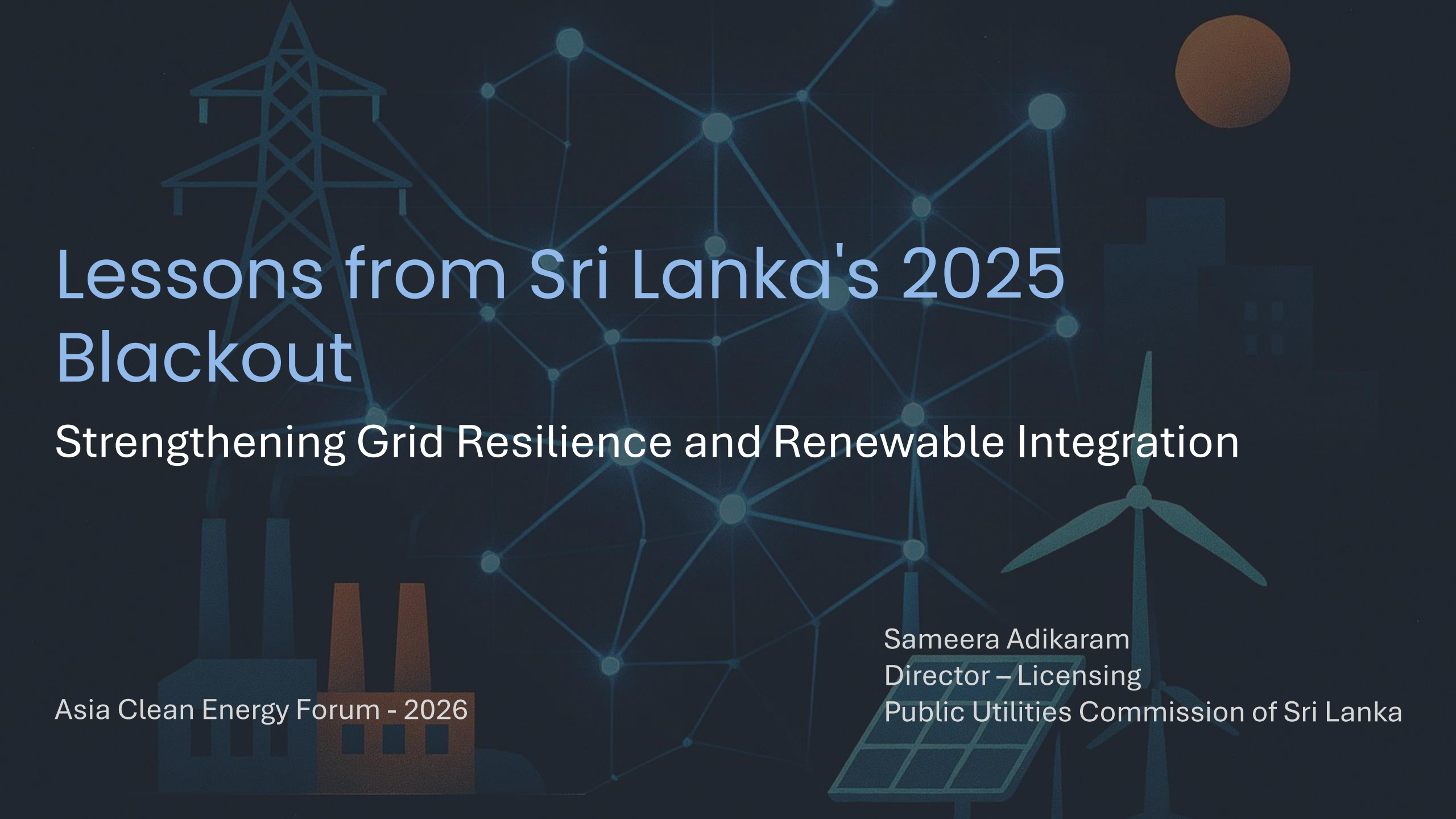




Lessons from Sri Lanka's 2025 Blackout

Strengthening Grid Resilience and Renewable Integration

Asia Clean Energy Forum - 2026

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Public Utilities Commission of Sri Lanka

A Wake-Up Call for High-Renewable Grids

The nationwide blackout occurred on **09th February 2025** revealed critical vulnerabilities in high-renewable power systems that every nation must address

4.5 hours

Total national grid failure duration

10.1 GWh

Energy demand
unserved (5.5 GWh
blackout + 4.6 GWh
rotational cuts)

4 days

Rotational power
cuts required

70%

Sri Lanka's
renewable energy
target by 2030

*This event offers crucial insights for clean energy transition as grids
integrate higher renewable penetration*

11:13:39 hrs

Phase-to-phase-to-earth fault occurred on 33 kV Bus Section at Panadura Grid Substation causing 40% voltage drop at the 132 kV level

11:13:41 hrs

Fault cleared in 1.1 seconds but frequency declined gradually from 50.12Hz to 49.5Hz within 5.5 Seconds

11:13:48–54 hrs

All five under-frequency load shedding stages activated, failed to arrest frequency drop

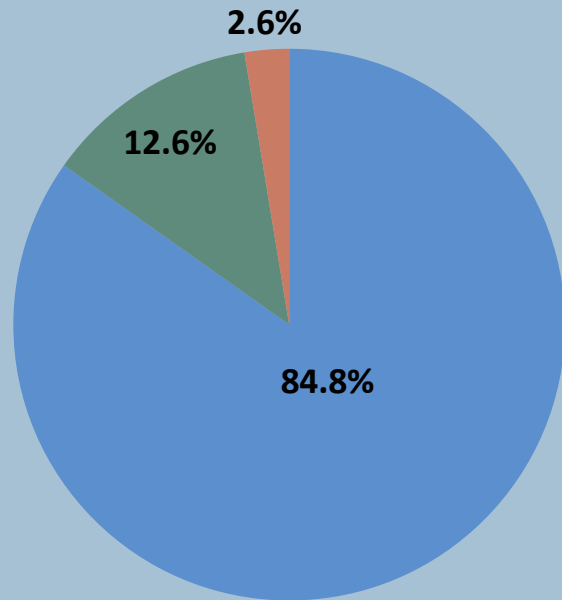
11:14:01 hrs

Total system collapsed after frequency reaching 40Hz after 22 seconds, all major generation units tripped

What Happened – The Incident Timeline

- Panadura Grid Substation fault cleared within 1.1 seconds by protection systems operating correctly within set limits
- Despite fault clearance, system frequency continued declining from 49.95Hz to 49.5Hz in just 4.4 seconds, indicating insufficient frequency response
- All five stages of Under-frequency load shedding scheme activated but could not prevent cascade failure

Reason for Tripping of Inverters – Inverter Logs



■ No Grid ■ Under Frequency ■ Under Voltage

77 MW

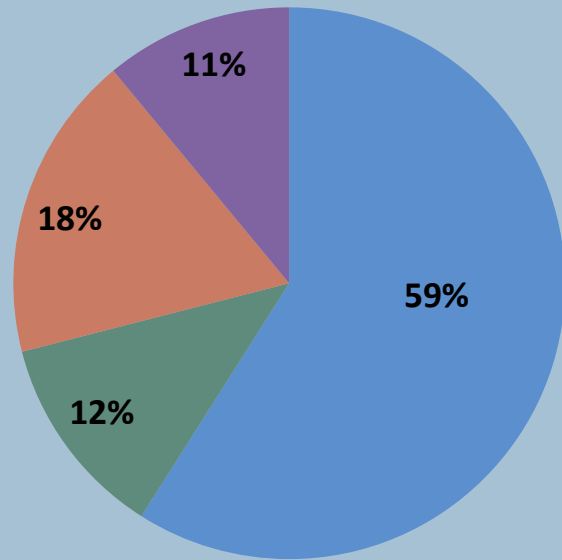
Rooftop solar disconnected during voltage drop

Root Cause Analysis– Rooftop Solar Inverter Response

- No evidence on major generator failure during first 5.5 Seconds of the failure
- Analysis of 1,608 inverter samples revealed that **2.6%** inverters have tripped due to undervoltage
- **77MW** of rooftop solar PV disconnection may have contributed the initial frequency drop during the first 5.5 seconds of the event

Analysis of Underfrequency Trip Settings

Underfrequency Trip Setting of Inverters



■ $f=47\text{Hz}$ ■ $47\text{Hz} < f \leq 48\text{Hz}$ ■ $48\text{Hz} < f < 49.5\text{Hz}$ ■ $f=49.5\text{Hz}$

- Prescribed Underfrequency Trip Setting = 47 Hz
- Analysis of 1,608 inverter samples revealed that **11%** of inverters were set at **49.5 Hz**, and a further **18%** between **49.5 Hz and 48 Hz**, instead of the prescribed 47 Hz setting.
- None of the inverters would have tripped due to under-frequency during the first 5.5 seconds of the event (until the system frequency reached 49.5Hz)
- Significant RT solar capacity has disconnected as frequency fell below 49.5Hz, compounding system instability

Other Contributing Factors – Inadequate Frequency Response

4 MW

Victoria Unit 2 output increase (29→33 MW) despite 0.62 Hz frequency drop during the first 5.5 seconds

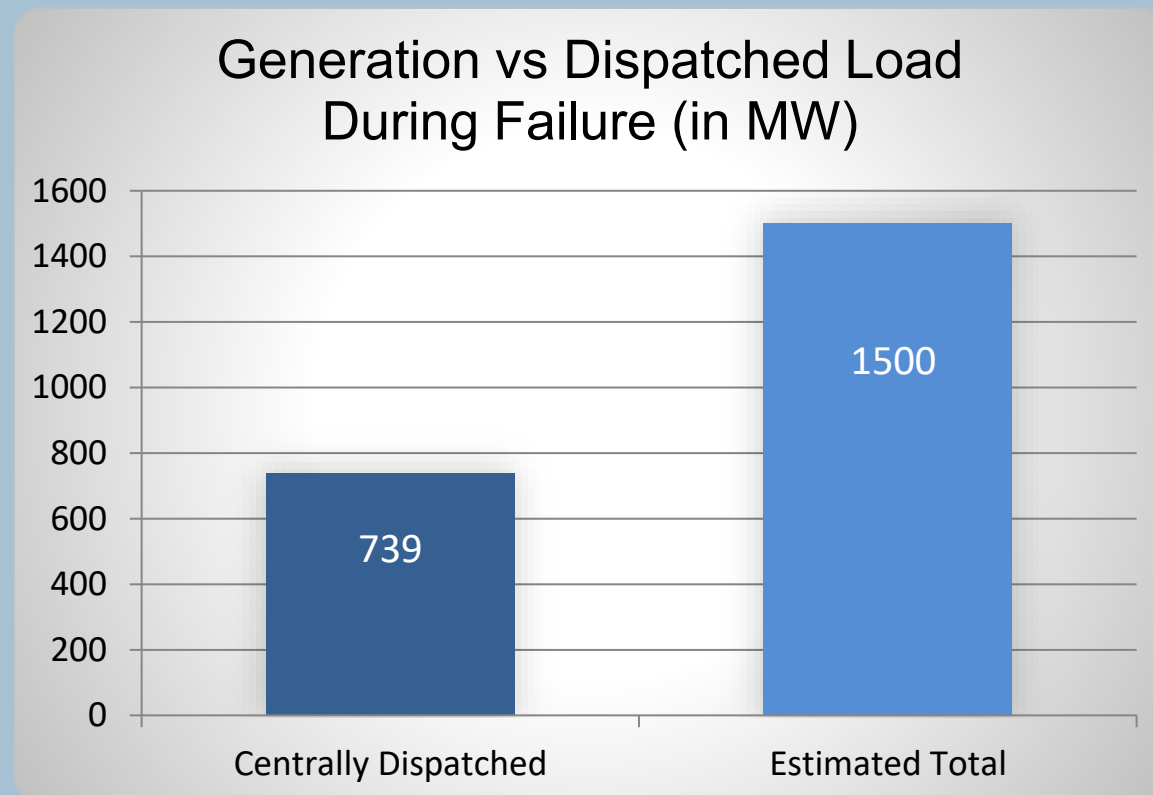
- At the time of the total system failure, Unit 2 of the Victoria Hydropower Station had been designated as the frequency-controlling generating unit
- Governor droop setting of the generator has correctly calibrated at 2% with sufficient headroom available, but the unit has delivered only a minimal increase of output during the critical first few seconds
- Combined effects of governor tuning, actuator response and hydraulic dynamics were not adequate to provide the fast primary frequency support required under low-inertia operating condition

DAQ Records of Victoria PS Unit 2

U2	DAQ	9/2/2025
Time	Power (MW)	Frequency (Hz)
11.13.40.000	29	50.12
11.13.45.000	33	49.51
11.13.50.000	47	48.27
11.13.55.000	55	47.48
11.13.56.800	72	46.07
11.13.57.800	70	44.86
11.13.58.700	71	43.48

Operation of Under Frequency Load Shedding (UFLS) Scheme

- UFLS scheme has been last updated in 2018 based on dispatchable load visible to System Control Centre
- More than 1000MW solar RT added from 2018-2024 to the distribution feeders
- Low visible system demand by the System Control Centre
- Embedded distributed generation on feeders substantially reduced the effectiveness of UFLS, as actual load relief achieved through UFLS is substantially lower than intended



Technical Solutions

Grid Hardening Requirements



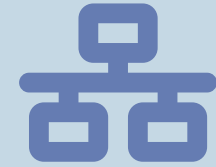
Inverter Grid Support

Implement routine inspection to ensure rooftop solar inverters configured with prescribed LVRT, HVRT, and frequency ride-through settings



Faster Frequency Response

Undertake PID controller tuning of governors at Victoria Power Station and other frequency-controlling machines to achieve faster primary frequency response



Adaptive Load Shedding

Implement Adaptive Load Shedding scheme capable of responding dynamically to system conditions, considering embedded generation in real-time

Policy & Regulatory Framework

Government gazette issued binding directions to all electricity licensees, establishing mandatory compliance framework for grid resilience

20

Regulatory
mandates issued
across all license
categories

3

To Licence categories

Generation
Transmission
Distribution

Distribution Licensees:

- Establish structured replacement and upgrade policy ensuring newly replaced inverter models comply with updated technical requirements
- Develop and maintain centralized digital database of inverter types, firmware versions, ride-through capabilities

Generation Licensees:

- Review and optimize spinning reserve policies considering actual system inertia and renewable penetration levels
- Further investigate and enhance the frequency response characteristics of other synchronous generators

Transmission Licensee:

- Establish realtime monitoring, communication, and control capabilities to enhance the visibility and controllability of large rooftop (RT) solar PV schemes

References

[1] Investigation Report on the on the Total System Failure occurred in Sri Lanka on 09th February 2025

<https://www.pucsl.gov.lk/wp-content/uploads/2026/01/Report-Public-Hearing.pdf>

[2] The Government gazette issued with the directions to all electricity licensees

<http://www.pucsl.gov.lk/wp-content/uploads/2026/02/Gazzete-2474-17-Direction-of-Public Hearing.pdf>