Supplementary Information

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I. Nomenclature

This section sets out relevant nomenclature for the mathematical formulation:

TABLE I
MODEL INDICES AND SETS

Notation	Description
$r \in \mathcal{R}$	r denotes a resource and $\mathcal{R}$ is the set of all resources
$\mathcal{G} \subset \mathcal{R}$	$\mathcal{G}$ is the subset of all generation resources
$\mathcal{S} \subset \mathcal{R}$	$\mathcal{S}$ is the subset of all storage resources
$\mathcal{H} \subset \mathcal{R}$	$\mathcal{H}$ is the subset of all hydro generation resources
$\mathcal{G}^n, \mathcal{S}^n, \mathcal{H}^n \subset \mathcal{R}$	The subset of all resources, generation and hydro located at node/region n
$\mathcal{R}^{der} \subset \mathcal{R}$	$\mathcal{R}^{der}$ is the subset of all resilient distributed energy resources available for investment by the insurer
$\mathcal{G}^{der} \subset \mathcal{R}$	$\mathcal{G}^{der}$ is the subset of all resilient distributed generation resources available for investment by the insurer
$\mathcal{S}^{der} \subset \mathcal{R}$	$\mathcal{S}^{der}$ is the subset of all resilient distributed storage resources available for investment by the insurer
$m, n \in \mathcal{N}$	n denotes a zone/node and $\mathcal{N}$ is the set of all zones/nodes in the network (m is an alternate index)
$l \in \mathcal{L}$	l denotes a transmission line and $\mathcal{L}$ is the subset of all transmission lines in the network
$\mathcal{L}^n \subset \mathcal{L}$	$\mathcal{L}^n$ is the subset of all transmission lines originating from node n
$d \in \mathcal{D}$	d denotes a consumer and $\mathcal{D}$ represents the set of all consumers
$\mathcal{D}^n \subset \mathcal{D}$	The subset of all consumers located at node/region n
$i \in \mathcal{I}$	i denotes a segments used in the piecewise approximation of the operating reserve demand curve, and $\mathcal{I}$ is the set of segments
$j \in \mathcal{J}$	j denotes a segments used in the piecewise approximation of the capacity mechanism demand curve, and $\mathcal{J}$ is the set of segments
$\omega \in \Omega$	ω denotes a scenario and Ω represents the set of scenarios
$t \in \mathcal{T}$	t denotes a dispatch interval (a half-hour) and $\mathcal{T}$ represents the set of all dispatch intervals

TABLE II
PARAMETERS

Notation	Description
α^G_r	α-tail probability of the conditional-value-at-risk for market resources
α^i	α-tail probability of the conditional-value-at-risk for the insurer
α^c_d	α-tail probability of the conditional-value-at-risk for consumer d
$\beta_{r/d/i}$	weight given to the CVAR for market resource r, consumer d, and insurer i
π_ω	The probability of scenario ω
$C^{vc}_{rt\omega}$ $[\boldsymbol{C}^{vc}_{r\omega}]$	The short-run variable cost of energy delivered from resource r at time t in scenario ω
C^I_r	The annualised investment cost of resource r
C^R_r	The short-run variable cost of providing reserve from resource r at time t in scenario ω
C^{rsh}_i	The system penalty cost of unmet reserve for operating reserve demand curve segment i
C^{sh}_d	The system value of lost-load for demand d
C^U_j	The administrative penalty cost of unmet capacity reserve for capacity mechanism demand curve segment j
$\overline{P^D_{dt\omega}}$ $[\overline{\boldsymbol{P}}^D_{d\omega}]$	Consumer energy demand at time t in scenario ω
B_{nm}	The admittance of the transmission line from node m to n.
$A^G_{rt\omega}$ $[\boldsymbol{A}^G_{r\omega}]$	The generation availability of resource r at time t in scenario ω
A^{CM}_r	The derated capacity of resource r for the capacity mechanism auction, based on the effective load carrying capacity.
$A_{nm,t,\omega}$ $[\boldsymbol{A}^L_{nm,\omega}]$	Availability of the transmission line from node m to n
$\overline{P}_r$	The power capacity of resource r
u_r	The binary build status of resource r, taking a value of 0 or 1
q^+_r	he charging efficiency of storage resource r
q^-_r	The discharging efficiency of storage resource r
$i^{G+}_{rt\omega}$	Inflows to hydrological storage reservoir for resource r at time t in scenario ω
e_r	The maximum energy storage duration of resource r
R^{req}_i	The required reserve in MW for operating reserve demand curve segment i
$\overline{R^{req}}$	The total required operating reserves in MW
D^{th}_j	The required capacity demand in MW for capacity mechanism demand curve segment j
$p^{sh*}_{dt\omega}$ $[\boldsymbol{p}^{sh}_{d\omega}]$	Unserved energy of consumer d at time t for scenario ω, as an output from the market equilibrium.
γ	Annualised discount factor for capital investments
κ	Capital investment cost subsidy offered to consumers by the insurer for RDER investments
C^P_d	Insurance premium levied upon consumer d
C^{voll}_d	The consumers value of reliability for load shedding for consumer d
C^{comp}_d	The insurance compensation payout value for consumer d in \$ per MWh.
ED_ω	The economic dispatch problem for each scenario ω.
CM	This problem representing the clearing of the capacity mechanism.
CON_d	The risk-averse utility maximization problem for consumer d.
INS	The risk-averse utility maximization problem for the insurer using CVAR.
INS^a	The risk-averse utility maximization problem for the insurer using a worst-case approach.
U^G_r	Risk-averse utility for resource r.
U^c_d	Risk-averse utility for consumer d.
U^i	Risk-averse utility for the insurer.

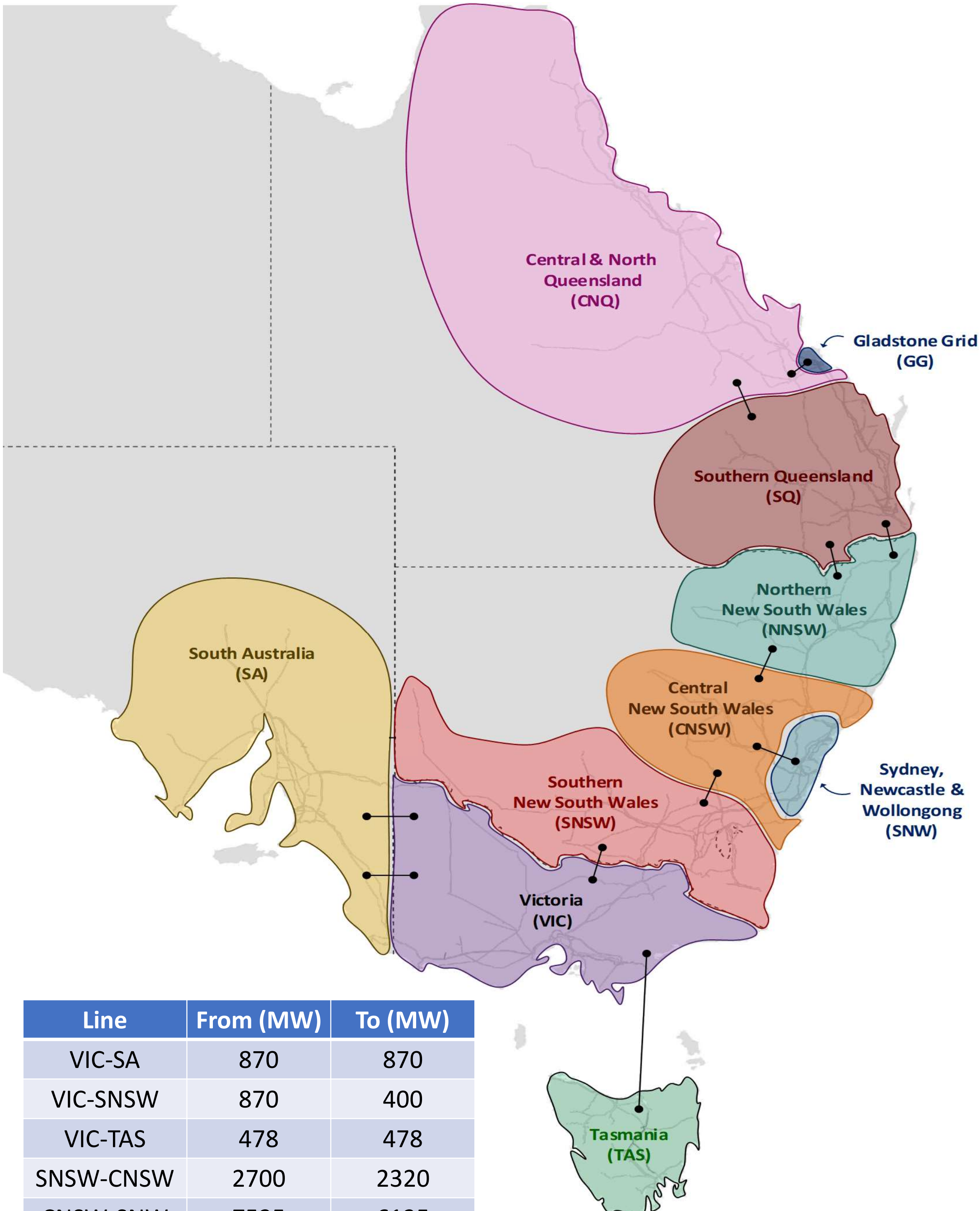
* The vectorized form of the parameters that vary over time are shown in **bold** and square brackets.

TABLE III
DECISION VARIABLES

Notation	Description
$p^{G}_{rt\omega}$ $[\boldsymbol{p^{G}_{r\omega}}]$	The energy dispatch of resource r at time t in scenario ω.
$p^{G+}_{rt\omega}$ $[\boldsymbol{p^{G+}_{r\omega}}]$	The energy discharge dispatch of storage resource r at time t in scenario ω.
$p^{G-}_{rt\omega}$ $[\boldsymbol{p^{G-}_{r\omega}}]$	The energy charge dispatch of storage resource r at time t in scenario ω.
$p^{sh}_{dt\omega}$ $[\boldsymbol{p^{sh}_{d\omega}}]$	The unserved load of consumer d at time t in scenario ω.
$S_{rt\omega}$ $[\boldsymbol{S_{r\omega}}]$	The state of charge of storage or hydro resource r at time t in scenario ω.
$p^{R}_{rt\omega}$ $[\boldsymbol{p^{R}_{r\omega}}]$	The reserve dispatch of resource r at time t in scenario ω.
$p^{R+}_{rt\omega}$ $[\boldsymbol{p^{R+}_{r\omega}}]$	The reserve discharge dispatch of storage resource r at time t in scenario ω.
$p^{R-}_{rt\omega}$ $[\boldsymbol{p^{G-}_{r\omega}}]$	The reserve charge dispatch of storage resource r at time t in scenario ω.
$p^{rsh}_{it\omega}[\boldsymbol{p^{rsh}_{i\omega}}]$	The unmet reserve for operating reserve demand curve segment i at time t for scenario ω
p^{CM}_{r}	The cleared capacity of resource r for the capacity mechanism auction
p^{U}_{j}	The unmet quantity of capacity market demand for capacity mechanism demand curve segment j
$\theta_{t\omega n}[\boldsymbol{\theta_{\omega n}}]$	The phase angle of node n at time t for scenario ω
$\lambda^{E}_{t\omega n}[\boldsymbol{\lambda^{E}_{\omega n}}]$	Locational marginal price for energy for node n at time t for scenario ω
$\lambda^{R}_{t\omega}[\boldsymbol{\lambda^{R}_{\omega}}]$	The system marginal price for operating reserve at time t for scenario ω
λ^{CM}	The system marginal price for capacity based on the clearing of the capacity mechanism.
$\overline{P_g}$	The resource capacity for DER resource g in the INS and CON_d problems.
v^{r}_{G}	Auxiliary decision variable representing value-at-risk for market resource r
v^{i}	Auxiliary decision variable representing value-at-risk for insurer i
v^{d}_{c}	Auxiliary decision variable representing value-at-risk for consumer d
$\Psi^{G}_{r\omega}$	Scenario profits for resource r
Ψ^{i}	Scenario profits for the insurer
Ψ^{c}_{d}	Scenario profits for consumer d
$\varrho^{G}_{g\omega}$	CVAR auxiliary decision variable as positive difference between z^{G}_{r} and scenario profits $\Psi^{G}_{r\omega}$ for resource r
ϱ^{i}_{ω}	CVAR auxiliary decision variable as positive difference between z^{i} and Ψ^{i} scenario profits for the insurer
$\varrho^{c}_{d\omega}$	CVAR auxiliary decision variable as positive difference between z^{c}_{d} and Ψ^{c}_{d} scenario profits for consumer d
ϕ^{i}	Required capital reserves for insurer
$p^{c}_{d,t,\omega}[\boldsymbol{p}^{c}_{d\omega}]$	Quantity of load shed for consumer d at time t for scenario ω

* The vectorized form of the decision variables that vary over time are shown in **bold** and square brackets.

II. Modelled network topology



Line	From (MW)	To (MW)
VIC-SA	870	870
VIC-SNSW	870	400
VIC-TAS	478	478
SNSW-CNSW	2700	2320
CNSW-SNW	7525	6125
CNSW-NNSW	910	930
NNSW-SQ	685	1335
SQ-CNQ	700	2100
CNQ-GG	700	750

Fig. 1. Modelled network topology of the National Electricity Market with ten local regions. Black Lines with adjoining dots represent transmission links between regions. Transmission network capacities between regions are indicated in the adjoining table. Adapted from [35]

III. Extreme year scenarios used for Case Study

TABLE IV
Description of extreme year scenarios for case study

#	Scenario	Description
1.	Extreme demand & islanding - VIC/SA	Demand increased by 20% over peak representative day.
		Availability for VIC-SA links constrained by 90%
2.	Extreme demand & islanding - TAS	Demand increased by 40% over peak representative day.
		TAS-VIC link unavailable %
3.	Extreme demand & islanding - QLD	Demand increased by 30% over peak representative day.
		Lines to northern QLD (SQ-CNQ and CNQ-GG) unavailable
4.	High temperature thermal unavailability	Demand increased by 10% over peak representative day.
		Thermal generation availability across all regions reduced by 40%
5.	Renewables ‘dunkelflaute’	Demand increased by 10% over peak representative day.
		Variable renewable generation availability across all regions reduced by 80%
6.	Drought	Hydro inflows across all regions reduced by 20% over year