International Comparison—Major Blackouts and Restoration

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Three Tasks

1. International comparison of major blackouts
2. International comparison of regulatory arrangements to mitigate blackouts and improve restoration
3. Black-start planning with very high levels of wind and solar

Task 1: Blackout comparison

1. 2003 Eastern US
2. 2013 Sarawak
3. 2008 Oahu, Hawaii
4. 2003 Italy
5. 2011 San Diego

Blackouts

Characteristic		Event				
		2003 Eastern US	2013 Sarawak	2008 Oahu, Hawaii	2003 Italy	2011 San Diego
General description		Major regional outage	Total system outage	Total island outage	National outage	Regional blackout
The physical extent		68,000 MW	1,600 MW	1,000 MW	35,000 MW	8,000 MW
The economic cost		6-10 B USD			150 M USD	120 M USD
Any social impact		Major economic and social disruption	Chaos during rush hour in Kuching, the capital	International embarrassment	Occurred in early AM during holiday festivities	Occurred in early afternoon just before rush hour
Restoration time	NEM Stage 1	6 hours*	3 hours	5 hours	3 hours‡	N.A.
	NEM Stage 2	10 hours$^{\Delta}$	4 hours	9 hours	4½ hours‡	4-6 hours*
	NEM Stage 3	2 days for most 4 days for a few	8½ hours	96% in 18 hours	99% in 15 hours	12 hours
Time for restart services to come online		< 30 minutes for hydro	30 minutes	< 30 minutes	30 minutes‡	Only interconnectors
The readiness of generation and supply equipment		Some non-B-S generation had problems	Normal	Normal	Normal, but only 8 of 31 TTHL units operated	Normal

* Estimated

Δ The blackout was so extensive that some parts of the transmission system took longer to restore.

‡ The Italian peninsula is very long, so the times are for the main northern portion of system.

Task 2: Regulatory comparison

1. PJM—much of eastern US
2. South Africa
3. Italy
4. ERCOT—most of Texas
5. Ireland

Regulatory comparison

Characteristic	System/region				
	PJM	South Africa	Italy	ERCOT	Ireland
Any specific variables for system restoration	Synchronize in 3 hrs 4 hrs to energize nuclear units	Each black-start plant must energize a large coal plant in 4 hrs	None, only general comments	Unwritten understanding of 4 hrs for nuclear plants	Thermal black-start plants must synchronize within 30 mins of being energized
Any requirement to restore certain percentages of total load within a specific timeline	Time only for nuclear units Restore "critical load"	None	None	No time required Amount is confidential	None There are priority loads
Scale of the power system event that must be addressed	The plan is to use the zonal black-start resources to restore the system.	National	National	Entire system	National
Any deterministic requirements	At least 2 for each zone Can be located in adjacent zone	2 plants for entire nation—pumped-hydro plant and 2 large diesel at a coal plant	None	None, but multiple black-start units will be needed for such a large system	At least one black-start unit in each of four subsystems

Task 3: Planning with lots of wind and solar

- Impacting blackouts
  - System inertia
  - Ramp rates
  - Under-frequency & under-voltage response
  - Coincident response
- Impacting restoration
  - Managing stability will be a challenge
  - Wind & PV start fast
  - PV is invisible

T3: Potential mitigation

- More conventional generation with B-S capability—OCGTs and CCGTs
- Additional inertia & fault current
- Coordinate UVLS and UFLS (day/night different)
- Four-quadrant inverters
- Customer and grid-connected storage
- South Australia—additional interconnections

Conclusions: blackouts

- Causes have different results
  - Generation
  - Transmission
- Not at peak load
- All involve multiple "issues"
- A few electrical islands usually survive

Conclusions: restoration

- Situation awareness is essential first step
- Interconnections used early
- In widespread outages
  - Some equipment fails
  - Setbacks occur in restoration
- Partial energizing in 3-4 hours
- Multiple B-S resources (incl. interconnections)

Specific AEMC/NEM comments

- Present SRS seems consistent with B-Os
- Interconnections are used early in restoration
- All generators will help (regardless of SRS)
- The AEMO must have clear authority to settle disputes during restoration
- UFLS, UVLS, and relay settings should be reviewed
- Survey OCGTs and CCGTs for B-S capability

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THANK YOU