waste. The reactor complex has been designed to be able to store 40 years' worth of spent fuel in bunkers on site. At any time the spent fuel balls can be transported to a permanent. nuclear waste repository, depending on the government policy of the country concerned.
Ecological inclusion: Architect Johann Koch of JKDA and Stratek Global have confirmed their commitment to designing structures around local ecosystem elementals, ensuring that the community and the ecosystem are part of the design process.

A Beautiful World and the SMR Revolution

The HTMR-100 stands at the intersection of tradition and innovation. It bridges the gap between our energy needs and environmental stewardship. Stratek Global's vision is clear: SMRs will change the way society operates, ushering in an era of sustainable, beautiful, and community-centric energy solutions.
Stratek Global's HTMR-100 is a testament to human ingenuity, proving that progress need not sacrifice aesthetics or ecological responsibility.

NUCLEAR FUEL || NATURE AND ABUNDANCE

FRANCOIS MELLET

Uranium in nature, is a slightly radioactive metal that occurs throughout the Earth's crust. It occurs in most rocks in concentrations of 2 to 4 parts per million. It is about 500 times more abundant than gold and is as common in the Earth's crust as tin, tungsten and molybdenum. It is also naturally present in sea water. It is found in some coal deposits at greater than 100 ppm (0.01%).

Uranium was discovered in 1789 by Martin Klaproth, a German chemist, and was named after the planet Uranus. Being relatively soluble it is also found in the oceans, at an average concentration of 3 parts per billion. In some places in South Africa and Namibia the concentration of uranium in the ground is sufficiently high for the mining of uranium to be economically feasible. In South Africa, much of the productive ground for uranium is associated with the gold mines, since uranium is a by-product associated with gold mining. But in Namibia there are dedicated uranium mines which are not gold mines.

In the past, from ancient Roman times, uranium was also used to color glass. Another more recent Uranium use, up to the 1950s, was in luminous paint, particularly on the dials of watches and aircraft instruments. Today the only substantial use for uranium is as fuel in nuclear reactors, mostly for electricity generation.

Uranium in nature produces so little radioactivity that it can be handled with bare hands. However, before it can be used in a reactor for electricity generation it must undergo a series of processes to produce a useable nuclear fuel.

Nuclear Fuel

Like other natural elements, uranium occurs in slightly differing forms known as isotopes. These isotopes differ from each other in the number of neutrons in the nucleus. Natural uranium, as found in the Earth's crust, is a mixture of two isotopes: Uranium-238, accounting for 99.3%; and U-235 which is 0.7%. The U-235 is the valuable one. For most of the world's reactors, the uranium has to be enriched. Enrichment means increasing the proportion of the U-235 isotope from its natural level of 0.7% to 3-5%, or maybe up to 20% in the case of some modern reactors. The uranium is then fabricated into Fuel Elements. A conventional Pressurised Water Reactor (PWR) like Koeberg in South Africa uses long metal fuel assemblies

ILLUSTRATION OF A KOEBERG-TYPE FUEL ELEMENT OF 17X17 ZIRCALLOY TUBES 3,4M LONG.

PHOTO OF FUEL PELLETS LOADED INTO THE TUBES.

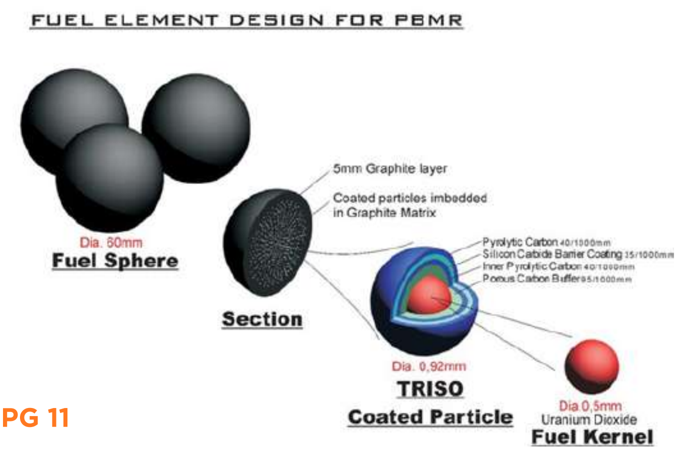
A PEBBLE-TYPE REACTOR

In contrast, the Pebble Bed Modular Reactor (PBMR) type power plant, developed in South Africa, is fuelled using fuel spheres about the size of a tennis ball. Each sphere contains small grains of low enriched uranium in a graphite ball. This type of fuel is known as TRi-structural-ISOtropic fuel, called TRISO. Each micro fuel particle is coated with four layers of three materials. These provide micro-containment, and strength and flexibility.

TRISO fuel particles are the size of sugar grains. It is comprised of various layers. An outer shell of carbon coats a layer of silicon carbide, which coats another layer of carbon, which then coats the uranium centre — where the energy-releasing nuclear fission happens.

TRISO PARTICLE – NEARLY 1 MM DIAMETER

The fuel sphere is the size of a tennis ball containing 15000 fuel particles. Each fuel pebble contains 9 g of uranium, and this holds so much energy that half a dozen balls will sustain a family of four for a decade.



CONTINUE ON PG 11

NUCLEAR FUEL || NATURE AND ABUNDANCE

FRANCOIS MELLET CONT.... FROM PG 10

SOUTH AFRICAN FABRICATION

During the early years of Koeberg Power Station, fuel elements were being imported from the USA and France. In order to secure a sustainable operation of South Africa's only nuclear power station a strategic decision was made to fabricate South Africa's own fuel assemblies.

Production of low enriched uranium commenced in August 1988 at Valindaba, part of Pelindaba near Pretoria. There was also a Zircaloy Tubing Facility in Pelindaba plus all the fuel fabrication systems.
The first complete fuel loading batch with locally fabricated fuel took place in 1991 on Koeberg Unit 2 when a third of the 157 fuel assemblies were replaced during a standard re-fuelling outage. This was an extremely proud moment for South African Nuclear Engineering.

FIRST SOUTH AFRICAN FABRICATED FUEL ELEMENT FOR KOEBERG NUCLEAR POWER STATION

Scientists and engineers in South Africa have now developed and fabricated the very complex TRISO fuel. In fact, some TRISO fuel developments have been carried out, and fuel produced, for American companies. South Africa has a small fuel fabrication plant in existence now, but this can be scaled up to export TRISO fuel to other countries

A TRISO 'PEBBLE' FUEL BALL FABRICATED IN PRETORIA, SOUTH AFRICA

NUCLEAR WASTE

Nuclear waste is produced at a power station or research reactor during normal operations.
Low Level Waste (LLW) is produced from ongoing operational and maintenance activities as well as the de-commissioning of certain equipment during or at the end of power station life.
Intermediate Level Waste (ILW) is based on radiation concentrations of liquids or such things as filter materials. They are normally placed in high-density concrete containers and placed underground in near surface disposal facilities.

For the power station reactor, once the inner fuel in the center of the reactor core is exhausted (due to higher neutron dose in the core center), the reactor commences power coast-down towards a re-fueling outage. The Spent Fuel Elements are removed and replaced with new fuel elements. The Spent Fuel should not really be regarded as nuclear waste at this stage, because there is still a significant amount of unused uranium in the spent fuel. In addition there are other very valuable elements in the spent fuel. These spent fuel elements could be reprocessed in the future to separate the valuable elements for reuse.

In the future, when all elements of value have been removed, the remaining material may now be truly considered as "nuclear waste". The volume will be much less.
Spent fuel can be safely handled and transported in a controlled manner.

NATIONAL NUCLEAR WASTE REPOSITORY

South Africa has its National Nuclear Waste Repository at Vaalputs, which is a desert site in the Northern Cape. This is a 10 000 hectare site, that is 20 000 football fields. Vaalputs is currently used for Low and Intermediate Level Nuclear Waste storage. However, it can be used for high level waste in the future. This is a government decision. This facility is ideally located, being 100 km inland from the remote town of Springbok, in a very dry region with an annual rainfall of about 75 mm. The number of people living in the area is less than 1 person per km^2.This is a very economical site, having been operated since 1986 by a South African Team from the local region.

For comparison, France has their Low and Intermediate Level Waste facilities located within 5 km of populated towns in a very wet region by European standards, where extensive concrete and clay engineered solutions are required. For High Level, Long Life Waste, high cost experimentation has been ongoing in France for the last 16 years to find a solution in sedimentary clay rock. This Underground Research Laboratory (URL) is at a depth of 500 m and is located within 2.5 km of surrounding villages.

The final solution design is now planned to also be at a depth of about 500 m with tunnels covering an area of 15 km^2, at a budgeted cost of 25 billion Euros over the next 150 years.

By comparison, we in South Africa, can develop more modest solutions, mainly due to our remote areas, low rainfall and very dry ground. We have the expertise to develop the necessary transport and storage solutions that are "fit for purpose".

A 1000 MWe nuclear power plant will produce 20 tons of spent fuel per annum, compared to a typical similar coal-fired unit in South Africa, which would produce 1,4 million tons of ash.
The nuclear is 70 000 times less by volume.

***Francois Mellet is an Electrical Engineer who spent 19 years at Eskom gaining experience in coal and nuclear power stations. At Koeberg Nuclear Power Station he occupied the positions of Electrical Commissioning Engineer, Project Engineer and Unit Outage Manager. He spent a year in the European nuclear industries of EdF in France, EnBW Kernkraft GmbH in Germany and with Suppliers ABB, Alsthom, Merlin Gerin, Tudor and Framatome.
He is currently the Director: Operations at Stratek Global (Pty) Ltd, and South African CEO of Arint Engineering Services based in Pretoria.***

THE IMPACT OF RENEWABLE ENERGY PENETRATION ON GRID STABILITY

KNOX MSEBENZI

There is an increasing trend to introduce renewable energy sources (RES) into existing grids. This is because of a worldwide movement to go for such sources and move away from the traditional sources that are depending on fossil fuels. The existing grids were however built before they were introduced. RES lack the mechanical inertia around which the grids were designed, and hence introduce some challenges relating to their stability.

RES such as solar and wind have a distinctive challenge to maintain voltage and frequency stability. This is due to their inherent intermittency which make it difficult for grid operators to balance electrical demand with generation. They are not dispatchable. Electricity, as a utility, is traditionally generated as it is being consumed. The job of the system operator is to constantly match the generation with a dynamic load at a defined tolerance of voltage and frequency. The generation sources themselves are subject to tripping, posing a challenge to the operator to maintain voltage and frequency by implementing a variety of measures such as load shedding. The behavior of an electrical power system following a disturbance such as a short circuit or generating unit trip is what is analyzed in power system stability to avoid voltage dips, surges or blackouts.

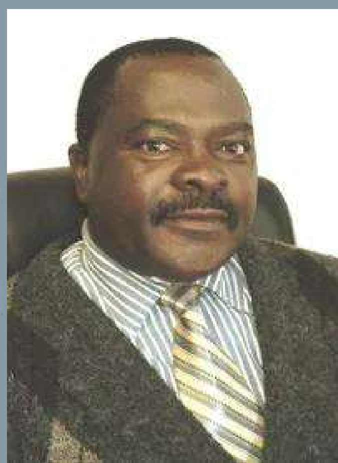
The conventional power generation systems are characterized by having many synchronous generators connected to the grid. These are typically very large electrical machines with huge rotors, running at 3000 revolutions per minute (RPM) or 50 revolutions per second, giving rise to corresponding generated voltage at 50 hertz (Hz). The electrical machine rotors are directly coupled to steam or hydro turbine rotors. In the event of a sudden reduction of load, the rotors will tend to accelerate above 50 Hz. In the opposite event of a sudden loss of a generating unit (unit trip), the remaining rotors will tend to slow down as the load is instantaneously greater than the generation. This results in the lowering of the frequency. Fortunately, the massive rotors in the electrical system will resist sudden changes in rotational speed because they have inertia – obeying Newton's first law of motion. This is what gives a system of protective relays and circuit breakers time to operate to prevent the loss of the entire power system. System operators now have the time to take remedial action to stabilize the system.

As the load dynamically changes, so does the voltage in obeying Ohm's Law. Synchronous machines are equipped with automatic voltage regulators. The rotor of a machine has a winding which is fed with a direct current to produce a magnetic field which, when rotated in the windings of the stator, induces a voltage. By controlling this current, also known as excitation current, the voltage output of the machine is controlled and this can be done automatically in a control loop.

With the introduction of RES on the grid, this capacity and flexibility is compromised as the voltage and frequency is from electronic inverters which are static devices without inertia. This is true for battery energy storage systems (BESS) as well, which are closely associated with RES. It is clear that the higher the penetration of RES, the less the system inertia in a power system. The impact of these RES has resulted in some grids, where their penetration is high, struggling to control the system frequency within tight tolerances. It is reported that some precision manufacturing industries which depend on tightly controlled frequencies in parts of Australia and California, where RES penetration is very high, have had to relocate to areas where the grid is more stable.

As there is a worldwide trend to move away from fossil fuels, in response to climate change, it is clear that it would be unwise to even dream of replacing these conventional sources with RES. A certain proportion of sources that are inertia bearing are essential for any system to remain stable. Converting current coal stations to nuclear makes perfect sense.

Knox Msebenzi, MSc, Pr Eng, is the past MD of the Nuclear Industry Association of South Africa (NIASA).He is an electrical engineer who has spent many years in the nuclear industry. He is a public commentator having written newspaper articles and having appeared on radio and TV.



NUCLEAR, WIND AND SOLAR

ANDREW KENNY

What's a nuclear engineer's favourite meal?
FISSION CHIPS

The greatest gift that nature has given us in the last 80 years is the means to employ nuclear energy. Right now nuclear is able to provide the whole world with electricity for the remaining life of our planet. Nuclear is by far the safest source of energy we know, with the least waste problem, and there is more than enough nuclear fuel in the ground and the sea to feed nuclear power reactors for millions of years. Properly managed, nuclear has proven to be economical, and in many instances, the cheapest source of electricity.

Nuclear power stations, which did not exist 80 years ago, now provide 9% of the world's electricity (75% in France). This is good but it should be much better. The problems facing nuclear power are not of technology but of politics, regulation and public perceptions.

The nuclear force is the strongest force in nature. This means it can provide concentrated energy, and a very small amount of material can provide a large amount of energy, very safely and very reliably. Wind and solar, by contrast, use weak, dilute and intermittent energy sources. They require huge amounts of materials and gigantic machines to produce the same amount of electricity as a small nuclear reactor. Wind turbines need ten times as much concrete and steel as nuclear per kWh. To get the same amount of electricity as Koeberg, in two containment buildings 57 metres high, you would require over a thousand gigantic wind turbines 120 metres high. Much worse, since they are intermittent, they can never provide electricity all the time that it is needed. Nuclear can.

This is the reason nuclear power is so good for grid electricity, and solar and wind (often called "renewables") are so bad. Solar and wind are good for off-grid applications: solar water heating, wind pumps on Karoo farms, small amounts of electricity for households, small business and remote clinics. But they are hopeless for grid electricity and have been a disastrous and expensive failure in every country that has tried them including Germany, Denmark, the UK, the USA, Australia and South Africa. Large amounts of solar and wind on the grid always send prices soaring and see electrical faults increasing. The German economy has been crippled because they shut down their nuclear reactors (for idiotic reasons) and spent billions of Euros on tens of thousands of gargantuan wind turbines. Electricity prices have rocketed, householders are reduced to energy poverty, and industries are shutting down. Germany is committing economic suicide because of a mad green dream.

Unlike solar and wind, nuclear has proved that it can be cheap and reliable. From the 1970s on, France embarked on a determined nuclear power program. It was a spectacular success, giving French industry and the French people a plentiful supply of clean, safe electricity, at among the lowest prices in Europe. Koeberg was built by the French 40 years ago, and has been South Africa's best power station. Then French nuclear lost its way: it bowed to the greens and restricted nuclear expansion, it stopped building, it became complacent. When it finally woke up and began building again, it had lost experience and skills and made a mess of its new reactors (a financial mess, not a safety mess). But it seems to be recovering and France did show how successful nuclear could be – and should be.

Only two of the three major nuclear power accidents have harmed anybody directly. The accident at Three Mile Island in the USA in 1979 harmed nobody. The radiation release from the Fukushima Daiichi accident in 2011 harmed nobody but people did die in the unnecessary evacuation. Chernobyl in the USSR in 1986 did not kill over 60 people. The fundamental cause was the terrible RMBK design, which would never have been allowed in the West. However, Pressurised Water Reactors (PWRs), similar to those used in the West, including Koeberg, have been run with complete safety in the USSR and now modern Russia, and have been exported around the world.

By contrast, in the last 80 years, hundreds of thousands of people have been killed in accidents in coal, gas, oil and hydro. Hardly any of these accidents make the news at all.
Wind turbines kill at least ten times as many people as nuclear, per unit of electricity produced.

Most atoms last forever; only radioactive atoms do not last forever. So all the deadly toxins, such as arsenic, used in solar panels last forever. The scare about the long life of nuclear waste is nonsense. In fact, nuclear waste is small, concentrated, chemically stable and easy to store safely. The South African national nuclear waste repository, Vaalputs in the Northern Cape, could easily store all South Africa's nuclear waste for centuries to come.

In operation, nuclear power releases no CO2. It embarrasses me to hear nuclear advocates using this as a reason to promote nuclear power. Actually, rising CO2 will do nothing but good. It will have little if any effect on the climate but a wonderful effect in making plants grow better. We should adopt nuclear power because it is clean, safe, affordable, plentiful and sustainable – and just say, 'yes, and it does reduce CO2'.

What is hindering nuclear power today are public perceptions, made worse by nuclear power's appalling cowardice and pitiful public relations, and excessive, ridiculous regulation. A new generation of nuclear power technologies, including Small Modular Reactors (SMRs), are technically ready for building but are held back by kilometers of red tape and years of regulation.

If we could overcome these, nuclear power would give everyone, especially the poor, a bountiful supply of the energy of prosperity.

Andrew Kenny is a nuclear engineer who has published many public interest articles around the world. He has worked with large power stations and other industrial operations.

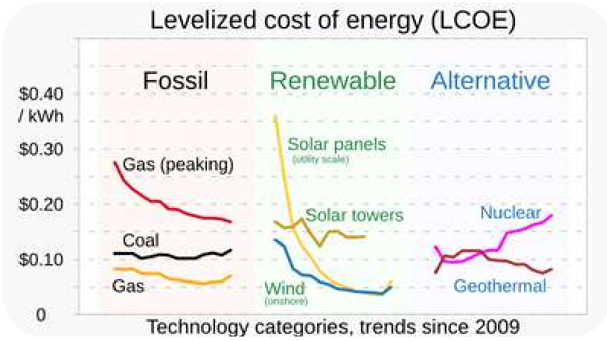
DID YOU KNOW??

Nuclear Energy is the World's Second Largest Source of Low-Carbon Electricity

Nuclear accounts for 10.4% of the world's electricity and it is preceded only by hydropower, which tops the low-carbon sources contributing 15.8% of the global share.

Why is wind power popular?

BECAUSE IT HAS A LOT OF FANS!

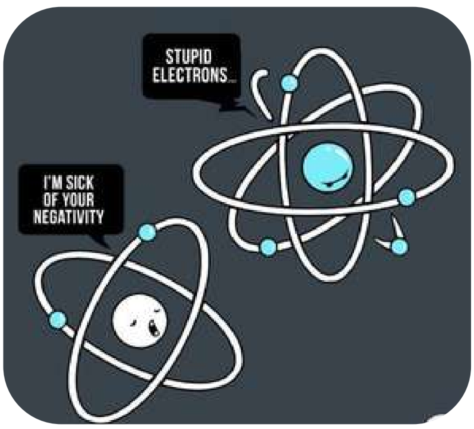


There are 439 Operational Nuclear Plants Around the World

Today, 32 countries have operational nuclear plants, 96 of which are located in the US, followed by France with 58, China with 50, and Russia with 38. There are plans to build 55 new reactors worldwide in the coming years.

Nuclear power plants keep energy costs down.

While building nuclear plants is costly, they are relatively cheap to operate, which helps keep energy costs down. One of the more interesting facts about nuclear energy is that it's immune from the economic fluctuations that typically affect coal and gas prices.



NUCLEAR NETWORK AFRICA

THE WORLD OF NUCLEAR

Any person who has influence and a role to play in representing any Nuclear-Related Developments to advance nuclear power in Africa. or in any international entity, which can contribute to the development of Africa's nuclear energy capability is encouraged to be part of this great journey.

Any company, ranging in capability from a nut and bolt to the most sophisticated piece of equipment, should join the journey now.

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