Centre for Energy and Environmental Markets

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Distributed resource participation in the Australian National Electricity Market

A seminar presented at Lawrence Berkeley National Laboratory

Presented by
Hugh Outhred
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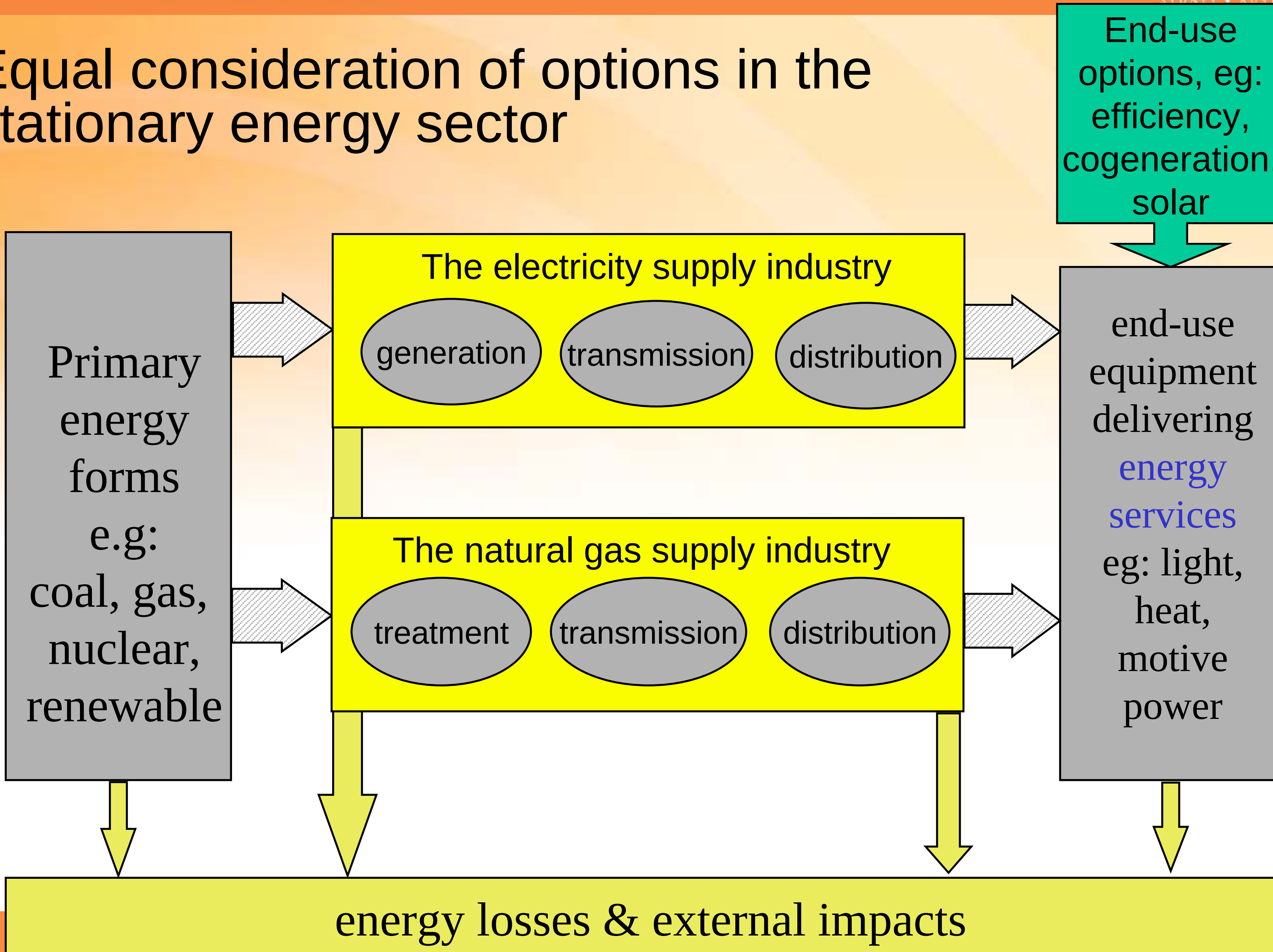
Outline

- A long-term vision for distributed resource participation in electricity industries
- Current state of play in the Australian NEM
- Current initiatives & future prospects in Australia
- Conclusions & recommendations

A vision for distributed resource (DR) participation in the electricity industry

- Equal consideration for distributed resources:
  - In all aspects of electricity industry operation & planning
  - Such that industry outcomes are economically efficient & socially & environmentally sound
- An appropriate balance and compatibility between:
  - Centralised decision-making (engineering and policy):
    - From the short term (engineering) to the long term (policy)
  - Decentralised decision-making (commercial):
    - Operation and investment decisions

Equal consideration of options in the stationary energy sector

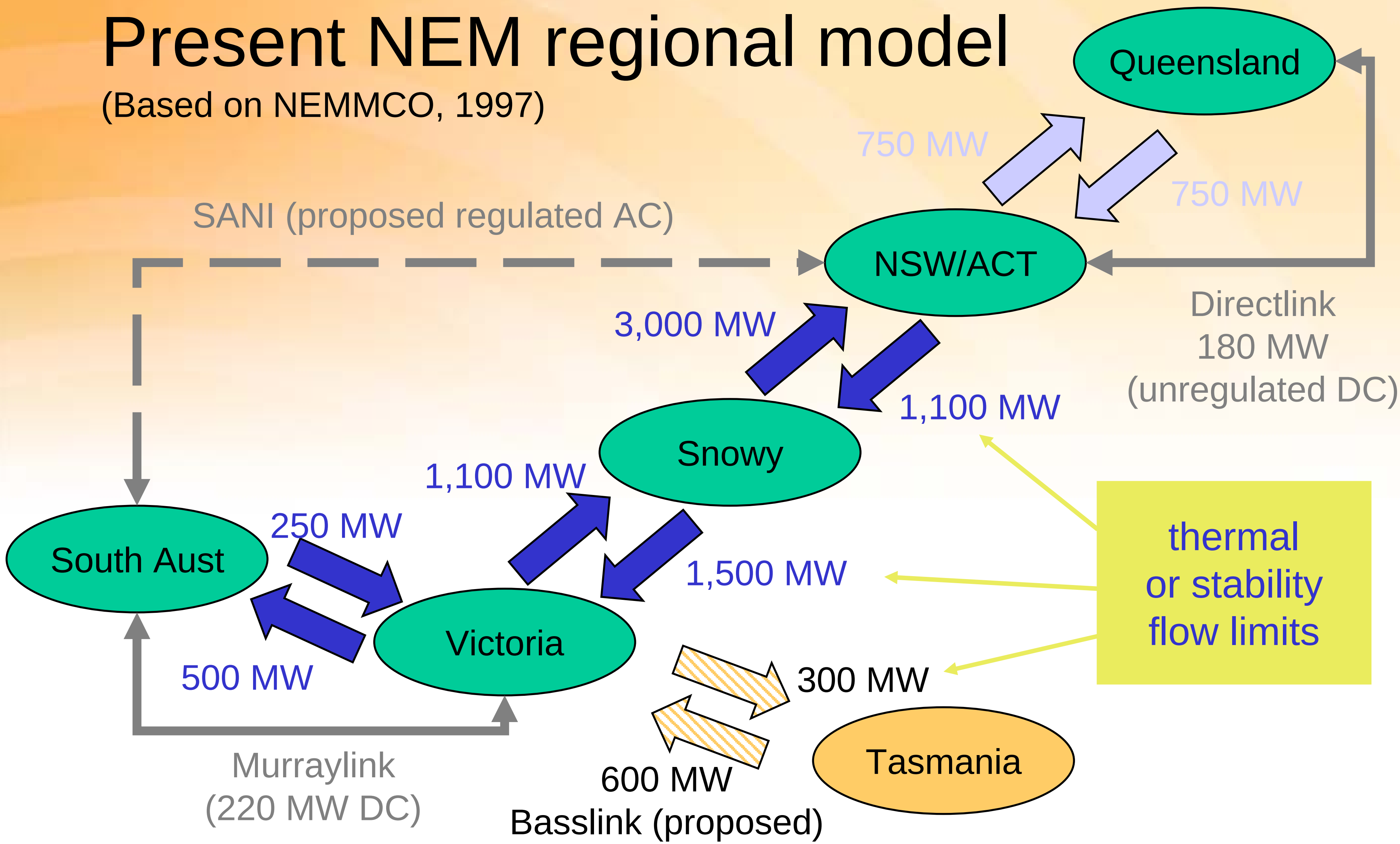


Challenges in managing risks to future end-use energy service delivery

- Compatibility between engineering, commercial & policy approaches to managing risks:
  - Ancillary services must manage short-term risks:
    - Need to maintain electricity industry security
    - Need smooth hand-over from engineering to commercial decision-making
- Compatibility between policy and commercial approaches to managing risk:
  - These may occur in parallel to a long-term horizon:
    - Difficult to achieve compatibility
  - The traditional *obligation to serve* is a barrier to DR

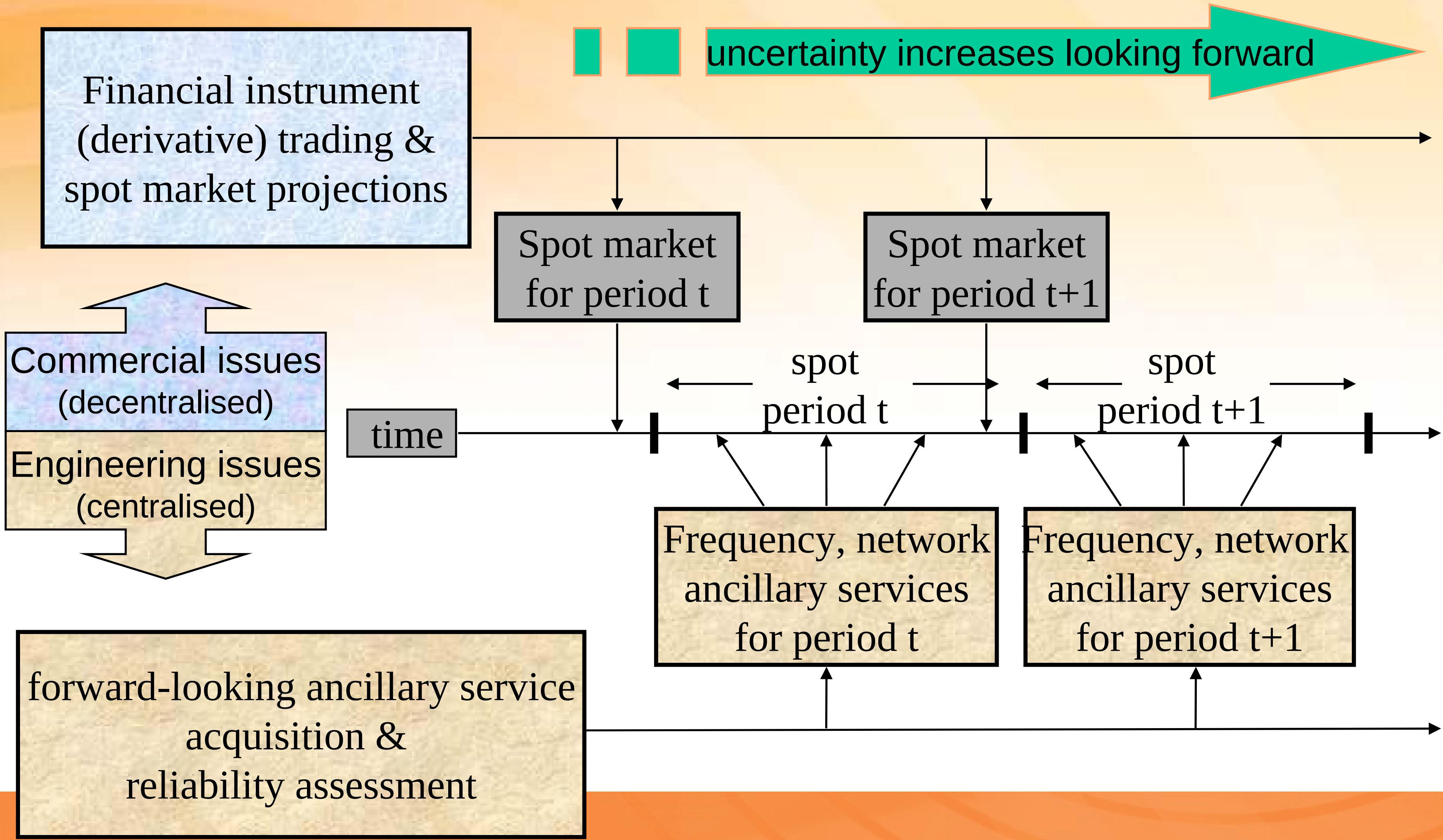
Present NEM regional model

(Based on NEMMCO, 1997)



Centralised & decentralised decision-making

(requires adequate location detail & active demand-side involvement)

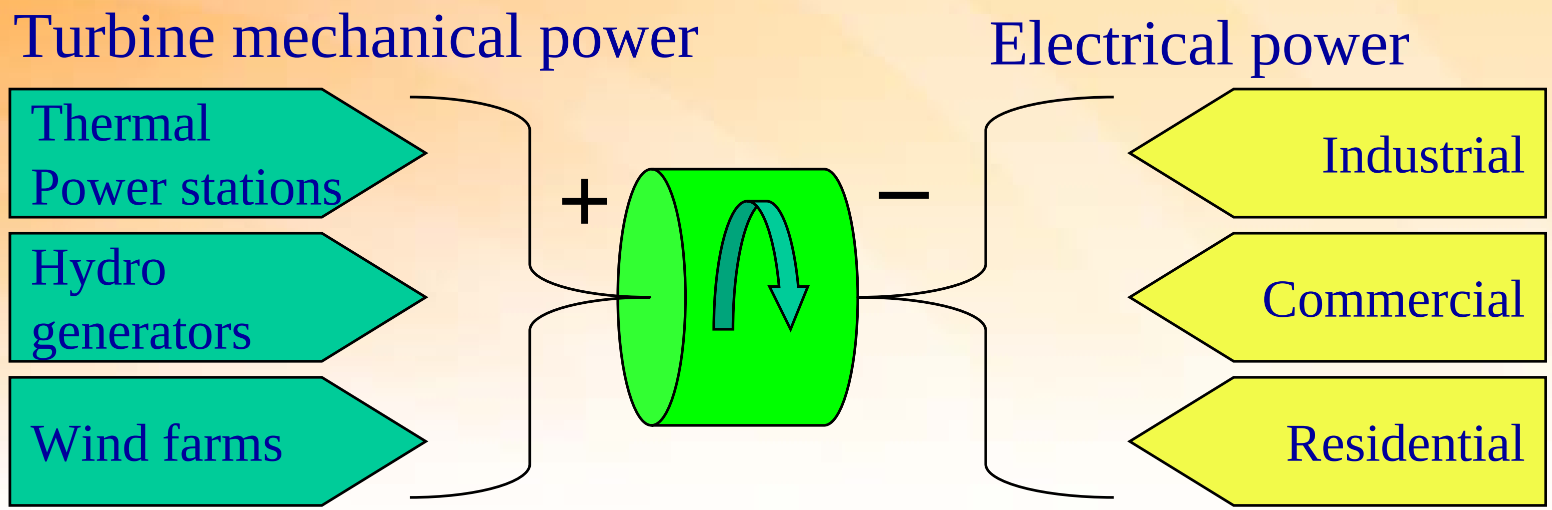


Power system security definitions
(National Electricity Code Chapter 4)

- Satisfactory operating state:
  - Frequency “normal” (49.9-50.1Hz), except for brief excursions within 49.75-50.25Hz
  - Voltage magnitudes within specified limits
  - All equipment operating within equipment rating
- Contingencies (equipment outages):
  - Credible, eg single generator or network element (N-1)
  - Non-credible, eg multiple outages except abnormal condns
- Secure operating state:
  - Currently in a satisfactory operating state
  - Would return to a satisfactory operating state following any single credible contingency (consider loss of largest gen / interconnector)

=> Require sufficient FCAS available to cover sudden loss of largest generation unit / interconnector within each NEM region

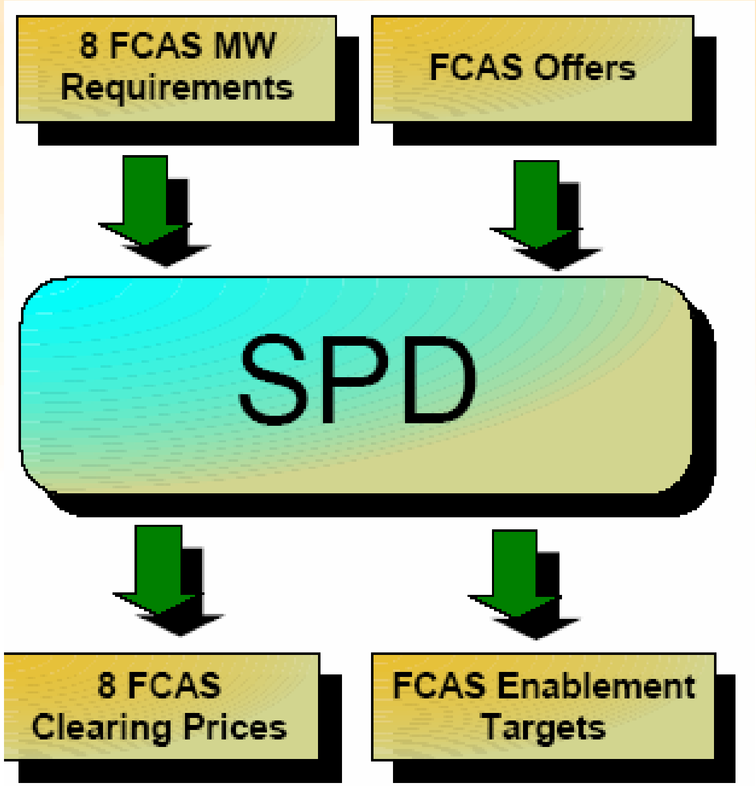
Supply-demand balance in the electricity industry if network effects are ignored



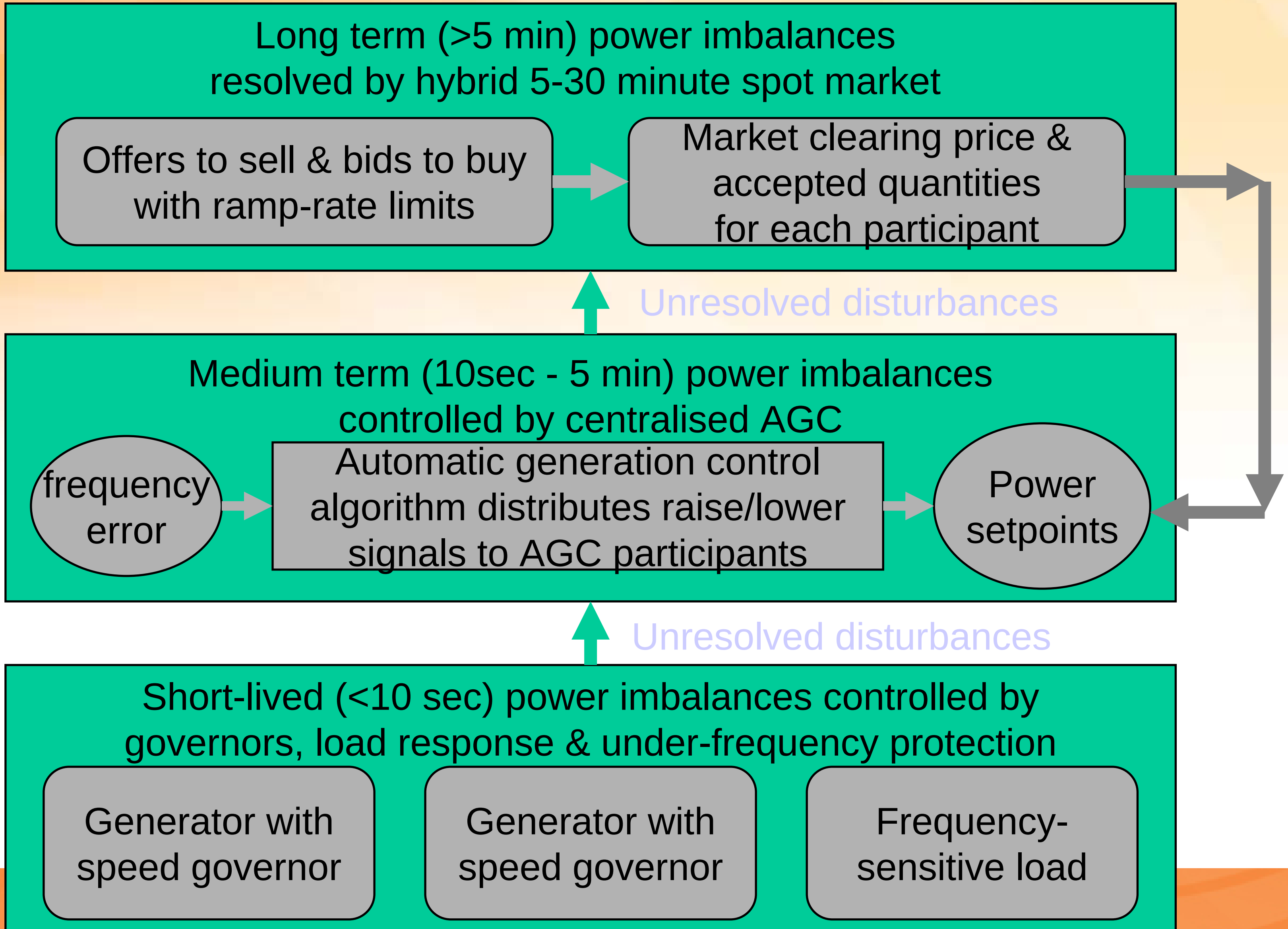
- Frequency is a measure of supply-demand balance:
  - Rate of change of KE = turbine mechanical power - electrical power
- Power flows & network availability are stochastic processes:
  - Hence frequency is always varying
- A typical issue:- wind farms make frequency more variable:
  - Does this matter & if so, who should pay for additional control action?

NEM frequency control ancillary services

Regulation	*Regulation Raise* *Regulation Lower*
Contingency	*Fast Raise and Fast Lower* (Six second response to arrest the immediate frequency deviation) *Slow Raise and Slow Lower* (Sixty second response to keep the frequency within the single contingency band) *Delayed Raise and Delayed Lower* (Five minute response to return the frequency to the Normal Operating Band)



frequency control & NEM 5-30 minute spot market



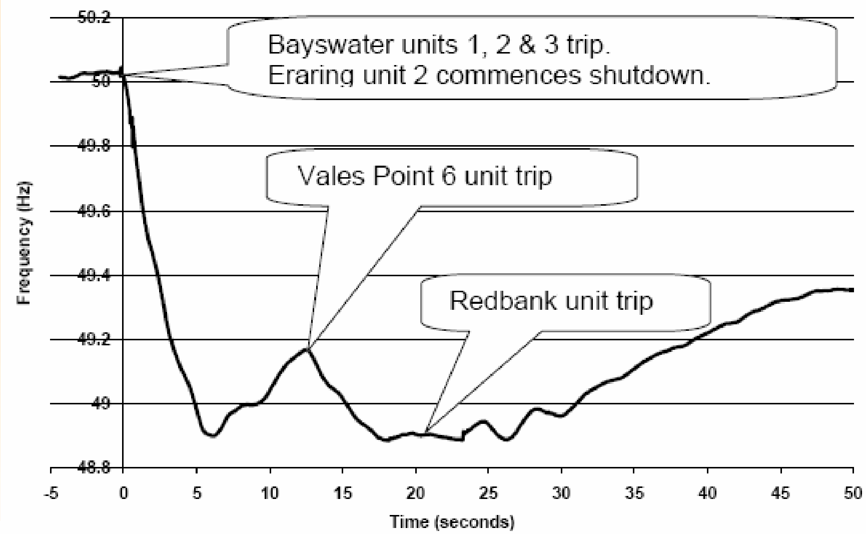
NEM design philosophy for frequency & angle-related aspects of security

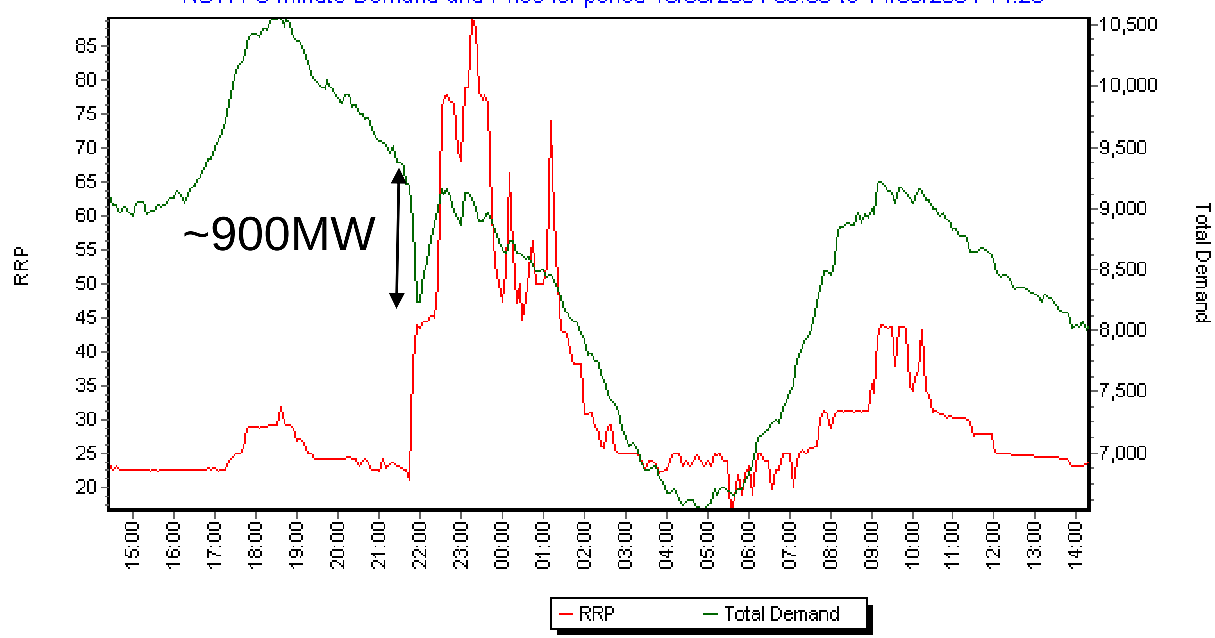
- Engineering decision-making:
  - Control system design approach for:
    - Continuous small disturbances
    - Credible large disturbances
  - Disaster management approach for:
    - Non-credible large disturbances
- Commercial decision-making:
  - Five-minute dispatch pricing gives rapid hand-over
  - Market flow constraints between regions include angle-related security constraints
- Both categories provide opportunities for DR

Current transformer (CT) failure

21:42, Friday 13/8/04 causes 6 NSW generators to trip totalling 3100MW: frequency fell to 48.9Hz, ~2100 MW load shed in NSW, Qld, Vic & SA (www.nemmco.com.au)

Figure 1-5: Power System Frequency



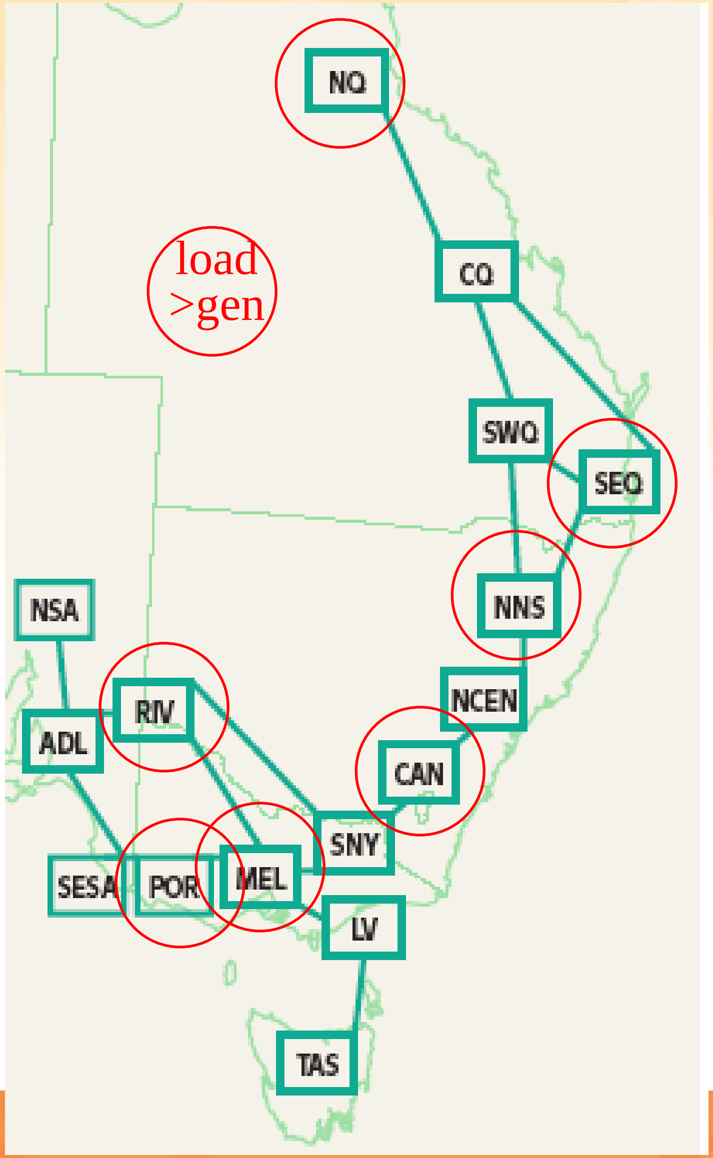


Decision making following the CT failure

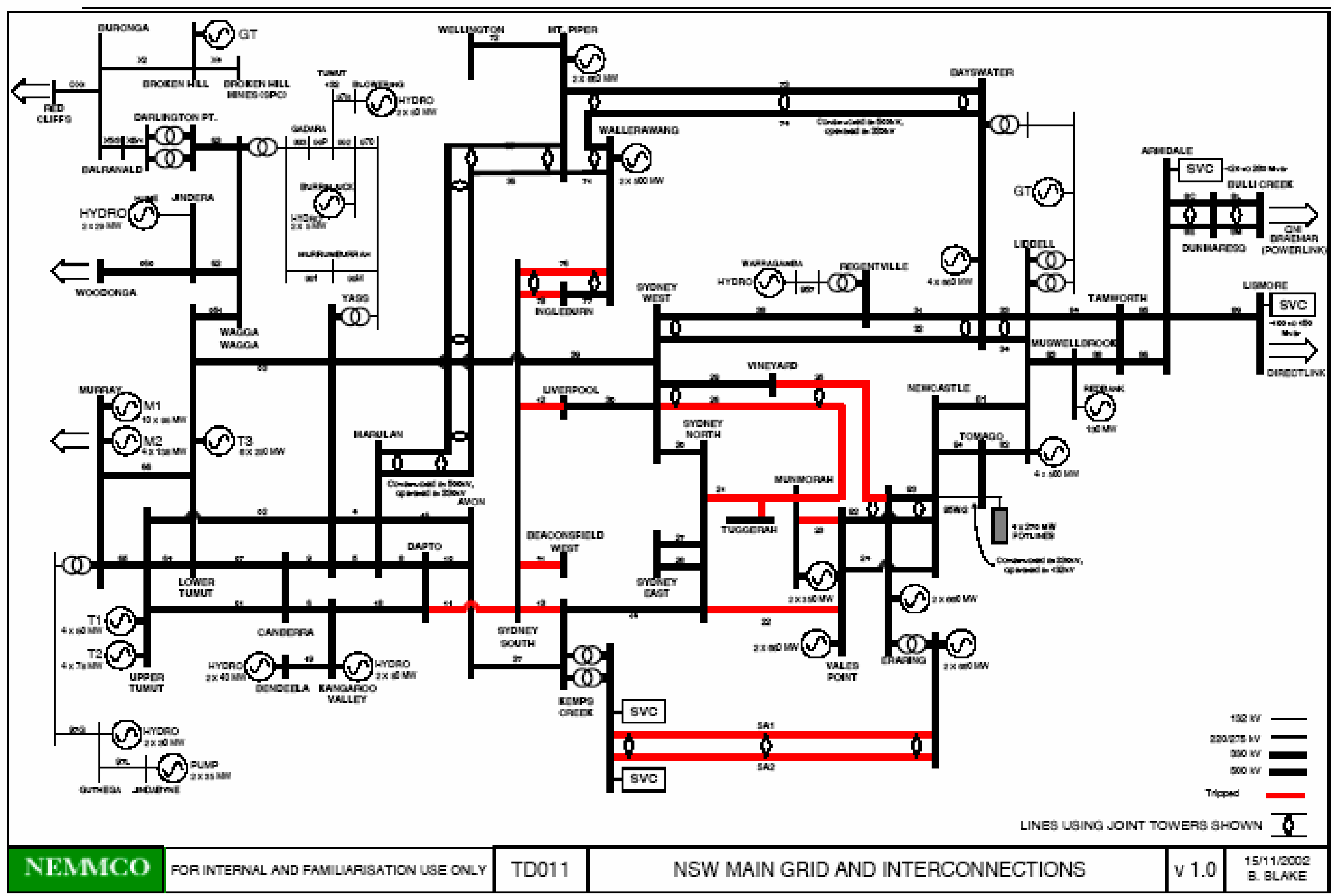
- Initial engineering response:
  - Load shed by prearranged under-frequency protection
  - Generator output increased via frequency control (FCAS)
- Transformed into initial commercial response:
  - Energy & FCAS offer stack & flow constraints reflect the outage within 5 minutes:- initiating commercial response
- Long-term commercial and policy responses:
  - Not clear if derivative market behaviour responded
  - As yet no policy response:
    - Was DR contribution adequately compensated?

16 region NEM model
(NEMMCO SOO, 2004)

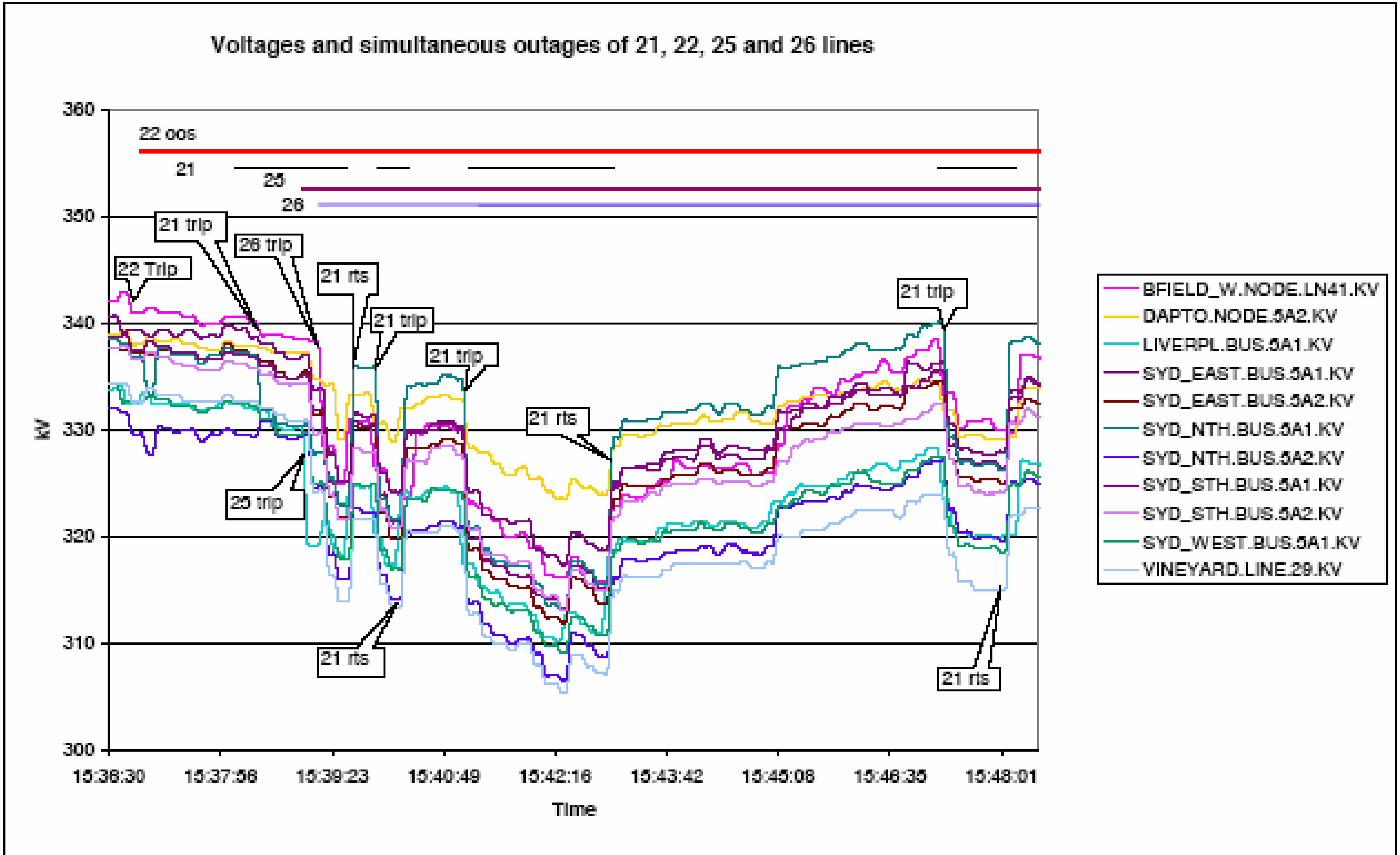
Node	Pk Ld (MW)	Gen (MW)	Net Gen (MW)
NQ	1250	800	- 450
CQ	1900	4150	2250
SWQ	200	2150	1950
SEQ	4350	1450	- 2900
NNS	800	150	- 650
NCEN	10000	11650	1650
CAN	800	300	- 500
SNY	800	3900	3100
MEL	5750	800	- 4950
LV	900	7000	6100
POR	650	0	- 650
SESA	100	150	50
RIV	500	50	- 450
ADE	2100	2250	150
NSA	200	1100	900
TAS	1500	2500	1000



NSW bushfires Dec 02: lines with multiple trips shown in red



Sydney region voltages during 12/02 bushfire outages

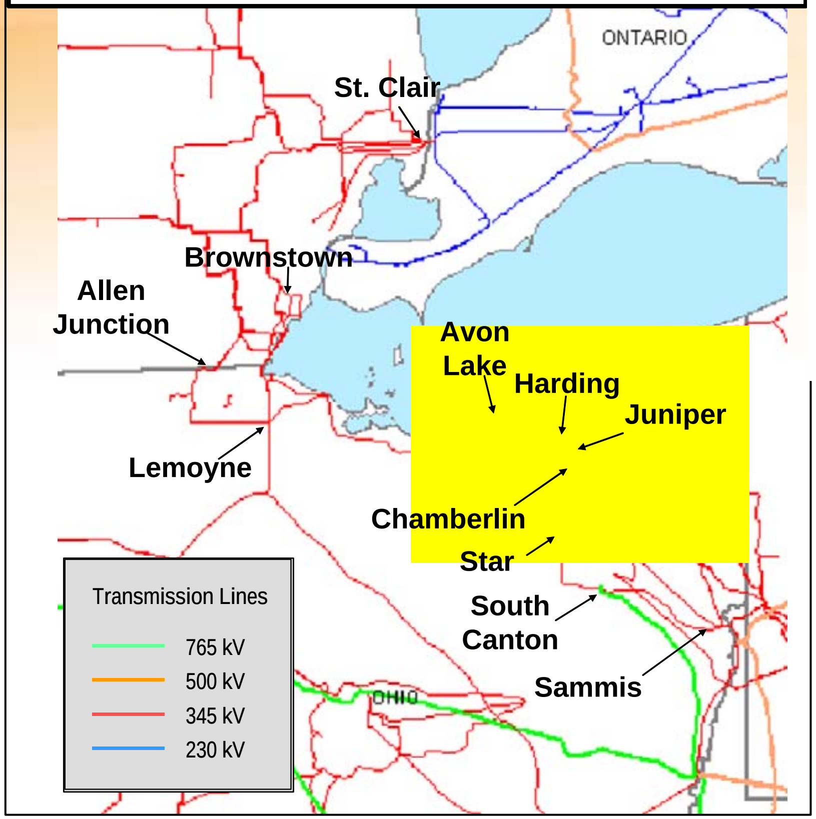


NEM management of voltage disturbances

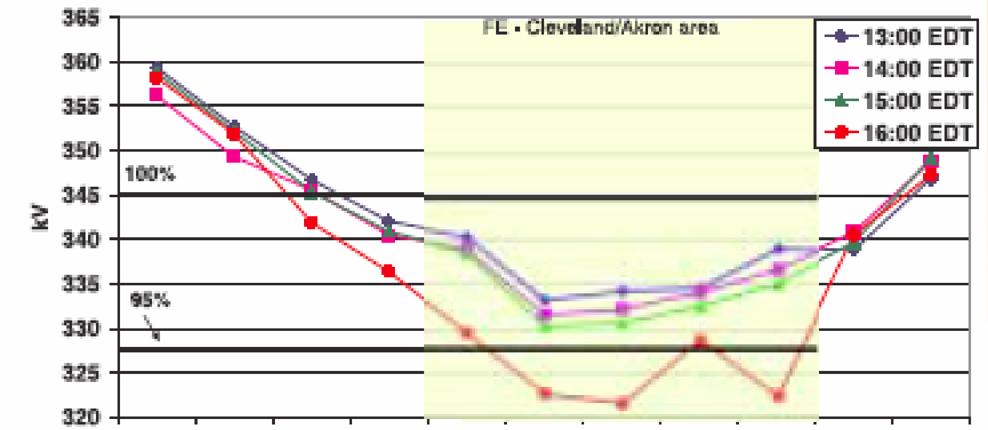
- Initial engineering response:
  - Reactive power production increased where available
  - Load shed by preset under-voltage protection
- Not transformed into commercial response:
  - NEM spot energy market uses transport flow model
- Long-term commercial and policy responses:
  - As yet no policy intent to integrate engineering & commercial management of voltage disturbances
  - Instead, poor reliability & quality are key drivers for network investment

August 2003 North American Blackout
(final report summary)

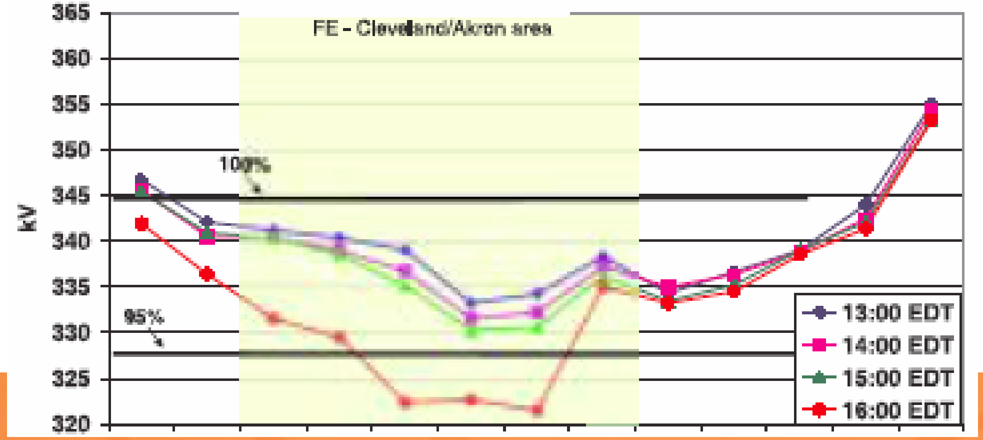
North to South 345kV Voltage Profile Locations



Hourly North-South 345kV Actual (Measured) Voltages on August 14th



Hourly West-East 345kV Actual (Measured) Voltages on August 14th



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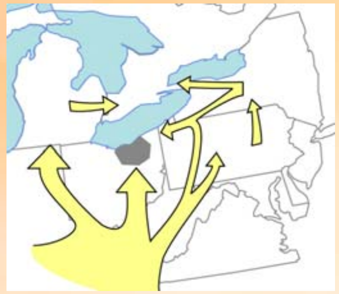
16:05:57

2.

16:05:58

3.

16:09:25

4.

16:10:37

5.

16:10:39

6.

16:10:40

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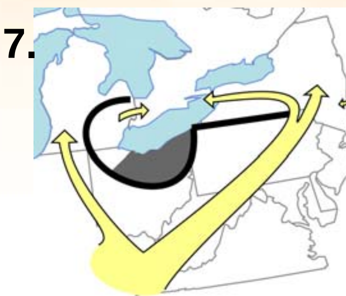
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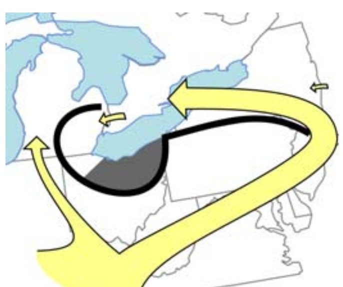

16:10:44

9.

16:10:45

10.

16:13:00

The critical role of voltage in an electricity industry

- Voltage is an important measure of the quality of electrical energy:
  - A technical measure:- equipment may malfunction outside its design voltage range
  - A commercial measure:- risk of non-delivery of energy services (end-user) or inability to produce (generator)
- Voltage is shared by all participants at a node and may be a scarce resource after a contingency:
  - Technical rationing via under/over voltage protection
  - Market rationing via bid & offer functions

AC loadflow with voltage-value functions

(an alternative to specifying voltage constraints)

- Outside a preferred voltage range:
  - A generator wants greater compensation
  - A consumer won't pay as much
- bid (offer) price = [VVF]x[standard offer]
  - Where the voltage-value function (VVF) used for these studies was (Pamudji, 1995):

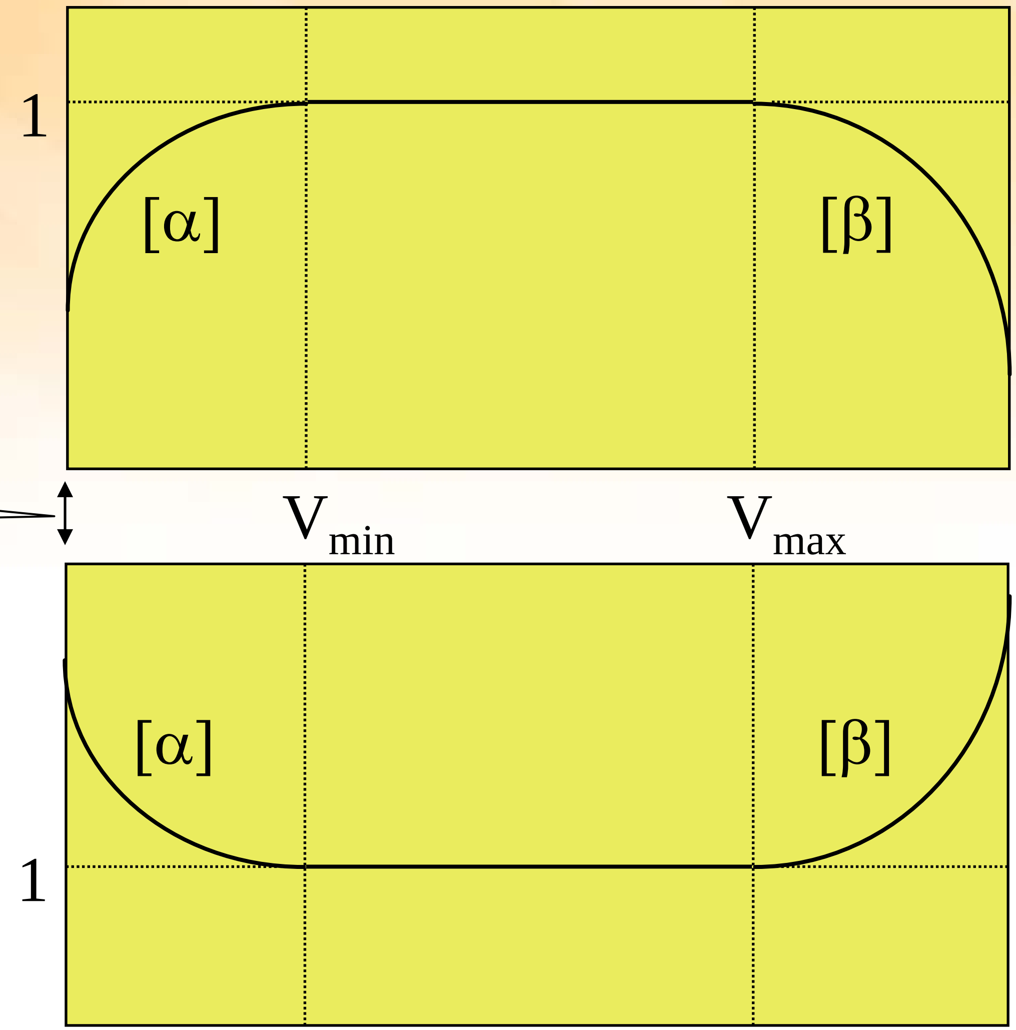
$$VVF = \begin{cases} 1 + (V_{min} - V)^3 & \text{if } V < V_{min} \\ 1 & \text{if } V_{min} < V < V_{max} \\ 1 + (V - V_{max})^3 & \text{if } V > V_{max} \end{cases}$$

Effect of VVF's on bids & offers

(Pamudji, 1995)

Bid VVF

(a consumer won't pay as much outside a preferred voltage range)



Under-voltage Protection Setting

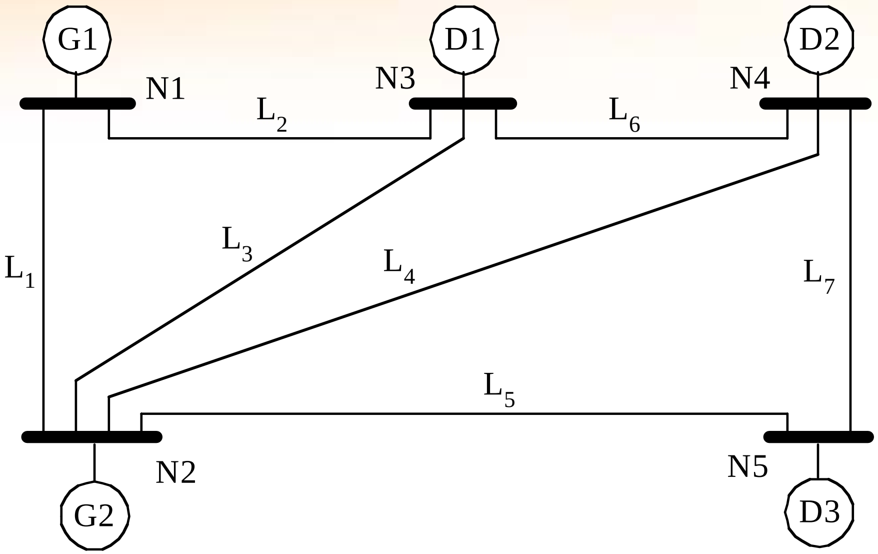
Offer VVF

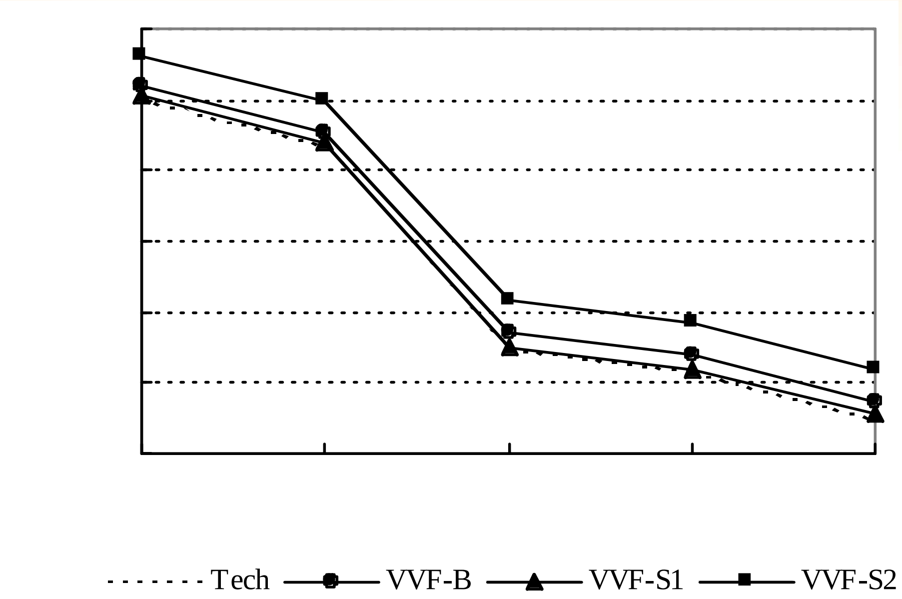
(a generator wants greater compensation outside a preferred voltage range)

VVF vs technical regulation of voltage

(Kim, 2005)

Node	Technical Regulation	VVF-B $\alpha_1=\beta_1=5000$	VVF-S1 $\alpha_1=\beta_1=100000$	VVF-S2 $\alpha_1=\beta_1=500$
N1	1.050	1.054	1.051	1.062
N2	1.037	1.041	1.038	1.050
N3	0.979	0.984	0.980	0.993
N4	0.973	0.978	0.974	0.987
N5	0.960	0.965	0.961	0.974





Conclusions on DR contribution to NEM

- Two important issues in valuing DR:
  - Quality of supply, particularly voltage & frequency
  - Obligation to serve *(externalities also important)*
- DR role can be facilitated by coordinated technical & market mechanisms:
  - NEM manages frequency better than voltage:
    - Voltage is a primarily a retail market issue & politically charged
  - VVF model offers a possible way forward for voltage but we need to explore market behaviour first

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