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What's really going on with SA's energy supply?

Understanding loadshedding and power cuts

@NSTF_SA @proSET_SA

The electricity crisis is affecting everyone in South Africa. It has an impact on the economy, employment, people's daily lives, and more. When you find out that loadshedding is actually a *solution* to a potentially devastating national blackout, it's clear that there is much more to understand.

The National Science and Technology Forum (NSTF) hosted an NSTF Discussion Forum on 'Loadshedding and power cuts – what is really going on?'. It was driven by pro*SET*, a sector of the NSTF representing over 40 professional societies. It ran online from 25-26 October 2021.

South Africa's power system

There are multiple layers to understanding loadshedding. It begins with South Africa's power system value chain: generation, transmission and distribution (transporting electricity to the consumer), and customer services.

A centralised control is needed to keep the power system stable. This was explained in a presentation, 'Why loadshedding is necessary', by **Mr Gav Hurford,** National Control Manager: System Operator, Transmission, Eskom.

The NSTF provides neutral collaborative platforms where issues and sectors meet

- One of the National Science and Technology Forum (NSTF) functions is to hold discussion forums, bringing the private and public sector together to address important issues and engage with government policy.
- Feedback from these discussion forums is given to role players and stakeholders.
- Recommendations are put forward to government as part of the SET community's (science, engineering and technology) efforts to make input into SET-related policies and implementation.

In general, bulk electricity cannot be stored. It must be generated at *exactly* the same time it is consumed. The System Operator manages the supply/demand balance at every second.

There is very hierarchical control of the high voltage power system, with instructions moving top down from national control (765-132 kV) to regional control (132-66 kV) and finally local control (66-11 kV), such as municipalities. Hurford says: “There is no ‘big red button’ in the National Control Centre (NCC) that we hit to start loadshedding. It’s a lot more systematic than that.”

National Control Centre and the supply/demand balance of 50Hz
The System Operator is part of the NCC and the NCC is responsible for the overall wellbeing and real-time operation of the entire power system. In general, this means:

- **Dispatching available generators to meet demand or reducing demand to match the available generation (eg loadshedding).** If there’s too much demand and not enough power generation, the whole system starts to slow down ie the frequency starts to drop. This puts the network in jeopardy. Typically the network should run at 50Hz or close to it. Hurford says that this supply/demand balance of 50Hz relates to the generators’ mechanical capabilities. South Africa’s large coal-fired generators must remain running at or close to 50Hz.
- **Managing maintenance outages of the vast transmission network.** The South African network is interconnected from Cape Town up to the Democratic Republic of Congo, and from Namibia across to Maputo. These all run at the same frequency of 50Hz. The bigger the grid, the more stable it tends to be. However, it also means the countries are “locked in and share the same fate”, says Hurford. South Africa’s Eskom operates the largest system. According to the 2019/2020 Southern African Power Pool (SAPP) statistics (sapp.co.zw), the maximum demand was 38 897 MW. Next highest was Zambia with 2 237 MW. It’s clear that South Africa won’t receive a lot of help from its neighbours.
- **Controlling the power system to maintain stability.**
- **Overseeing the safety of people and plants.**

South Africa’s NCC operates parts of the network in Swaziland and parts of the network in Mozambique. Hurford says there are plans to make the NCC a separate entity outside of Eskom.

Eskom’s generation responsibilities
The following shows Eskom’s generation responsibilities as of August 2021. It also shows the extent of the current power mix in South Africa.

Generation responsibilities (August 2021)

Type	Number	Nominal capacity
Coal-fired	15 stations	39 498 MW
Gas/liquid fuel turbine	4 stations	2 409 MW
Hydroelectric	6 stations	661 MW
Pumped storage	3 stations	2 724 MW
Nuclear	1 station	1 854 MW
Wind energy	1 station	100 MW
Dispatchable IPP	2 stations	1 005 MW
Wind IPP	29 stations	2 821 MW
Solar PV IPP	44 stations	2 212 MW
CSP IPP	6 stations	500 MW
Small Hydro IPP	3 stations	18 MW
Landfill IPP	3 stations	8 MW
Biomass IPP	0 stations	0 MW
Total Eskom	30 stations	47 246 MW
Renewable (IPP & Eskom)	86 stations	5 659 MW

- The brown rows show what is owned by Eskom.
- The green shows the two Independent Power Producers (IPP) and these are open cycle gas turbines (OCGT) which burn diesel.
- The grey shows renewables that have been added to the power grid since 2015 (about 5600 MW). The bulk of these are wind generation, solar PV (photo voltaic, like solar panels) and CSP (concentrated solar power).

Source: 'Why loadshedding is necessary'

Hurford says that South Africa already has significant amounts of renewable energy (RE) on the grid. Typically, during the week there is a contribution of 12% and there have been contributions of over 20%.

Grid Code and maintaining the 50Hz supply/demand balance
The South African power industry is governed by the Grid Code, a National Energy Regulator of South Africa (NERSA) suite of documents. It lays out what licensees (participants in the power system) can and can't do, what is expected of them technically, and what to do to maintain the stability of the power system. It includes what to do in a power crisis.

The frequency of the power system needs to stay within 49Hz and 50.1Hz. In that range, generators should operate continuously. Grid Code Level 1 restrictions occur when the frequency drops by 0.5Hz (49Hz-48.5Hz). A large generator only tolerates this for about 80 minutes *over its lifetime* of 30 years.

Automatic tripping starts at Level 2 (48.5Hz-48Hz). Here the lifetime tolerance is about 10 minutes, operating for one minute in this range. Each consequent level shows a 0.5Hz drop with automatic tripping after a very short time.

Below 47.5 Hz it becomes chaotic, says Hurford. Generators will then automatically trip off to protect themselves and there will be a cascading situation. As more generators trip off, there is less capacity available to supply the demand and the frequency drops even further. This results in the tripping of every generator connected to the power system and a national blackout. (Note that there are other causes for large and national blackouts beyond lack of generation capacity, including faults on the transmission system.)

To maintain the supply/demand balance, Eskom uses a range of options.

- **During normal system operations:** The base load power and self-dispatched generation comes from nuclear, coal, IPPs, and Eskom's RE.
- **As demand increases within normal system operations:** Eskom uses more RE. There are also various products. Examples include specific customers switching off their plant or part of a plant, as well as contractual agreements where Eskom can interrupt demand. The benefit of these products is rapid response. (It's quite a slow process to ramp up a large coal fire station – about 8 MW per minute – for example.)
- **At highest peak during normal system operations:** There is a country response with calls to reduce load ie the 'power alert'. Hurford says that the public does respond and the impact can be significant. "We can get about 275 MW response if we haven't shed for a while," he says.
- **System Emergency:** This is declared in terms of the National Code of Practice (NRS048-9). It's a document adopted by industry and approved by NERSA. It sets out a systematic way of loadshedding, from the System Operator declaring a system emergency to loadshedding stages and further. The third edition is currently being developed. The guiding principle of NRS048-9 is that all participants be treated equitably. This does involve ensuring essential services meet criteria, like hospitals having back-up generators. NRS048-9 allows for very specific circumstances – if something critical is happening – where power is not interrupted.
- **After System Emergency:** There is large customer and international load curtailment, scheduled loadshedding (stages 1-8), and unscheduled

loadshedding. Load curtailment means load reduction from customers who can reduce demand on instruction. Loadshedding is load reduction from disconnecting the load at selected points on the transmission and distribution network.

- **Beyond stage 8 loadshedding:** Hurford says there are contingency plans if South Africa needs to go beyond stage 8, such as large blocks (towns and cities) dropped off the network plus more. The aim is to prevent a total power system collapse.

Impact of national blackouts

Planned and unplanned loadshedding is part of the solution to avoid a national blackout. So far, South Africa has not had a full national blackout. However, there have been a number around the world. Hurford says the one in March 2019 in Venezuela drew many parallels with South Africa. They have a similar system and the cause was poor maintenance. Venezuela was down for around five months.

The impact in Venezuela included: looting, running out of water, the inability to process sewerage, people dying at hospital (no electricity for essential equipment), business interruption, the inability to keep food fresh, and much more. There was an impact on almost every single part of daily life.

There are other considerations with a national blackout. Hurford says the telecommunications backbone would fail in about eight hours. Another example is the impact on available liquid fuel. While it's used to power so much, it also needs powered storage. Just moving around the country would become severely limited.

South Africa's system design includes contingency plans and capabilities to deal with a blackout. There are Black Start capabilities to restart the power grid.

Understanding our emergency reserves

Emergency reserves provide a limited amount of energy and are only available for a short duration. There is also an ongoing need to replenish emergency reserves. The cycles become clearer when looking at pumped storage and open cycle gas turbines (OCGTs).

Pumped storage schemes involve water stored in an upper reservoir and then released to drive turbines that generate electricity. The water ends up in a lower reservoir. At night, excess energy allows the water to be pumped back up. It's a 168-hour cycle so reserve power is not easily restored. Hurford says that pumped storage is about 75% efficient but offers the only viable means of storing large amounts of energy. South Africa has three pump storage stations.

South Africa has 20 OCGTs and Eskom owns 14. These cost about 10 times more than coal to run, using almost 1900 litres of diesel per minute per generator. The cost is excessive. Beyond that, it's not even possible to move diesel fast enough to these generators.

Between pumped storage, OCGTs, and gas turbines, Eskom is able to dispatch almost 6000 MW, making up the majority of the emergency reserves.

Managing a constrained power system

"We've had to manage the power system very differently from the traditional way," says Hurford. "Obviously we need to do maintenance on generators but we can't shut them all down. We are forced to do maintenance as and when we can."

Managing the systems involves Eskom teams doing scenario planning, looking at installed generation capacity, plant unavailability, the demand forecast, planned outages for

maintenance, and potential unplanned outages. Eskom works with three scenarios at any given time. Even with this planning, the system is volatile and unreliable. It "makes giving the country certainty absolutely impossible", says Hurford.

However, the system is continuously monitored and, where there is enough time, Eskom gives the country as much warning as possible. Note that Eskom is fully mandated to do whatever is required to get the power system stable even if there's no time to give a warning. Hurford says he knows there's anger around loadshedding and consumers have a right to be angry. He also hopes that understanding the situation in more detail will ease the frustration.

System adequacy with a diversified energy mix

South Africa's power system is in crisis with urgent action needed to ensure system adequacy while simultaneously creating a cleaner and more diversified long-term energy mix. So says **Dr Jarrad Wright** when he presented on 'What happened? Loadshedding in South Africa and how to fix it'. He was, until recently, at the Council for Scientific and Industrial Research (CSIR) and is now at the National Renewable Energy Laboratory (NREL) in the USA.

Wright says there is a worrying trend of a continuous increase in loadshedding. There has also been a shift from equal levels of planned maintenance and unplanned outages in 2017 to more unplanned outages at higher levels as the years progress. This means there's limited space to do planned outages and maintenance. He says, "There is still a lot that needs to come into play until we get an adequate power system over the next 2-3 years."

To reduce loadshedding and increase power generation, his recommendations include enabling regulations and institutional capacity for customer response at scale (power self-supply) to all customer segments. Wright says South Africa also needs to accelerate the augmented Department of Mineral Resources and Energy (DMRE) Risk Mitigation Power Procurement Programme. All things need to be done in parallel including implementing the Integrated Resource Plan (IRP) 2019 now. This is so there is sufficient time for lengthy procurement processes, technology specific lead times, and so on.

The case for RE

Prof Frik Van Niekerk noted that we have a growing population and a growing energy need. At the same time, there is an unreliable energy supply and the burden of the climate crisis. The current renewable energy (RE) use is too low and he says our future planning is insufficient. Van Niekerk presented on 'A compelling case for fast tracking variable renewable energy in South Africa and the region'. He is from the Unit for Energy and Technology Systems, Faculty of Engineering, North-West University.

Van Niekerk says that we need a strategy to accelerate the green energy trajectory. He recommends deregulating and deploying RE of which there is an abundance in South Africa and Africa, ensuring a fair energy transition, and recognising the lowered cost of RE and storage technologies.

Dr Melanie Murcott also spoke on the just energy transition in 'Ending South Africa's reliance on energy from coal? An introduction to the policy framework for South Africa's Just Energy Transition'. She is from the Department of Public Law, Faculty of Law, University of Pretoria.

She notes that it's a false binary to pit concern for the environment against employment. The energy landscape in South Africa *must* transition, not just because of loadshedding. In a time of climate change, fossil fuel-driven energy is a justice issue, particularly for vulnerable and disadvantaged communities. (Note that according to World Bank data,

South Africa is the 13th highest greenhouse gas emitter in the world.)

Tommy Garner presented on 'The perspective of independent power producers'. He is Business Development Manager at Earth and Wire, and the Chair of the Independent Power Producers (IPP) Association. Garner notes that Eskom operates an ageing generation fleet, with more than half of the stations over 37 years old. Replacement and refurbishment of major components mean extensive outage time and is costly.

He says the significant increase of unplanned outages over time shows the low reliability. "You don't know when it's going to break down," says Garner. This makes it difficult to plan for maintenance.

Obstacles to RE

Van Niekerk looks at what is holding us back from more RE. He says that IRP2019 still has too much coal in the energy mix and the idea of 'new coal' should be avoided. IRP2019 isn't ambitious enough and there's insufficient attention to storage. Deregulation is needed, as well as a more distributed small-scale generation rather than just a centralised system. He emphasises more urgency around RE, including prioritising it within the highest offices of government.

He doesn't believe the problem to be technological but rather around political considerations. These include Eskom debt liability, labour politics, gate keeping, and procurement issues. Garner agrees with him.

Garner explains that when new technology gets to the point of lower costs, this drives more demand in the RE sector. (RE costs are now up to 45 times cheaper over the last 10 years while coal, nuclear and carbon capture are not reducing in cost.)

With more demand in the sector comes more production investment and more supply – which in turn drives lower costs. This feedback loop continues, with more infrastructure investment and more government support. This then drives better capability and more public acceptance. It also drives less demand of older technology.

Garner says that this was happening in 2010 when government added RE into the energy mix. There was also investment in the IPP office, and the Renewable Energy and Energy Efficiency Partnership (REEEP) programmes were very successful.

However, in 2014, these positive causal feedback loops came to a halt. As part of state capture and the Gupta family intervening in Eskom, government supported the fossil fuel industry, says Garner. Agreements for REEEP weren't signed and the programme started to fall over. There was less infrastructure investment and less government support in RE. Garner says this also led to IRP2019 including coal.

All of this has resulted in a stop-and-start process.

Garner says South Africa needs between 3-5 times our current generation capacity with

Other presentations

- **Prof Roula Inglesi-Lotz,** South African Association for Energy Economics (SAAEE) and Department of Economics, University of Pretoria (UP) presented on 'The impact of electricity shortage on South Africa's economy'. Among other things, she shows the effects of electricity supply on attracting Foreign Direct Investment and the need to stabilise the energy supply.
- **Prof Xiaohua Xia** from the Department of Electrical, Electronic and Computer

variable renewable energy (VRE) and between 35-90 hrs of battery storage. We can then go to a complete VRE system.

Hurford does note that, when planning power grids, we need to keep in mind the 'one in 10 year' event where there is no wind or sun to maintain stability of the network.

Engineering, University of Pretoria (UP) and Director: Centre for New Energy Systems, UP presented on 'Go solar'. He looked at an off-grid PV system that is being piloted at the university, suitable for rural and urban environments.

Note that Eskom has a public data portal (www.eskom.co.za/dataportal/) to find out what's going on with the power system.

Garner recommends updating IRP2019, especially regarding battery storage, prioritising investment in grid infrastructure, and government pushing through the unbundling of Eskom and supporting RE and IPP, among other things. He also sees deregulation as a significant driver.

Speakers or the NSTF Spokesperson, Ms Jansie Niehaus can be contacted through the NSTF office at media@nstf.org.za. Further information can be found on the NSTF website and the NSTF YouTube channel.

About the NSTF

The National Science and Technology Forum (NSTF), established in 1995, is a broadly-representative stakeholder body for all science, engineering and technology (SET) and innovation organisations in South Africa, which seeks to influence policy formulation and delivery.

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