Why load shedding is necessary

Gav Hurford

System Operator

Overview


What is the System Operator?


How big is the problem?

Why is 50Hz important?

What is a national black out?


Why do we run out of emergency reserves?

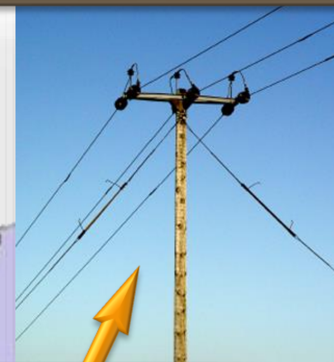

Managing a constrained power system.


Rules and governance.


Final thoughts

What is the System Operator?

Transmission & Distribution transports the electricity



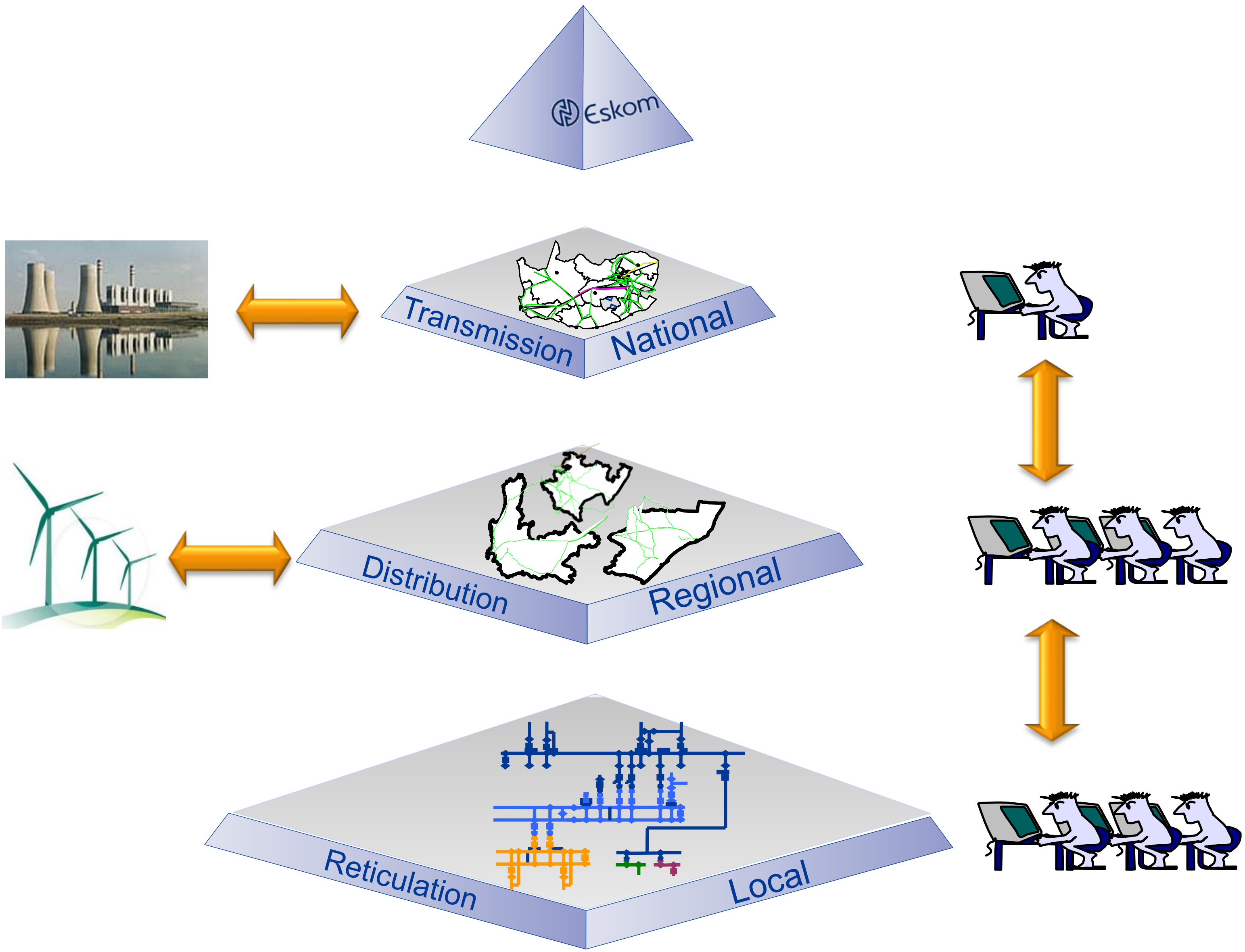
Customer Services sells the electricity

The System Operator is the electricity transport and distribution supervisor.

Generation makes the electricity

Bulk electricity cannot be stored, it must be generated at the same time it is consumed.
System Operator manages the supply/demand balance every second

Hierarchical control of the power system



<u>National Control</u>

- 765 kV – 132 kV
- Frequency control
- Voltage control
- System security

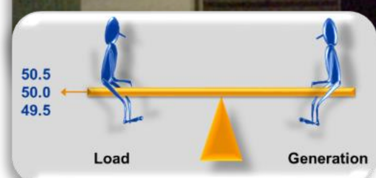
<u>Regional Control</u>

- 132 kV – 66 kV
- Voltage control
- System security

<u>Regional Control</u>

- 66 kV – 11 kV
- Customer supply

National Control is responsible for the real-time operation of the power system



Dispatching available generators to meet the demand or reducing demand to match the available generation.

Managing maintenance outages of the transmission network.

Controlling the power system to maintain stability.

Restoring the power system after incidents.

Overseeing safety of people and plant.

How big is the problem?

Generation responsibilities (August 2021)

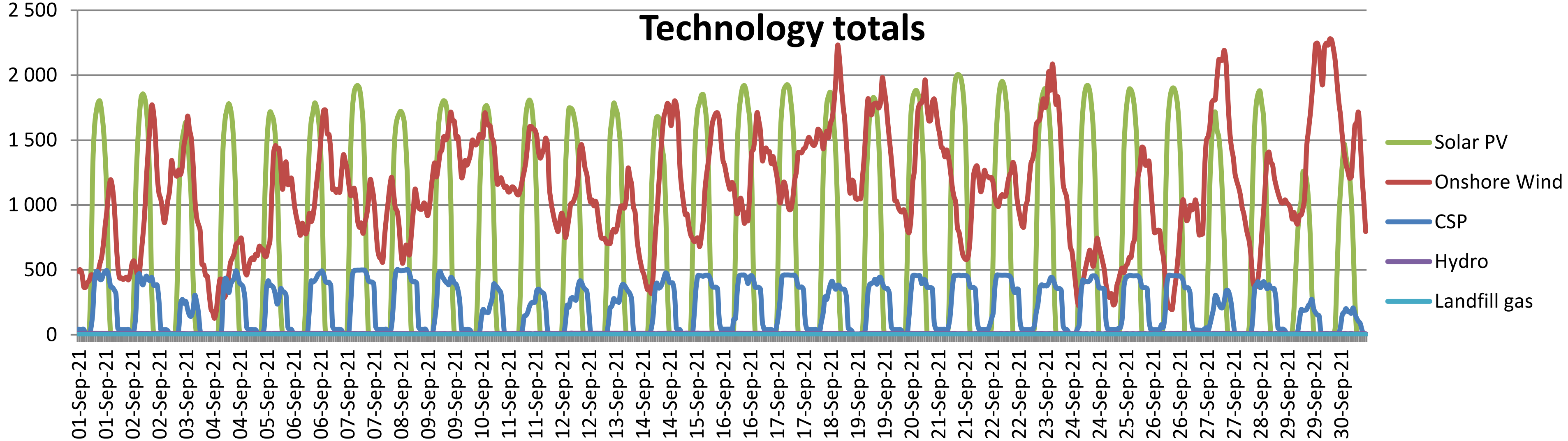
Type	Number	Nominal capacity
Coal-fired	15 stations	39 498 MW
Gas/liquid fuel turbine	4 stations	2 409 MW
Hydroelectric	6 stations	661 MW
Pumped storage	3 stations	2 724 MW
Nuclear	1 station	1 854 MW
Wind energy	1 station	100 MW
Dispatchable IPP	2 stations	1 005 MW
Wind IPP	29 stations	2 821 MW
Solar 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

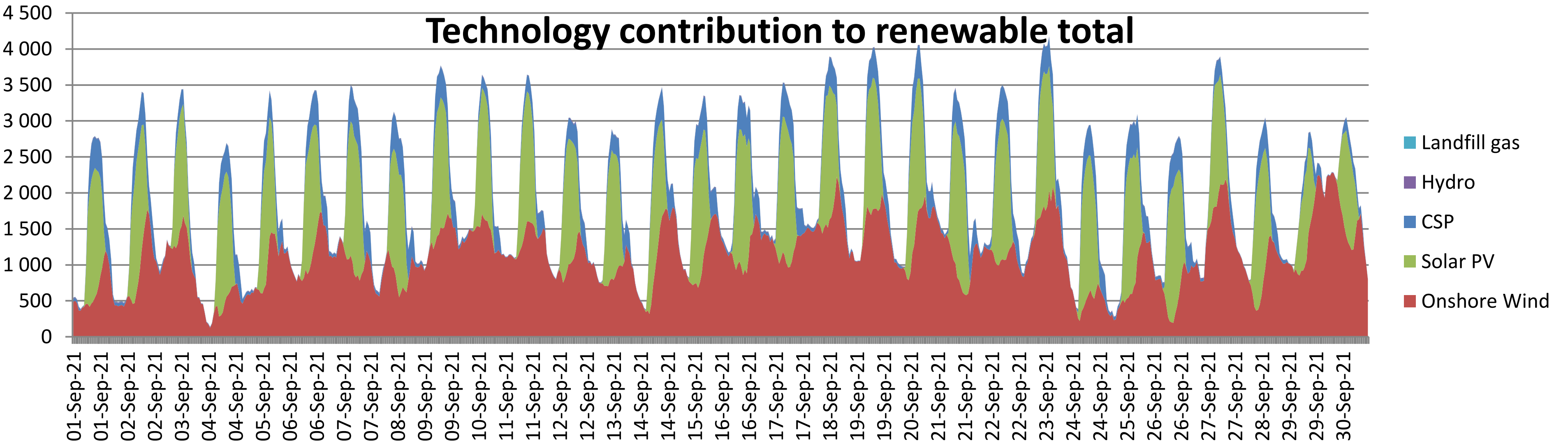

Arnot Power Station


Ankerlig Power Station


Gariep Power Station

Impact of renewable generation





- PV and to a lesser extent CSP continue to support the system during the day
- Some evenings wind has supplied over 2000 MW during peak, while others much less so.

Renewable statistics

Eskom

Current Installed Capacity (MW)	
CSP	500.0
PV	2,212.1
Wind (Eskom+IPP)	2,921.4
Total (Incl other REs)	5,659.0

Maximum Contribution (MW) - based on System Operator data (subject to metering verification)					
Cal Year	Indicator	CSP	PV	Wind (Eskom+IPP)	Total (Incl other REs)
All Time	Maximum	504.5	2,062.8	2,284.0	4,433.0
	Max Date	25-Nov-2020 12:00	10-Oct-2021 12:00	21-Jun-2021 13:00	02-Oct-2021 14:00
2016	Maximum	200.9	1,350.5	1,229.8	2,576.3
	Max Date	11-Aug-2016 14:00	16-Dec-2016 12:00	23-Dec-2016 13:00	23-Dec-2016 13:00
2017	Maximum	302.0	1,432.5	1,708.2	3,142.7
	Max Date	07-Nov-2017 10:00	27-Oct-2017 12:00	25-Dec-2017 18:00	13-Dec-2017 13:00
2018	Maximum	399.7	1,392.1	1,902.3	3,298.9
	Max Date	04-Dec-2018 16:00	03-Oct-2018 12:00	02-Oct-2018 16:00	28-Sep-2018 11:00
2019	Maximum	502.1	1,375.6	1,872.0	3,530.6
	Max Date	24-Sep-2019 11:00	19-Jan-2019 12:00	14-Dec-2019 15:00	27-Oct-2019 13:00
2020	Maximum	504.5	1,929.2	2,113.9	4,050.0
	Max Date	25-Nov-2020 12:00	25-Nov-2020 12:00	01-Dec-2020 19:00	24-Nov-2020 13:00
2021	Maximum	503.9	2,062.8	2,284.0	4,433.0
	Max Date	10-Oct-2021 11:00	10-Oct-2021 12:00	21-Jun-2021 13:00	02-Oct-2021 14:00

Witkop Solar Plant (30 MW), Limpopo

Sere Wind Farm

Maximum Difference between Consecutive Evening Peaks (MW) - based on System Operator data (subject to metering verification)		
Cal Year	Indicator	Total (Incl other REs)
All Time	Maximum	1,744
	Max Date	07-Aug-2021 to 08-Aug-2021
2016	Maximum	828
	Max Date	30-Aug-2016 to 31-Aug-2016
2017	Maximum	1,038
	Max Date	19-Jun-2017 to 20-Jun-2017
2018	Maximum	1,336
	Max Date	01-Sep-2018 to 02-Sep-2018
2019	Maximum	1,464
	Max Date	05-Jul-2019 to 06-Jul-2019
2020	Maximum	1,488
	Max Date	31-Aug-2020 to 01-Sep-2020
2021	Maximum	1,744
	Max Date	07-Aug-2021 to 08-Aug-2021

SAPP Statistics

(sapp.co.zw Statistics 2019/20)

Eskom

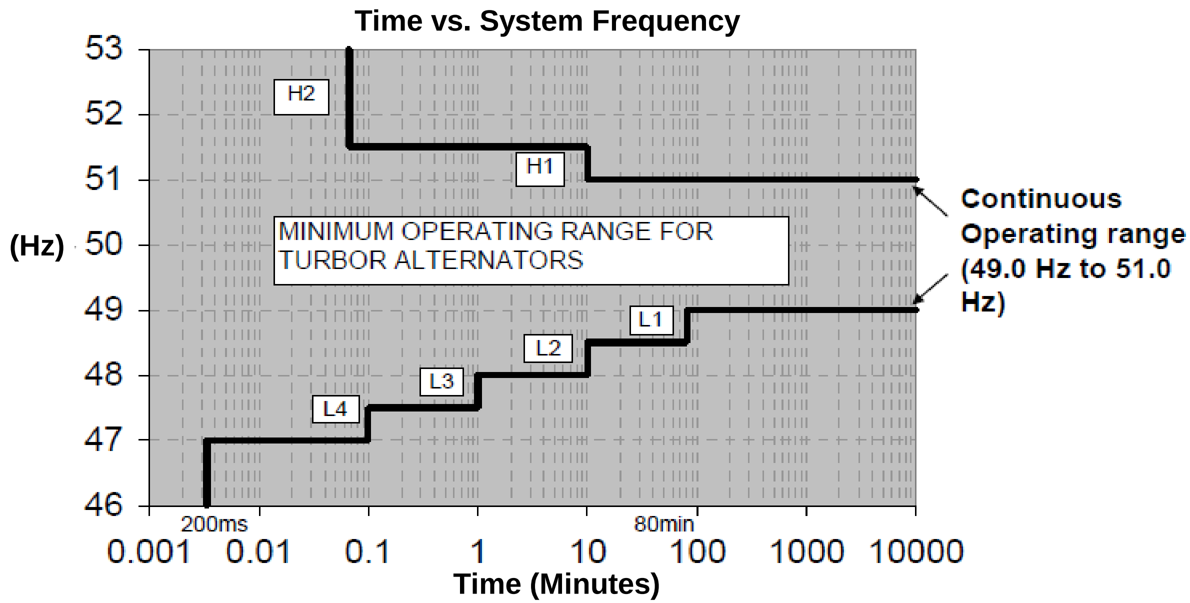
Country	Company	Operating Capacity (MW)	Maximum demand (MW)
Angola	RNT	4 426 MW	2 041 MW
Botswana	BPC	459 MW	610 MW
DRC	SNEL	1 589 MW	1 610 MW
Eswatini	EEC	55 MW	238 MW
Lesotho	LEC	70 MW	150 MW
Malawi	ESCOM	330 MW	317 MW
Mozambique	EDM/HCB/Motraco	2 279 MW	1 850 MW
Namibia	NamPower	390 MW	695 MW
South Africa	Eskom	42 817 MW	38 897 MW
Tanzania	TANESCO	1 758 MW	1 117 MW
Zambia	ZESCO/CEC/LHPC	2 766 MW	2 237 MW
Zimbabwe	ZESA	1 555 MW	1 724 MW
TOTAL SAPP		**58 494 MW**	**51 486 MW**

Why is 50Hz so important?

Generator Unit Requirements [Grid Code]

L1: 49.0 Hz to 48.5 Hz

- System Operator shall ensure the frequency reaches this range for less than **80 minutes** over a **30 year** period.
- Designed to operate in this range for at least **80 minutes** over the **plant life**.
- No automatic tripping.



L2: 48.5 Hz to 48.0 Hz

- Designed to operate in this range for at least **10 minutes** over the **plant life**.
- Operate for at least **1 minute** in this range after which the unit can be islanded or tripped.

L3: 48.0 Hz to 47.5 Hz

- Designed to operate in this range for at least **1 minutes** over the **plant life**.
- Operate for at least **10 seconds** in this range after which the unit can be islanded or tripped.

L4: Below 47.5 Hz

- Operate for at least **6 seconds** in this range after which the unit can be islanded or tripped.

Below 47.0 Hz

- If longer than 200ms, unit protection will operate. For some units the setting is 47.5 Hz

Maintaining the supply/demand balance

Extreme constraint

Normal system

Unscheduled demand reduction
- Unscheduled load shedding
- Large customer & international load curtailment

Scheduled demand reduction (Stages 1-8)
- Scheduled load shedding
- Large customer & international load curtailment

System Emergency declared in terms of the National Code of Practice (NRS048-9)

Voluntary demand reduction

Contracted demand reduction

Peaking & mid-merit power stations

- Country response to calls to reduce load
- Emergency demand secured by agreement
- Interruptible loads (Aluminium smelters)
- Demand market participation programme
- Open cycle gas turbines
- Water

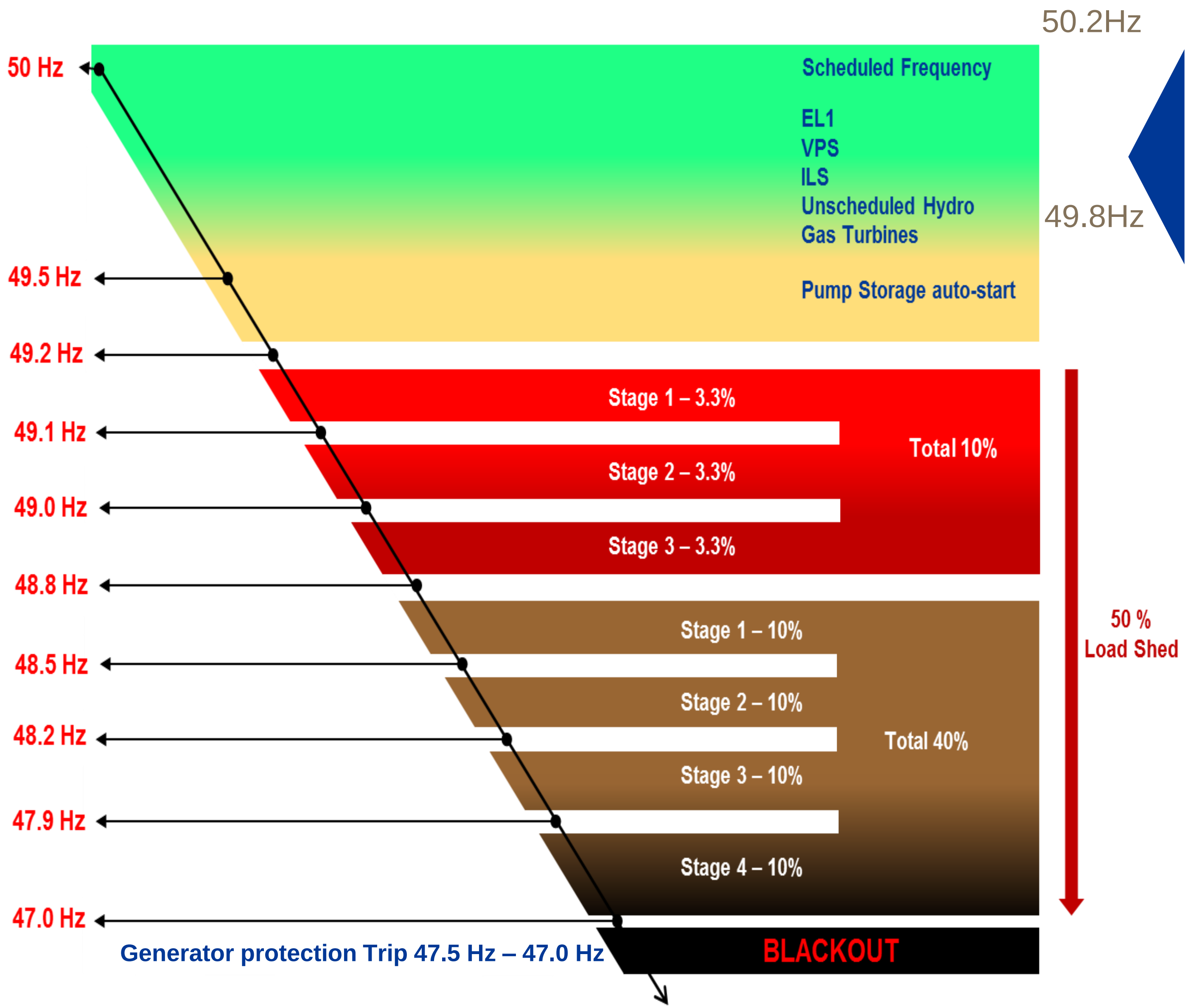
Base load power stations & self-dispatched generation
- Nuclear (Koeberg)
- Coal
- IPP's & Renewables

Emergency Load Reduction

load curtailment
load reduction obtained from customers who are able to reduce demand on instruction

load shedding
load reduction obtained by disconnecting load at selected points on the transmission or distribution system

Preventing Total Power System Collapse (Blackout)

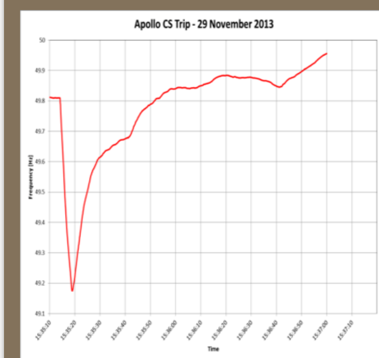


Controlled manual load shedding

To manage frequency (& reserves)

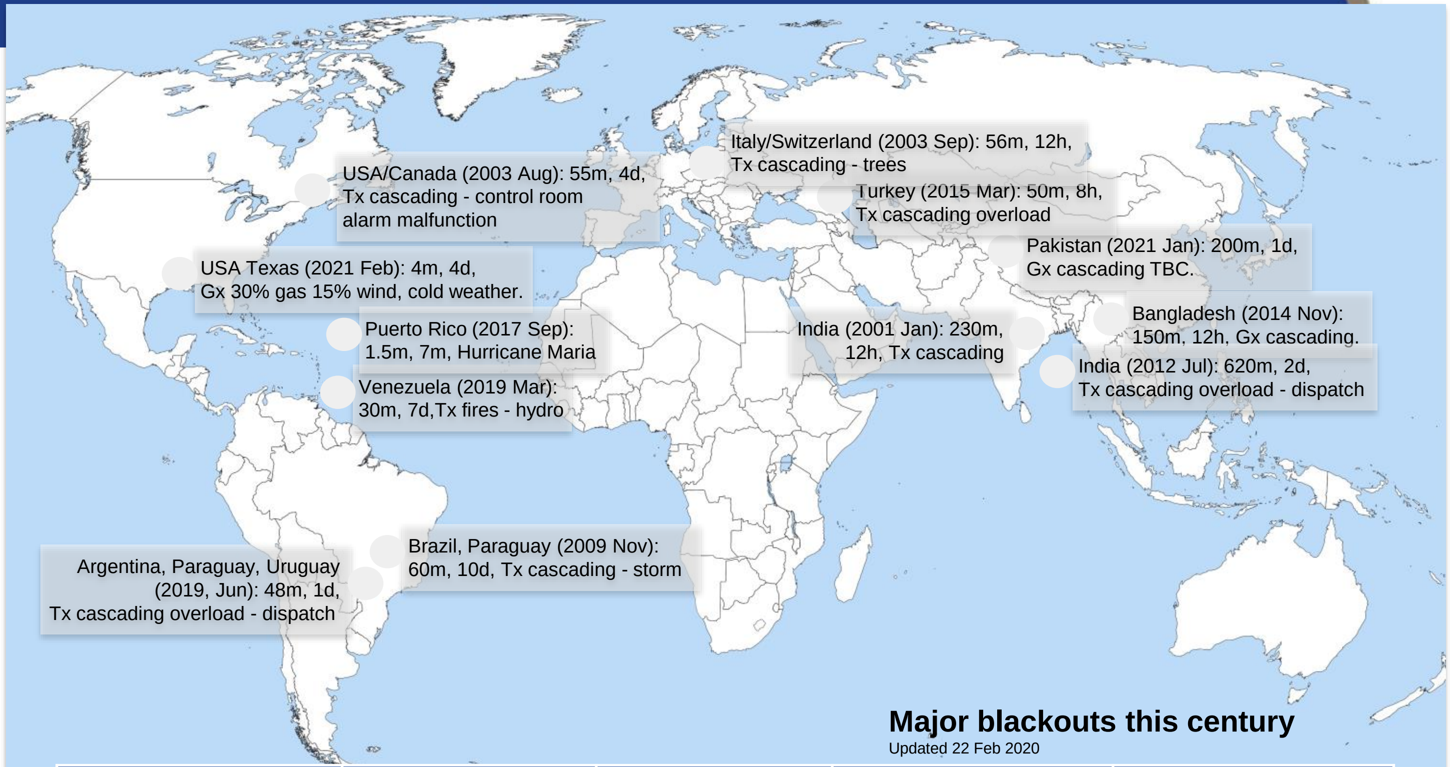
Automatic load shedding

(<*1sec*)



What is a national blackout?

Major blackout events



Major blackouts this century

Updated 22 Feb 2020

Area	Date	Duration (hrs)	Affected (millions)	Cause
Pakistan	January 2015	96	140	Political unrest
Turkey	March 2015	10	70	Line overload
Ukraine	December 2015	6	0.23	Cyber attack
Puerto Rico	September 2016	120	3.5	Fire
South Australia	December 2016	72	1.7	Tornadoes
Puerto Rico	September 2017	11 months	3.5	Hurricane Maria
Venezuela	March 2019	5 months	32	Poor maintenance
South America	June 2019	24	48	Tie-line trip
Java	August 2019	20	100	Line failure
United Kingdom	August 2019	1	1.1	Lightning strikes

Venezuela's blackout:
A terrifying glimpse into an Eskom grid collapse

Eskom

Sporadic looting, patients begging doctors to be kept alive and people living in fear of what the New York Times described as "being on the verge of social implosion".

The putrid odor of rotting flesh hung around the entrance to Caracas' main Bello Monte morgue on Friday where refrigerators had stopped working and worried relatives gathered outside, waiting to be allowed to bury their dead.

. . . according to reports, others weren't so lucky and at least 15 kidney dialysis patients have died so far, as claimed by a local NGO.

. . . a patient at the University Hospital in Caracas, died after her respirator stopped working.

People collect water from a sewage canal at the river Guaire in Caracas on 11 March, 2019 as a massive power outage continues affecting some areas of the country.
Photo: CRISTIAN HERNANDEZ / AFP

One of the attempts to restart the grid led to the explosion of a secondary power station over the weekend.

The impact is devastating on almost every single part of daily life. Sellers were only taking cash, either in dollars or bolivars

Shopkeepers and residents were battling to keep their produce fresh, with restaurants either preparing what they have or preparing to throw everything out

https://www.thesouthafrican.com/venezuela-blackout-eskom-grid-collapse-glimpse/

A few key impacts of a national blackout

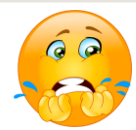
Telecommunications

- Mobile sites will be sustained 2-4hrs (*what about traffic & priority access*)
- Backbone failure within 8hrs
- Recharging batteries
- Other South African Telco’s will not be available after a while

Water

- Local reserve 48hr guideline for munics (not universally in place)
- Water treatment essential (cannot distribute raw water)
- Water required for data centres
- Power stations may have min 3 days (for 6 units) // downstream flooding

No MS TEAMS?



Liquid fuel

- Storage available “3-5 days” subject to requirements (no backup gens)
- Ports and refineries need electricity (No contingency plans)
- Industry will be required to ration and prioritise supply

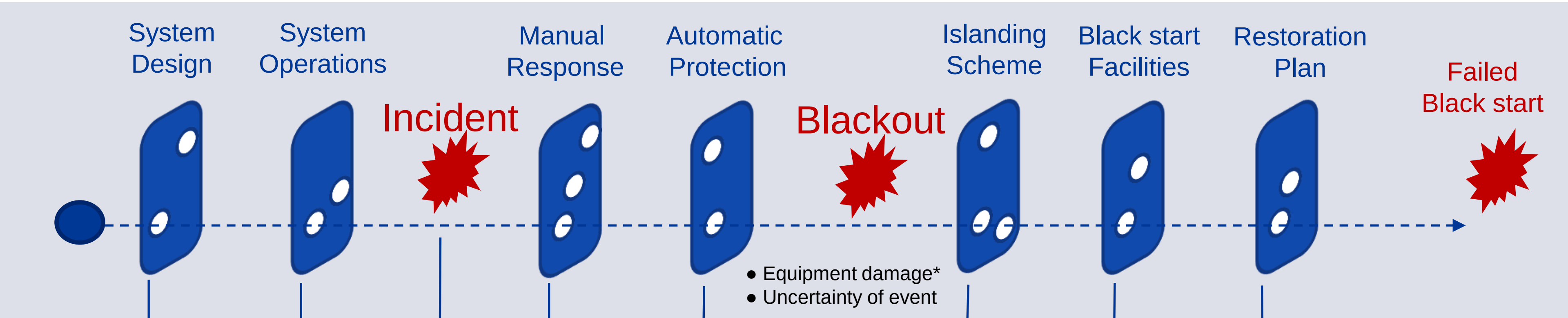
Security

- Sectors cannot rely on national security structures (limited resources)
- Correctional services – generators only 24hrs not adequate capacity
- International experience have shown widespread looting during a blackout

Power System Blackout Accident Model

Overview of the barriers

NB: Failure is generally related to the failure of several barriers



- General Grid Code compliance (e.g. generator specs, two facilities)
- System Operations best practice (reserves, skills)
- Network flexibility beyond design criteria (e.g. reactors)

- Response procedures (incl. Load shedding protocols, manual island)
- Control room skills/intuition (knowledge and experience)
- Third party (Munic control rooms)

- Coal automatic unit islanding (new units > 200MW) at identified Power Station
- Islanding procedures (tested)
- Power station operator skill/intuition to manage the unit
- Resources (e.g. fuel oil as required)

Speed of restoration Increase exponential based on islanded units

- Operational planning (reserves, DMP)
- Outage scheduling (Tx, Gx risk assessments and decisions)
- Real-time operations/response
- Protection implementation
- Situational awareness (visibility)

- Special protection schemes (automatic under-frequency, low voltage, reverse-power, transient stability, out-of-step, inter-lock, power system stabilizers, sub-synchronous resonance, etc)

- Three black start facilities capable of restarting the country
- Blackstart facilities Procedures (tested)
- Power station operator skill/intuition to manage the restart
- Resources

Contingency plans:
- Strike planning
- Solar storms
- Environmental
- Coal/Fuel

Failure scenarios:
- Severe system constraint (down to 7GW min with interconnected system)
- Sudden large generation incident (uncontrolled under-frequency incident)
- Transmission incident(s) (over/under-frequency, cascading collapse)
- Extended lack of control systems (visibility, telecoms or skills)
- Unknown ! (uncertain resources availability, etc)

- Technical restoration plan
- Training of Control Centre staff (simulator, etc)
- Critical Transmission circuits & load
- Support services (transmission batteries, generator diesel, voice comms)

Why do we need black start facilities?

- In South Africa, black start capability is more **critical** than in Europe or America because we do not have neighbours close-by that can restart our grid
    - Our **grid topology** makes black starting the Eskom system technically difficult because of the centralised generation pool and the very long transmission lines
- Black start capability is an **insurance policy** in response to an unlikely sequence of failures of Eskom's defense systems following a severe disturbance.
- **Large fossil fuel generators require 20MW – 60MW of power** to run the auxiliaries of the unit during start-up
- This power must be supplied in a **stable** manner for the duration of the start-up (minimum four hours)

Restoring a blackout

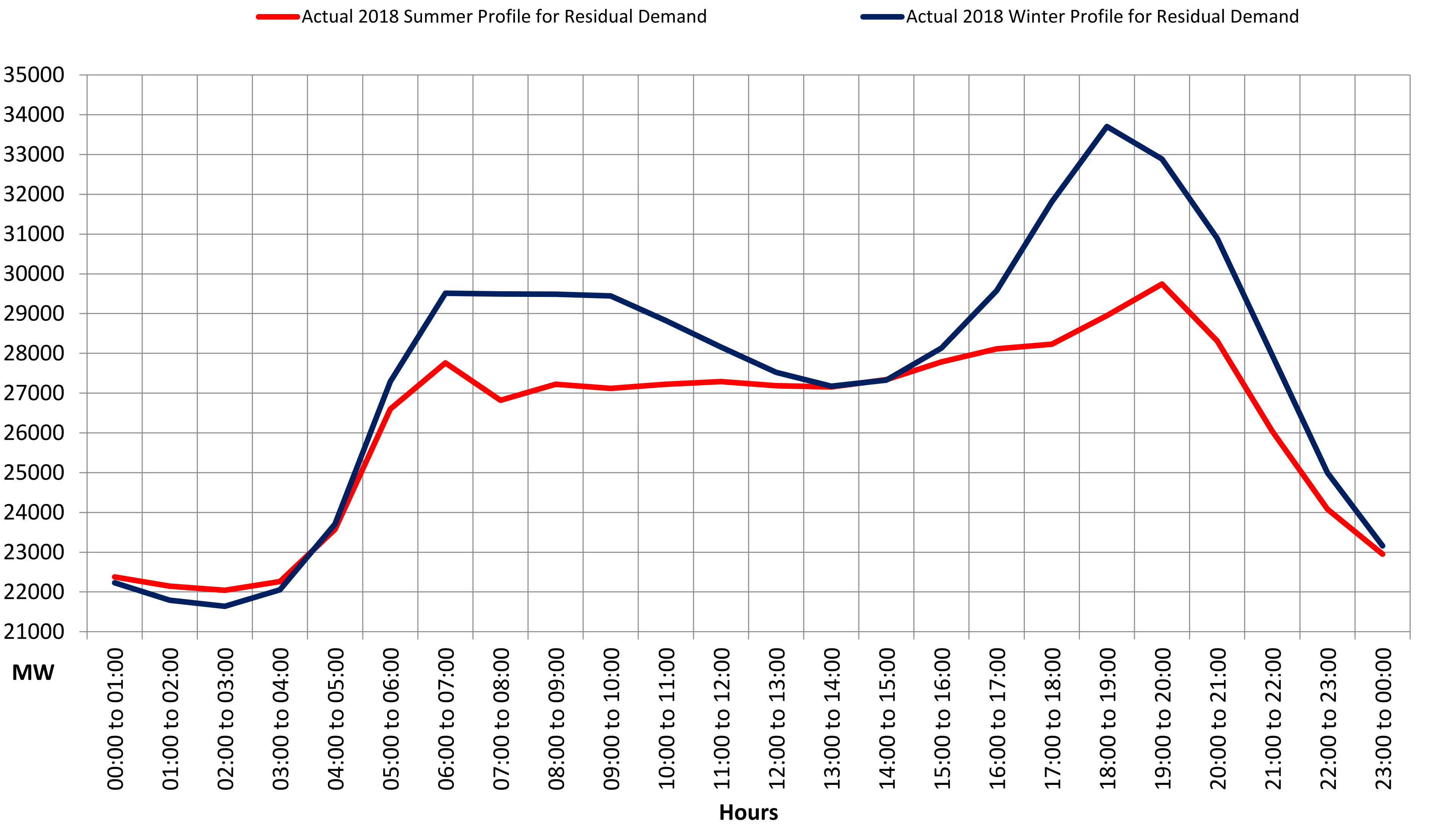
- Following a complete blackout of the grid, at least **one** black start facility is required to restart the power system.
- The **longer a coal fired generator** has been shut down, the longer it takes to restart the unit.

Condition	Generator off	Restart time
Hot start	2 – 4 hours	4 hours
Warm start	4 – 10 hours	6 hours
Cold start	> 10 hours	> 16 hours

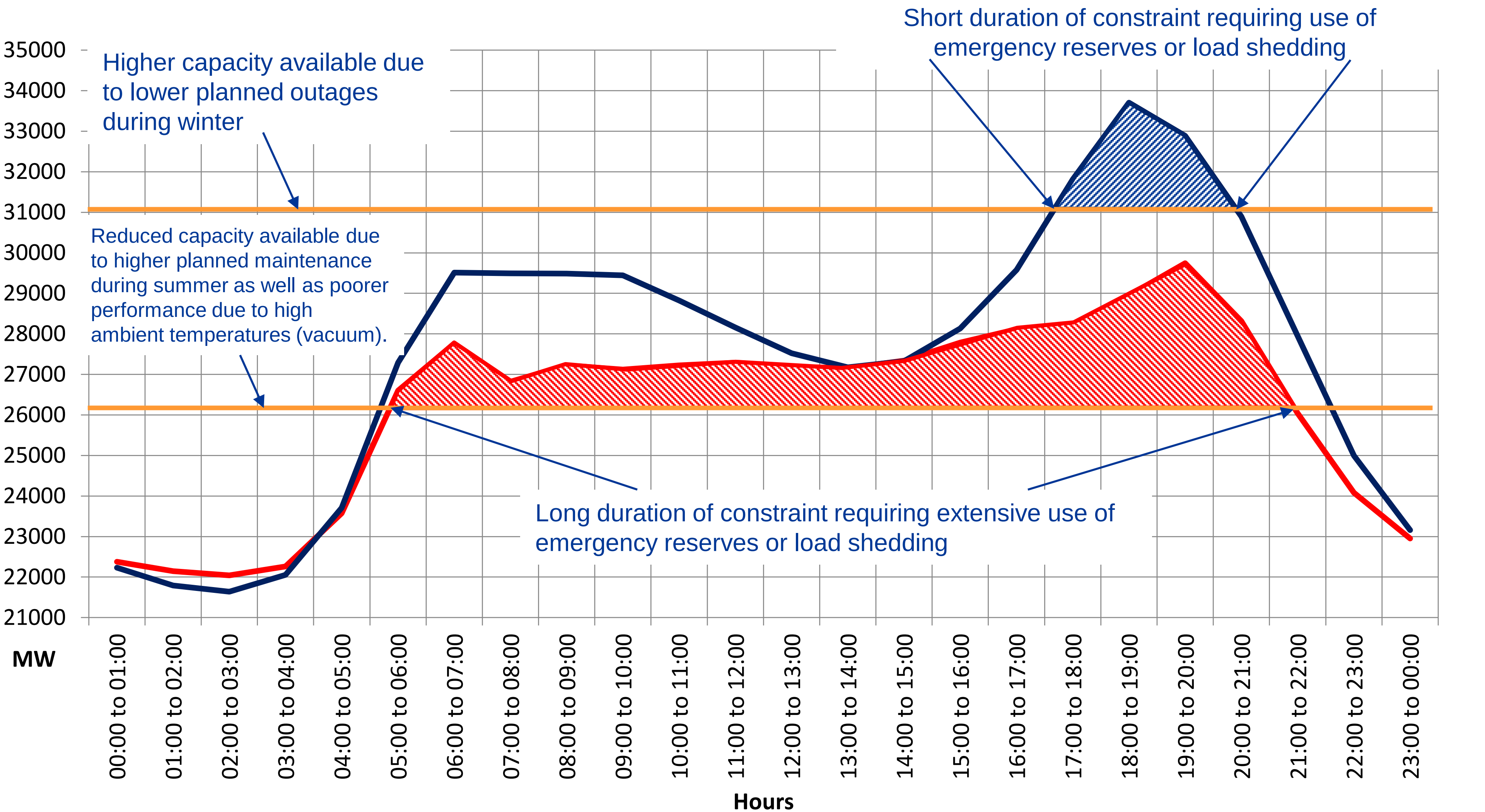
- After 4 hours, 3 generators will start (best case scenario).
- After 10 hours, 8 additional (11 total) generators will start (best case scenario).
- It is estimated that full restoration (completely energised Transmission network loaded to ~30 GW) will take 6 – 14 days (**best case scenario**).

Why do we run out of emergency reserves

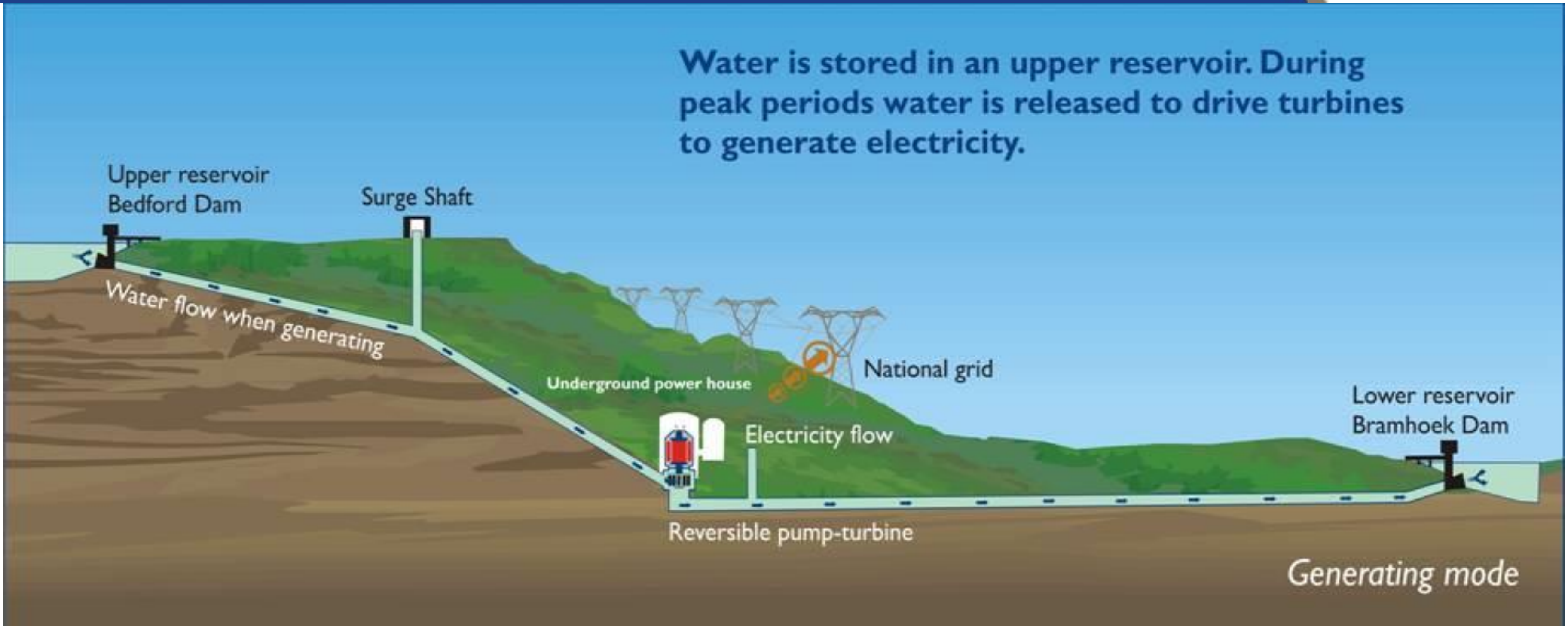
Summer and Winter Profiles



Summer and Winter Profiles



Pumped storage schemes

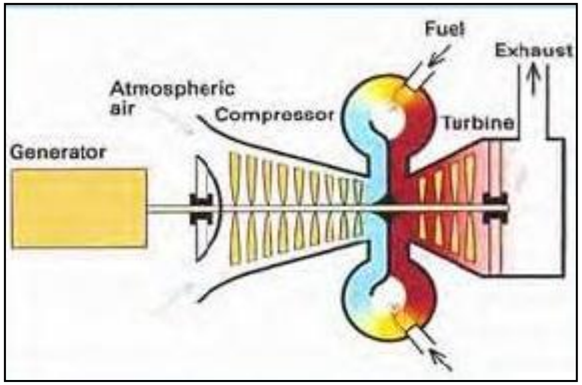


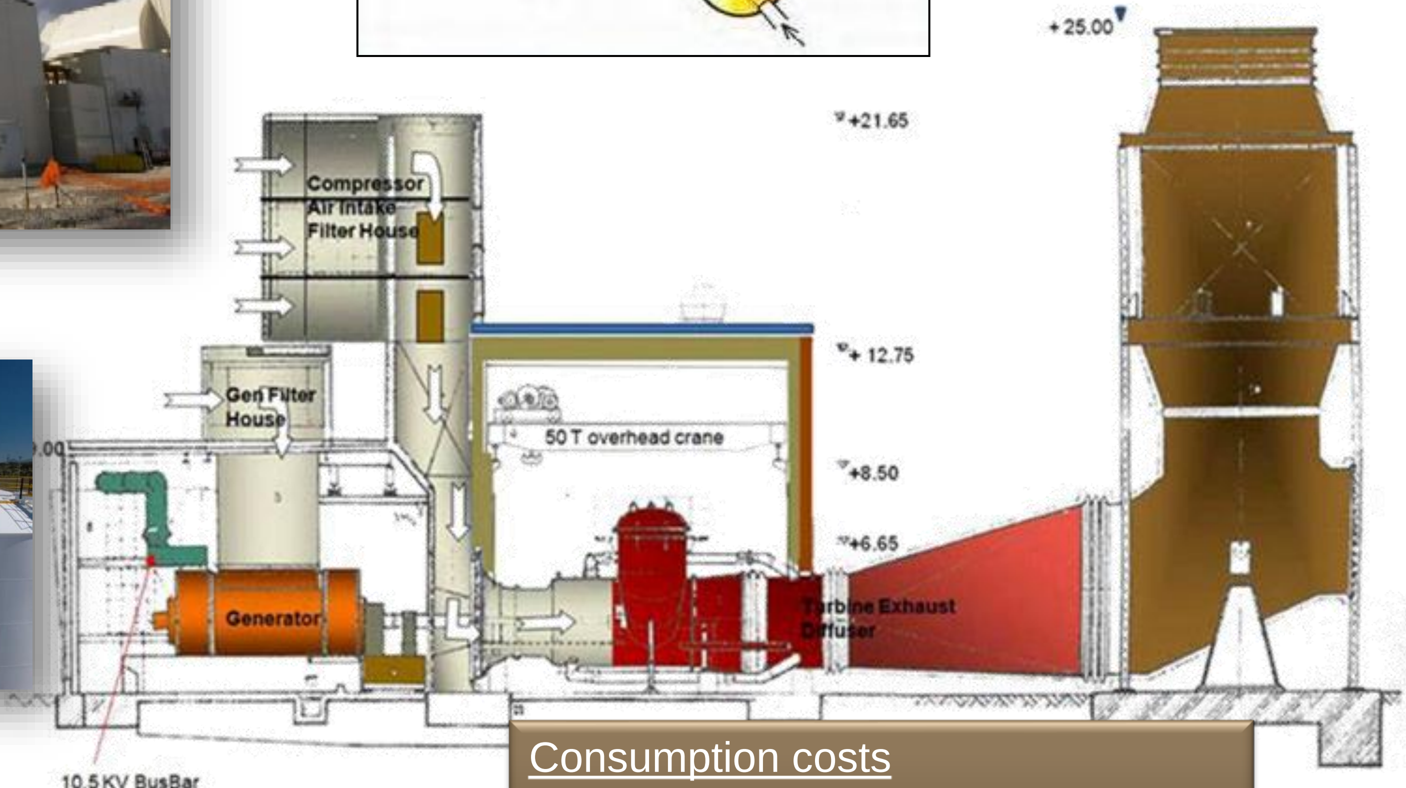
- The scheme is about 75% efficient but offers the only viable means of storing large amounts of energy.
- Pumped Storage Schemes complement traditional base load technologies such as large coal fired power and nuclear power stations because they can store surplus power during off-peak times and generate during peak times.
- Pumped storage schemes will be required to maintain power supply and grid stability when there is a large penetration of wind and solar power. (Particularly in SA because our neighbours cannot support us like in Europe or America)
- Pumped storage schemes are often combined with water transfer schemes.

Open cycle gas turbine

Ankerlig OCGT Power Station

Gourikwa OCGT Power Station





<u>Consumption costs</u>

- Consumption = 1 882 L/min/unit
- Unit cost ~ R3250/MWh

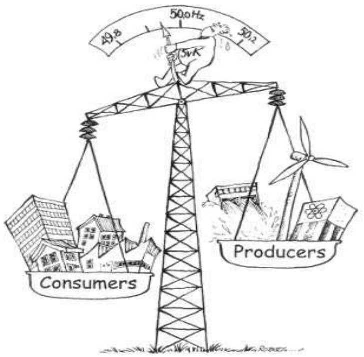
Emergency reserves

- Emergency reserves are typically energy constrained and only available for a short duration.
  - Restricted by contractual arrangement such as demand response (DR) products
  - Restricted by fuel availability such as pumped storage (constrained by dam levels) or OCGTs (constrained by diesel tank levels)
- Strictly speaking, pumped storage is not an emergency reserve but when they are used to generate for prolonged periods, we manage them as emergency reserves.

Emergency reserves

Resource	Capacity	Constraint
Pumped storage: Drakensberg Ingula Palmiet	2 732 MW 1 000 MW 1 332 MW 400 MW	 90 UH, 22.5 SH 54 UH, 13.5 SH 58 UH, 29 SH
OCGT: Ankerlig Gourikwa Avon Dedisa	3 080 MW 1 326 MW 740 MW 680 MW 334 MW	 326 UH, 36.2 SH 221 UH, 44.2 SH 210 UH, 52.5 SH 134 UH, 67 SH
GT: Accacia Port Rex	342 MW 171 MW 171 MW	 27 UH, 9 SH 46 UH, 15.3 SH
ILS	2 024 MW	120 minutes per week
VPS	0 – 500 MW	4 days a week of 120 minutes 40 – 150 MW in winter Up to 500 MW in summer
Critical peak day	~27 MW	Pilot project

OCGTs, GTs and pumped storage make up 6 000 MW of dispatchable generation. If the fuel for these generators is depleted it will add 6 stages of load shedding.



Managing a constrained power system

Planning process

18 month residual demand forecast

UCLF + OCLF forecast

Eskom Generation maintenance requirements for 18 months ahead (Capacity Plan)

Schedule maintenance and optimise available capacity excluding OCGTs

Optimised Capacity Plan with UCLF assumption

Include IPP dispatchable generation and emergency reserves

Optimised Plan with stress tested UCLF scenarios

- Power stations determine their maintenance requirements
- Environmental outage requirements are included

- Gx Production and System Ops in consultation with other stakeholders iteratively optimise the plan

- IPP dispatchable generation included by System Operator
- Emergency reserves such as ILS, VPS included by System Operator

- Estimated diesel requirement
- Estimated stage and frequency of load shedding

Components of the Plan

- Four critical components make up the Plan and determine the need for OCGT generation usage and load shedding:

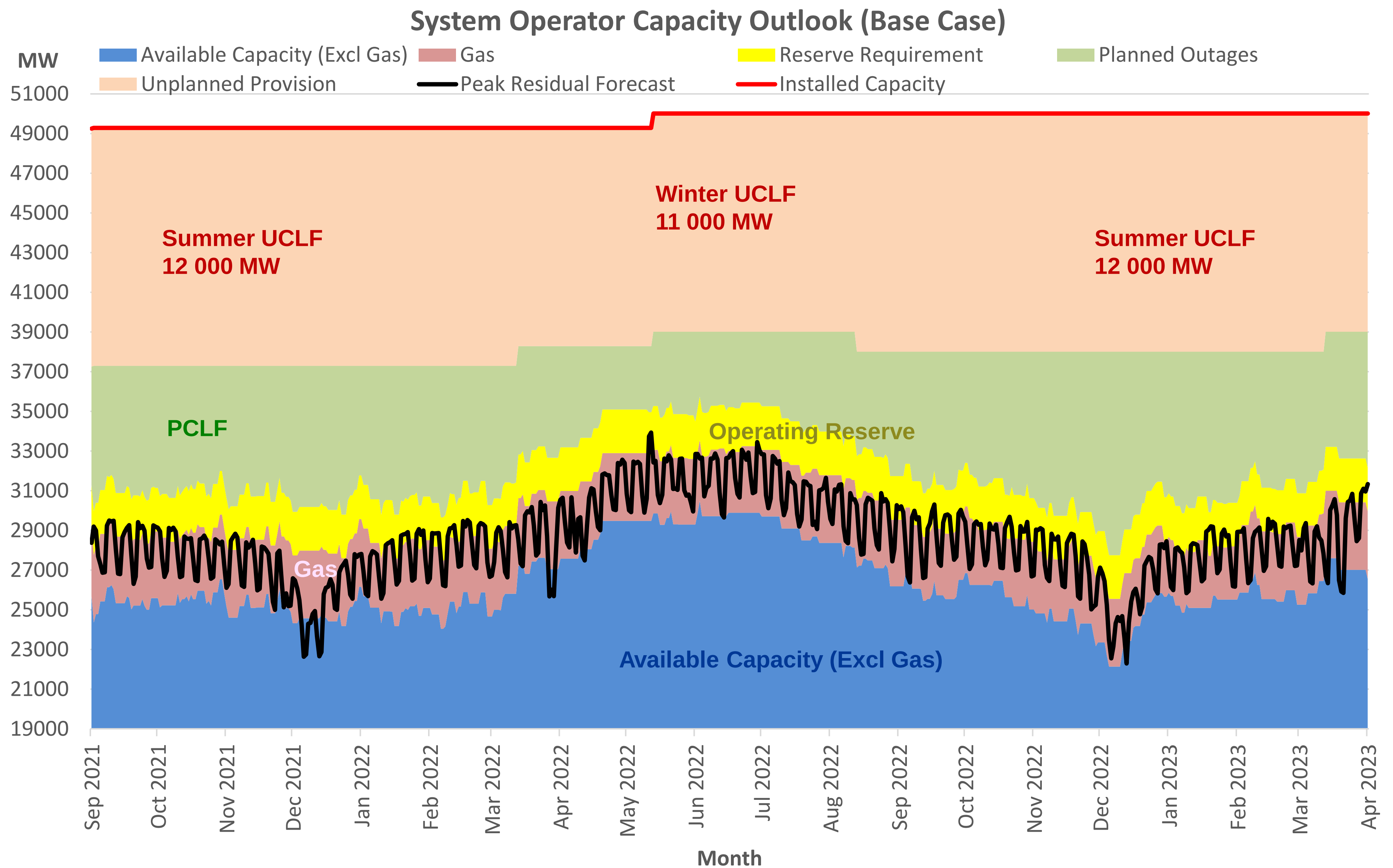
Installed generation capacity: This includes new build non-commercial generators and dispatchable IPP OCGTs but excludes self-dispatch renewable generation.

Demand forecast: The residual demand forecast (total demand less demand supplied by renewable generation) is used.

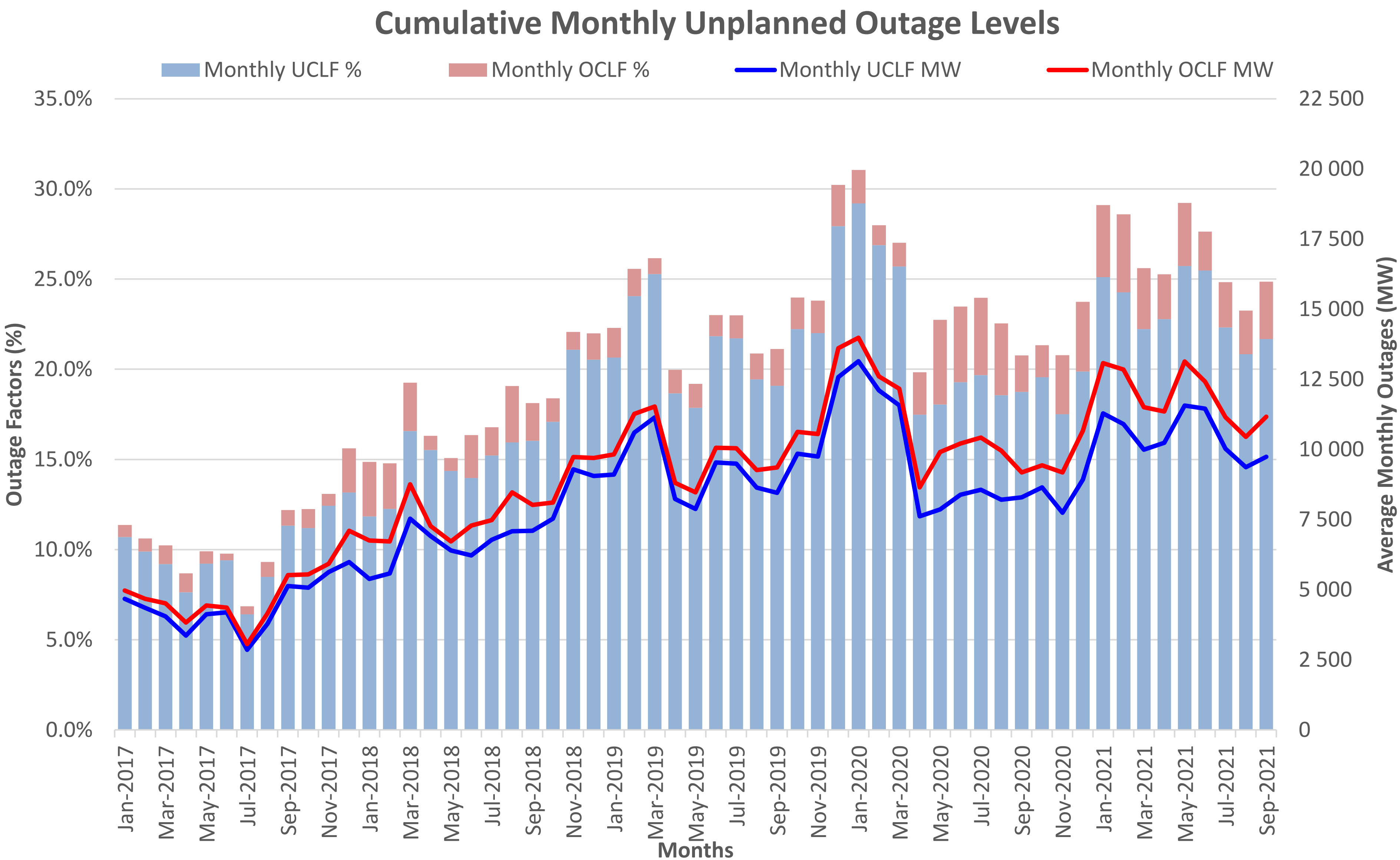
PCLF: Planned generation outages for maintenance.

UCLF + OCLF (Unplanned unavailability): Unplanned generation outages.

System Operator Capacity Outlook for the next 18 Months (Base Case)

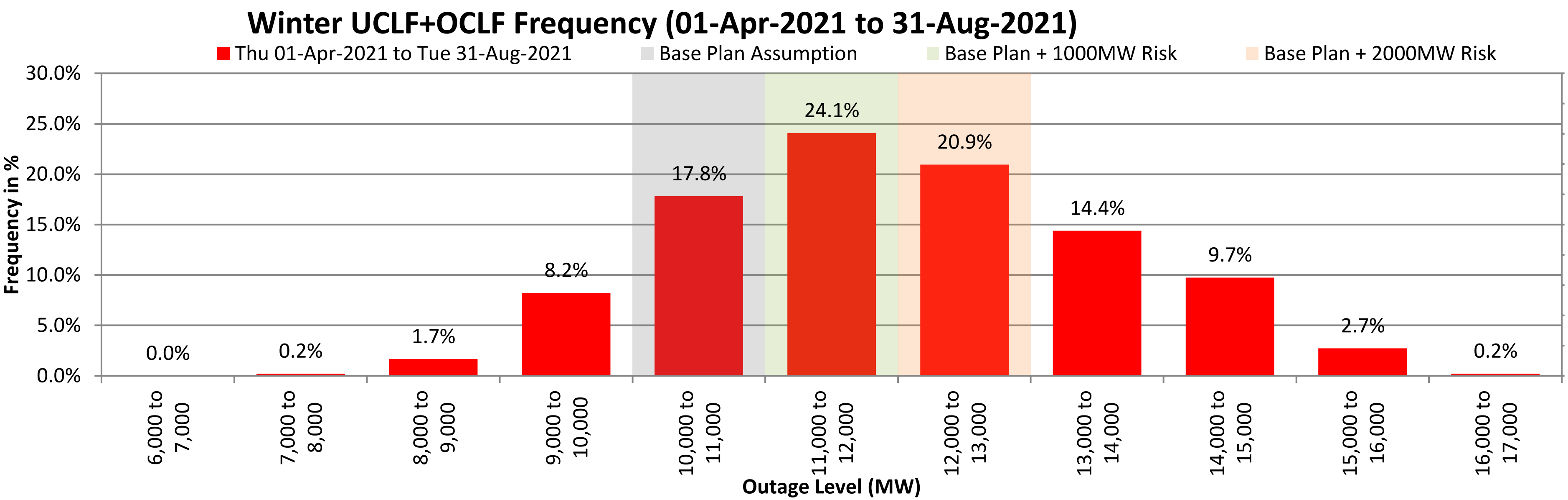


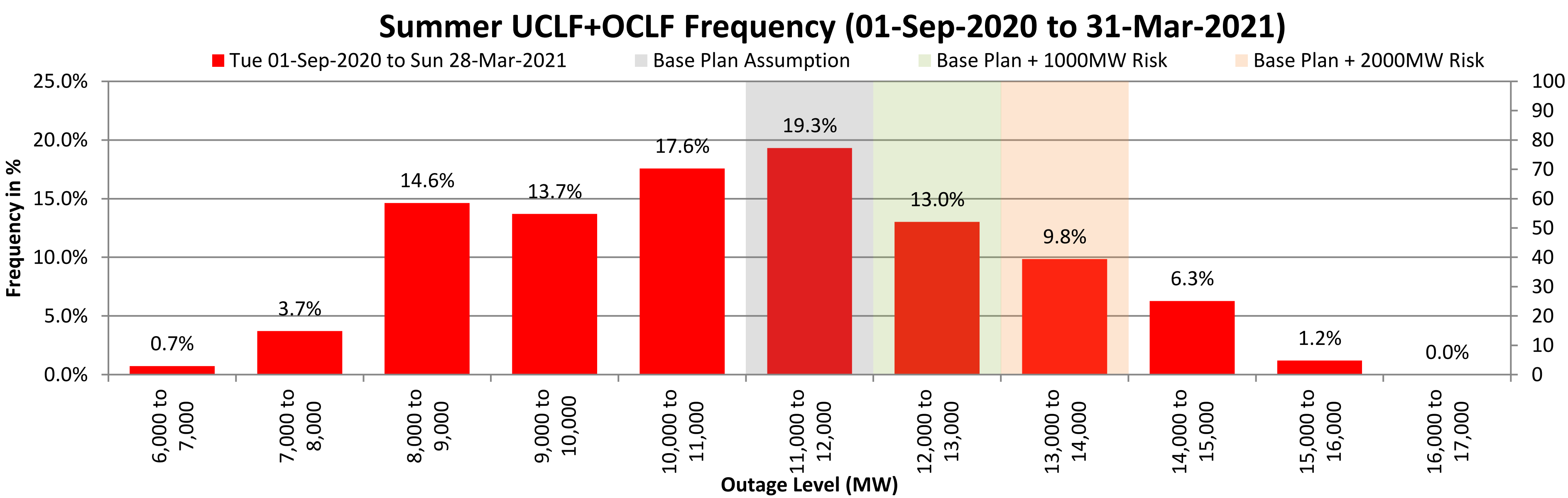
Cumulative Monthly Unplanned Outage Levels



Source: Gx Technical Indicators Reports

Unplanned Outage Performance Winter 2021





12-month outlook to 31 August 2022

Unplanned unavailability	Better than plan	Base case	Base case + 1000 MW	Base case + 2000 MW	Worse than plan
Summer 2021/22					
% of time spent in each scenario last summer	50.4%	19.3%	13.0%	9.8%	7.5%
Number of LS days Highest stage of LS OCGT costs		1 day Stage 1 R 2.5bn	40 days Stage 2 R 6.7bn	94 days Stage 3 R 13.5bn	
Winter 2022					
Number of LS days Highest stage of LS OCGT costs		0 days N/A R 0.8bn	3 days Stage 1 R 1.8bn	65 days Stage 2 R 3.5bn	

Dramatic increase in load shedding days and OCGT cost for only 1 000 MW change in UCLF + OCLF

History has shown that it is not possible to use more than about R 1.2bn of diesel in a month due to the physical limitations of moving the diesel to the OCGT stations. Where the Plan shows a diesel usage greater than this, additional stages of load shedding should be expected

Summer: 1 September 2021 – 31 March 2022. UCLF+OCLF: 12 000 MW – 14 000 MW
Winter: 1 April 2022 – 31 August 2022. UCLF+OCLF: 11 000 MW – 13 000 MW

Rules and governance around load shedding

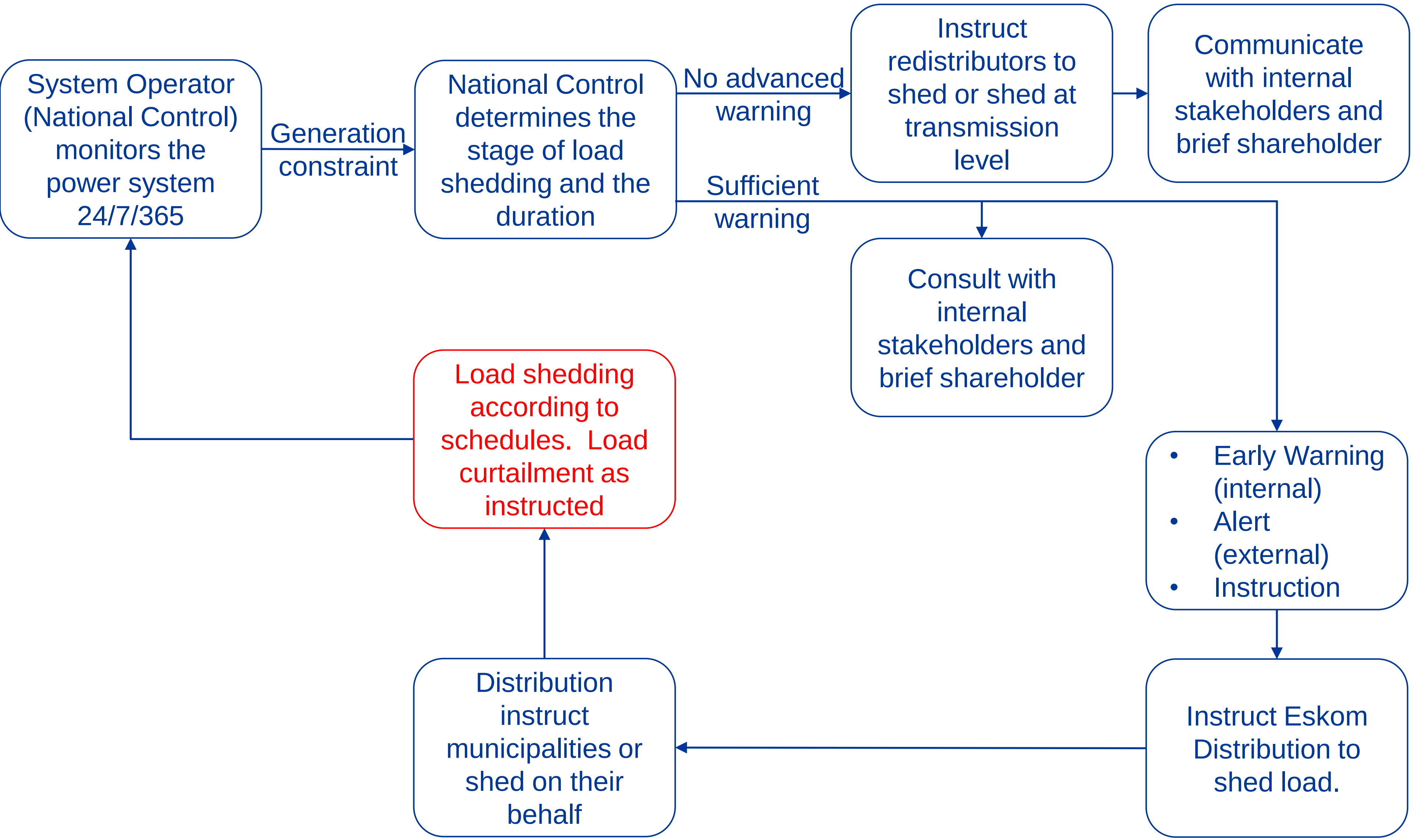
Grid Code & NRS048-9

- The Grid Code mandates the System Operator to maintain a stable grid including shedding load if necessary.
- NRS048-9 Ed. 2
  - This is not an Eskom document, it is an industry document adopted and approved by NERSA
  - The 3rd edition is currently being developed
  - Defines load shedding, load curtailment and load reduction
  - Defines criteria for critical and essential loads
  - Specifies guidelines for load shedding schedules including Stages 5-8
  - System Operator must declare a power system emergency. This is no longer done publically because it causes widespread panic among the public

NRS048-9

- A guiding principle of NRS048-9 is that all participants be treated equitably:
  - *"The development of mandatory load reduction requirements requires several factors to be taken into consideration.* ***These factors sometimes present conflicting requirements****, and need therefore to be balanced on a pragmatic basis."*
  - *Equitable participation refers to a* ***striving for general fairness*** *in the manner in which customers are required to participate in load reduction schemes. It is recognized that equal participation, on the other hand, is not always possible given the nature of load shedding, system characteristics, and real-time-operational constraints.*
  - *Equitable participation is a requirement that arises from the* ***Electricity Regulation Act****. This document therefore requires customers supplied by different licensees to be treated similarly.*

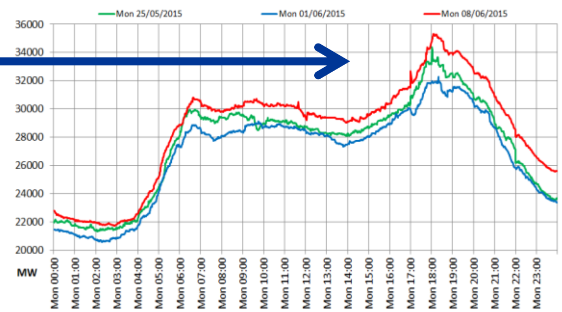
Implementing load shedding



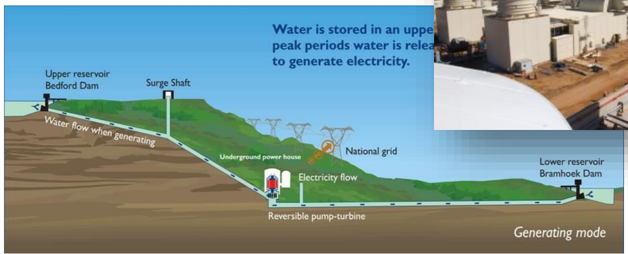
Final thoughts

There are two key reasons why we load shed:

1. Inadequate capacity to meet the demand
   - In winter this is normally only over the evening peaks
   - In summer this can be for up to 16 hours per day (or longer)



2. To enable the restoration of dam levels pumped storage stations and recovery of OCGT diesel tank levels at
   - When OCGTs are being run at extremely high load factors
   - Commonly during summer



Load shedding is a last resort

- Load shedding is implemented by the System Operator as a last resort in order to retain power system stability and prevent a complete blackout.
- Restoring supply from a national blackout will take 6 – 14 days.
- It is far better to disconnect customers temporarily and reconnect them to a stable power system than to blackout the power system.