Project EnergyConnect System Integration

Industry Update

23 November 2023

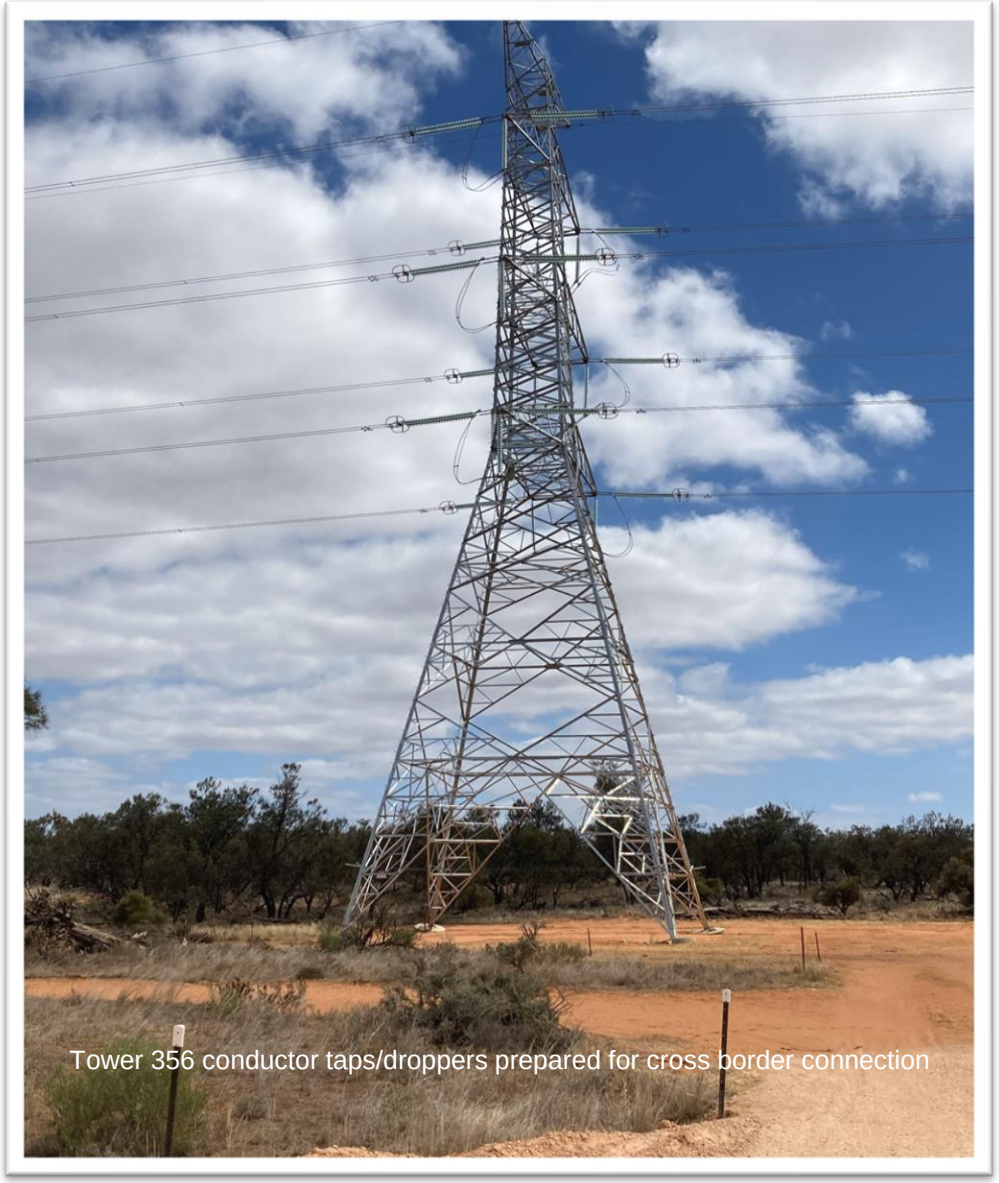
ElectraNet | Transgrid AEMO AusNet ProjectEnergyConnect.com.au

Purpose

- Project EnergyConnect (PEC) industry update
- Focus on System Integration activities
- Regular updates - next one in Q1 2024
- Slide pack published on the Project EnergyConnect website

Outline

- Brief recap of key points from previous industry update
- Key topics for this industry update
- Reference slides (covered at previous update)



Tower 356 conductor taps/droppers prepared for cross border connection

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Brief recap of key points from 17/08/23 industry update

Hugo Klingenberg - ElectraNet

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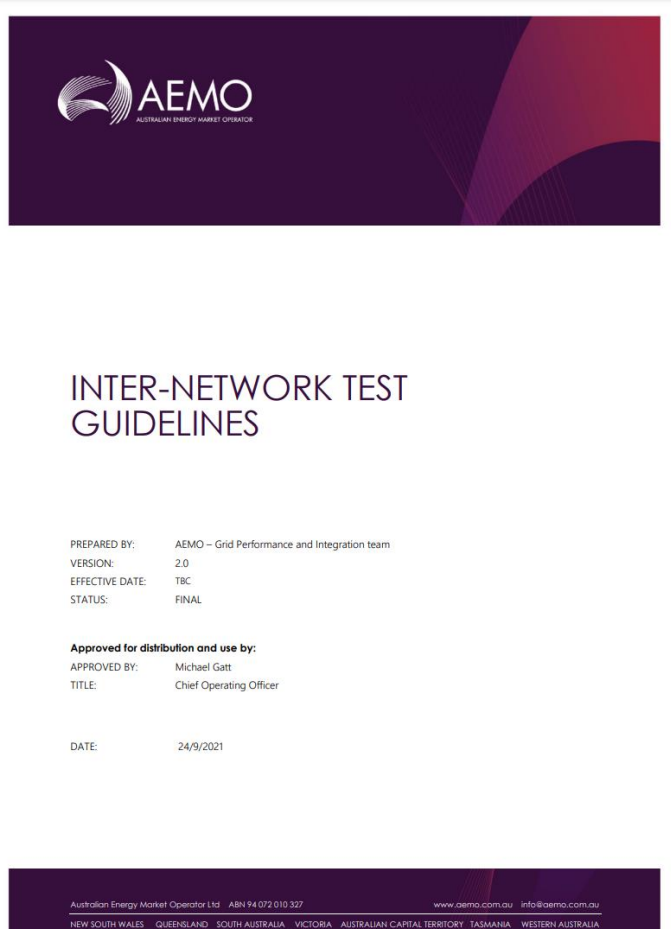
Capacity Release

- Capacity across PEC will be released according to an agreed inter-network test program
- Inter-network tests can only start once the following pre-requisites have been met:

Pre-requisites	PEC-1	PEC-2
AEMO market systems are ready		
All network infrastructure is 'AEMO asset ready'		
Relevant Special Protection Schemes have been reviewed/ commissioned		
Limits advice has been provided by TNSPs and developed into constraint equations by AEMO		

- Key milestones:
  - ☐ Draft inter-network test plan for PEC-1 plan to publish for industry consultation shortly
  - ☐ Overview of expected PEC-1 limits – following slides
  - ☐ Updated PEC-1 limits/ constraints for SA, NSW & Vic – Dec 2023
  - ☐ Final inter-network test plan for PEC-1 published – Feb 2024
  - ☐ PEC-2 indicative limits – later in this presentation
  - ☐ Updated PEC-2 limits/ constraints for SA, NSW & Vic – Dec 2024

Note: PEC modelling data is available via the AEMO data request process



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Key changes – PEC-1

PEC-1 results in effectively a bigger Heywood Interconnector (HIC)

Vast majority of existing constraints are expected to remain in place

- HIC trip will intertrip PEC-1
- PEC-1 150 MW – in both directions (with slight reduction at very high Murraylink flows)
- Combined transfer limits for PEC-1 and HIC - SA-VIC: 700 MW, VIC-SA: 750 MW*

Impact on existing Special Protection Schemes (SPSs):

- All Special Protection Schemes (SPSs) potentially impacted by the PEC-1 integration have been reviewed – One change: Trip parallel 132 kV circuit for either Tailem Bend to South East or Tungkillo to Tailem Bend 275 kV line trips
- Murraylink Very Fast Run Back (VFRB) scheme will be upgraded shortly after the second Buronga – Red Cliffs 220 kV circuit is commissioned

*Additional HIC capacity release is subject to effective management of interconnector drift and consideration of impact of mainland contingencies on SA interconnector flows.

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Expected impact of constraint changes – PEC-1

PEC-1 constraint / limit changes

New constraints

- Overload on Buronga PST for trips of Murraylink

Revised limits

- Existing Line X5 (Balranald – Darlington Point) voltage stability limit which is expected to be relieved marginally
- Existing thermal limits in NW Vic and SW NSW to include PEC term
- System strength limits under outages in NW Vic likely to change
- Further revision to limit factors when second Buronga – Red Cliffs 220 kV circuit is commissioned

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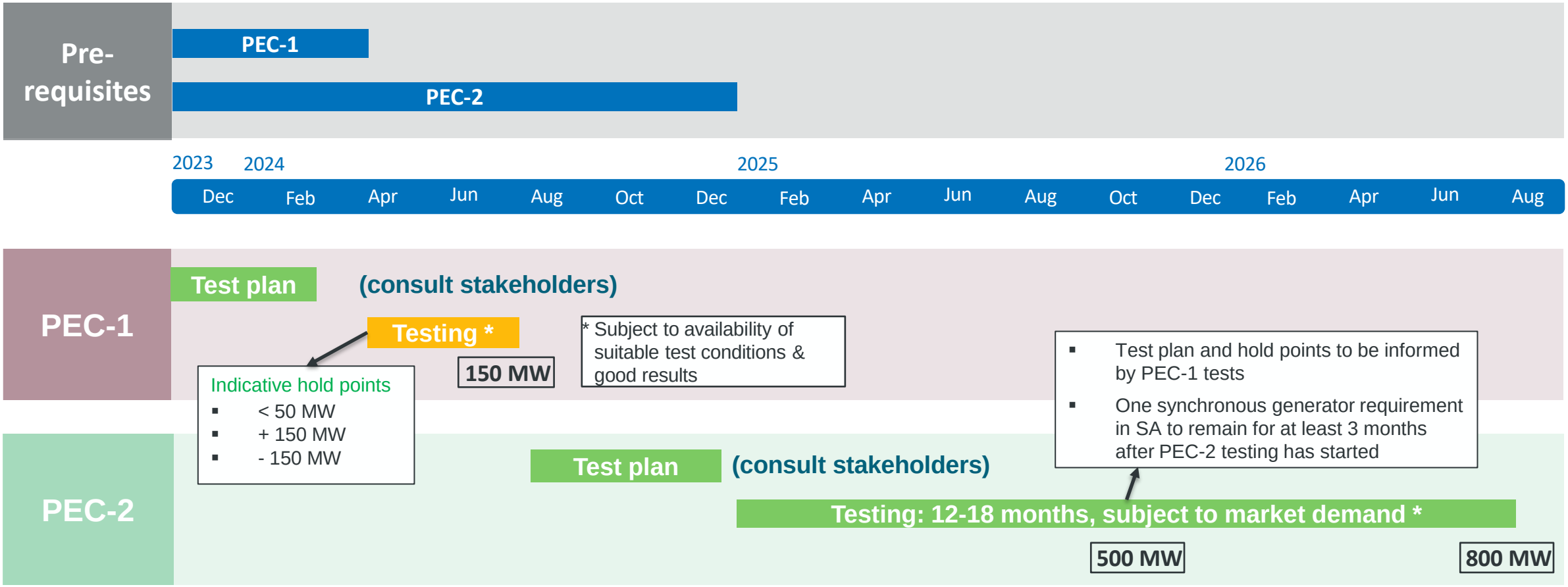
PEC capacity release – key dates

Estimated dates and indicative hold points for inter-network testing



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Outline for today's briefing

- Market integration and management of negative residues - AEMO
- PEC-1 inter-network test program - AEMO
- Expected Phase Shifting Transformer (PST) Operation - Transgrid
- Indicative limits for PEC-2 - ElectraNet
- Managing connection interest - Transgrid

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Market integration

Cara Teoh - AEMO

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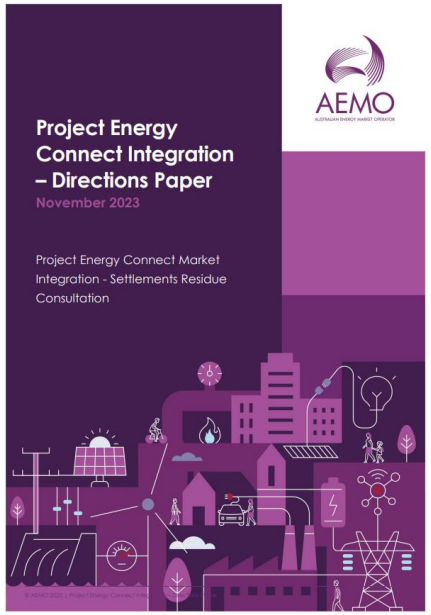
PEC Market Integration
Directions Paper Consultation Open



Topics for consideration in the Paper include:

- Negative residue management
- Reallocation of negative interregional settlement residues
- Payments for negative IRSR
- Implementation considerations for
  - SRA Units,
  - Changes to AEMO's systems,
  - Timing of implementation

- Stakeholder submissions are requested by **1 December**
- Once all feedback is received, AEMO will finalise and publish recommendations for market integration to proceed
- This will include initiation of relevant AEMC Rule Change and AEMO Procedure change processes.

➢ Please contact us at NEMReform@aemo.com.au if you would like to organise a meeting or send us questions

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Proposed approaches for negative IRSR

Management of negative IRSR

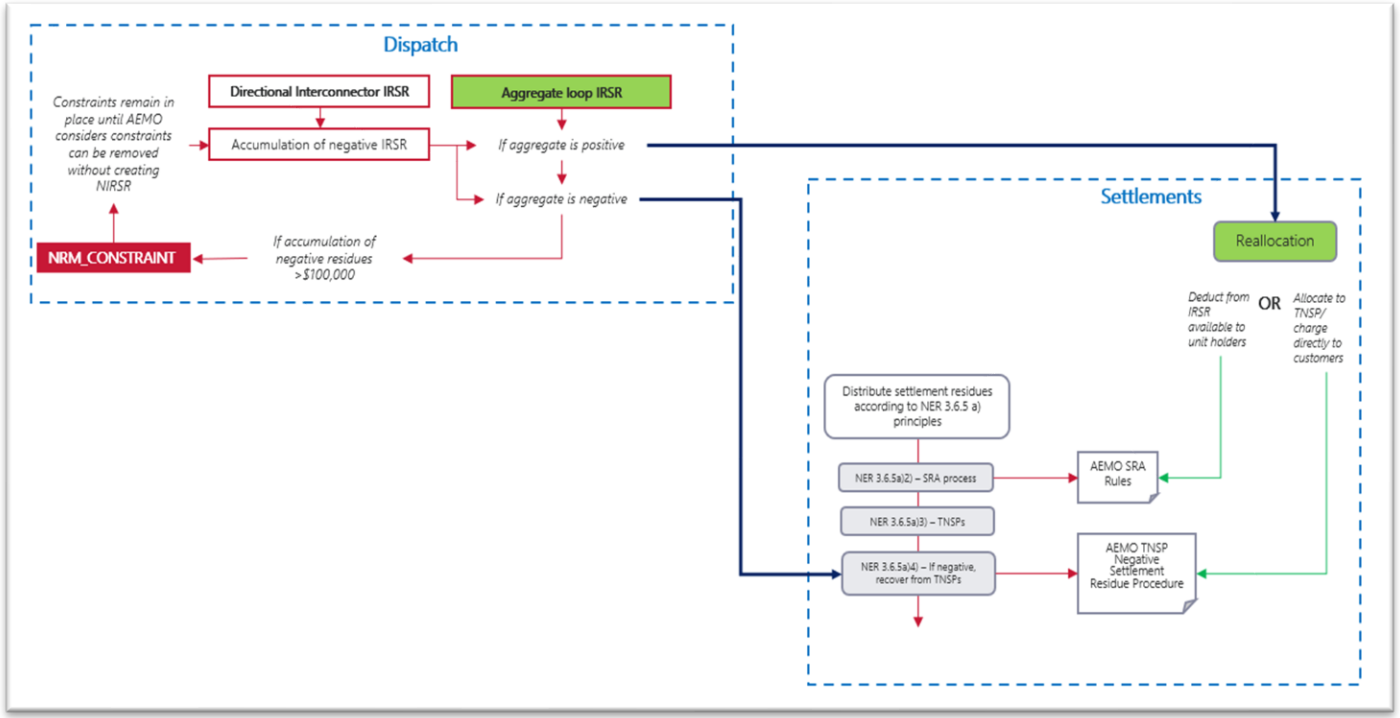
- Apply negative residue management clamping when settlement is in deficit only
- Not technically feasible nor economically efficient to maintain current process

Reallocation approach options

1) When settlement is in surplus around the loop, but negative IRSR is accruing, reallocate negative IRSR based on the relative ratio of positive IRSR for each trading interval
2) Spread the effect of negative IRSR and reflect the role counter-priced flows are having in allowing positive interconnectors to achieve those flows

Payment options of negative IRSR

1) Charge directly to customers in importing regions via the TNSP – affects TNSP cashflow
2) Deduct negative IRSR from the calculation of IRSR available for distribution to unit holders under the SRA – impacting hedging value of SRA
    - Customers will pay, but indirectly through lower SRA proceeds



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PEC-1 inter-network test program

Callan Masters - AEMO

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PEC-1 Draft inter-network test plan for industry consultation

Summary of proposed testing under NER 5.7.7:

- Assessment of system damping
- Switching of key transmission lines:
  - South East – Tailem Bend 275 kV line (including associated Black Range series capacitor)
  - Robertstown – Tunkillo 275 kV line
- Other tests:
  - Tapping of Buronga Phase Shifting Transformer
  - Murraylink interconnector runback
  - Murraylink interconnector reactive ramping
  - Buronga Synchronous condenser voltage step test
- Progression through successive hold points in increments of 50 MW or greater
- Monitoring of power system performance throughout
- Communication to the market throughout

Indicative timeline:

- November to December 2023 - industry consultation
- February 2024 - final test plan published
- April 2024 - commence inter-network testing

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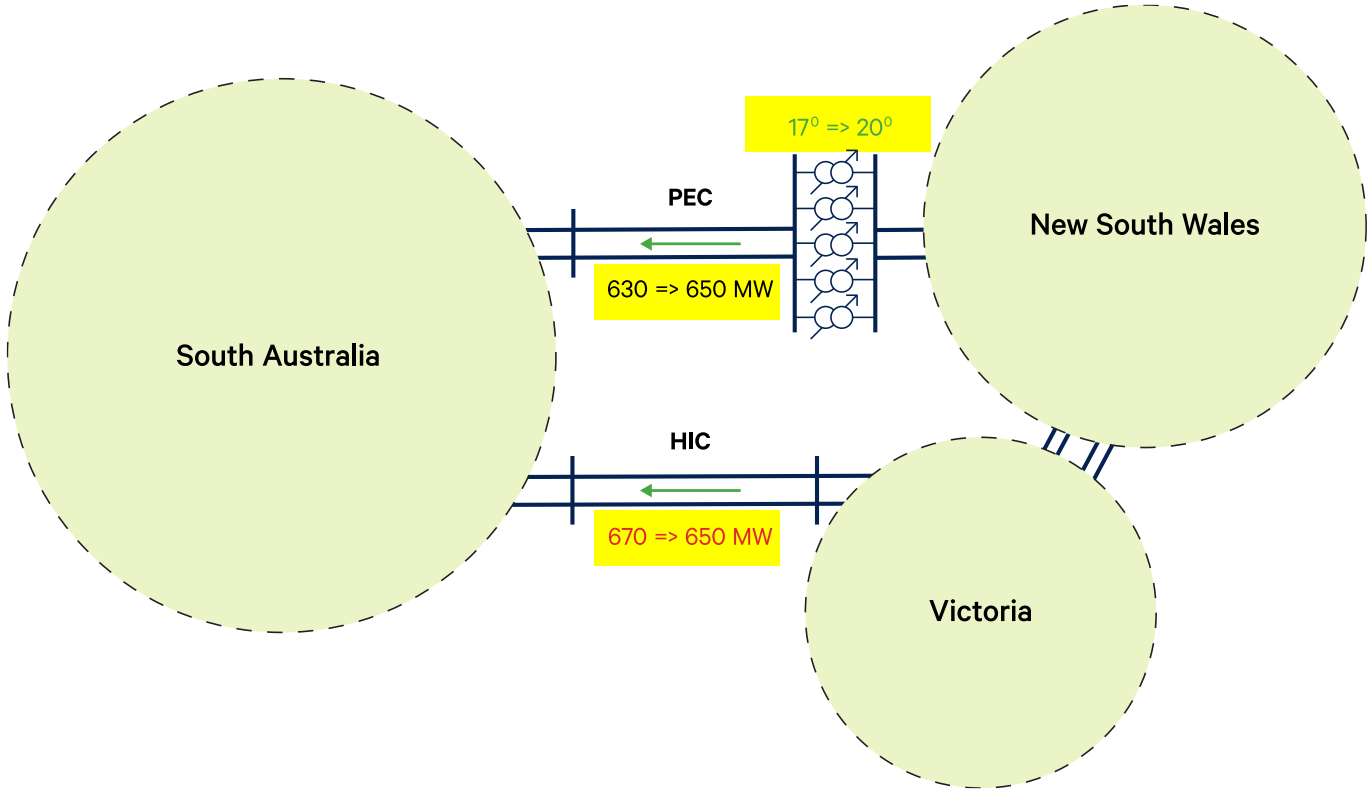
Expected PST operation

Jahan Peiris – Transgrid

Phase Shifting Transformers (PSTs): Expected operation

- PST allows optimisation of power flow sharing on PEC and Heywood (HIC) Interconnectors
- PST tap setting (angle) will be an input to the AEMO NEM Dispatch Engine
- Taps can be manually or automatically changed to divert flows between HIC and PEC when one of them gets closer to limits
- At times of high transfer, each PST tap change is expected to vary PEC flow by about 10 MW with PEC-1, and about 20 MW with PEC-2

Example	PST tap angle (degrees)	HIC (MW)	PEC (MW)	Combined transfer (MW)
SA import	17	670	630	1300
	≈1 tap ↓			
	20	650	650	1300
	40	510	780	1290
	0	780	520	1300
SA export	-25	730	710	1450
	≈1 tap ↓			
	-28	710	730	1450
	-40	640	810	1450
	0	890	530	1420



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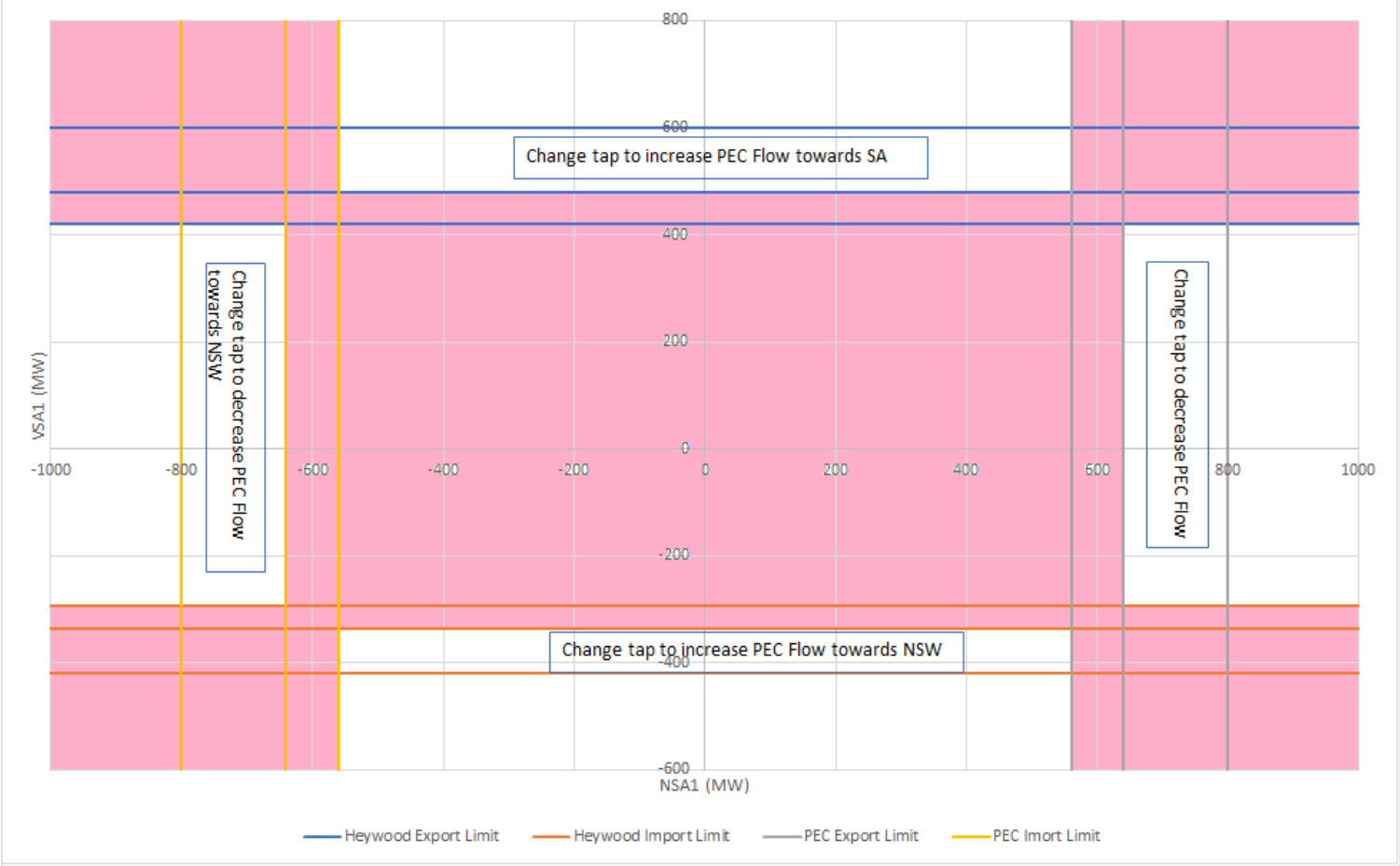
Phase Shifting Transformers (PSTs): Control strategy overview



- System normal conditions: PSTs operated in Auto mode to enable efficient power flow sharing on HIC and PEC interconnectors.
- Auto mode: PST tap changer will operate when one interconnector is above 80% of its nominal capacity, while the other is below 70% of its nominal capacity (**white** areas in the figure)
- The tap changer will not operate when the interconnectors are not approaching constraints or are equally constrained (**pink** areas in the figure).
- Non-Auto control mode will be activated under abnormal or high-risk system conditions. Under Non-Auto mode, the PSTs will be manually controlled by Transgrid under AEMO's instruction.

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Indicative limits for PEC-2

Hugo Klingenberg - ElectraNet

Anticipated constraints for PEC-2

New constraints

- Combined system normal limit of 1,300 MW import into SA and 1,450 MW export from SA across PEC and Heywood – hard design limit with Buronga PST at (+/-40 degrees)
- ElectraNet will develop new voltage, transient and thermal limit equations based on PEC-2 network configuration for both system normal and N-1 network operating conditions

Constraints being revised

- Line X5 (Balranald – Darlington Point) voltage stability limit – expected increase of 15 MW depending on PEC-1 and reactive plant status
- Thermal limits in NW Vic and SW NSW to include PEC term
- System strength limits to be assessed with PEC-2 and HIC operating in parallel
- System oscillatory (damping) limits will be assessed with PEC-2 and HIC operating in parallel

Anticipated conditions where above combined transfers may not be fully achievable

- Network element outages – refer next slides
- Regional generation dispatch or availability of generation sources
- Impact of local demand close to the PEC & HIC corridors

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Expected impact of prior outages following PEC-2 (1/3)

The MW values quoted are based on limited studies and are indicative only

Prior Outage	Expected impact on transfer capability	Expected impact on generators (in addition to transfer capability, mainly system strength)	Comment
Any circuit along the Wagga-Buronga-Bundey-South East-Heywood-Moorabool corridor (PEC and HIC corridor)	An outage of one circuit on this corridor results in loss of the other circuit to be a credible contingency event. Combined transfers across PEC and HIC will be reduced to about 800 MW	SA: No system strength impact anticipated NSW: No pre-contingent disconnection of existing renewable generators in south west NSW VIC: No impact on Vic gens anticipated	
SA transmission line (not on the PEC and HIC corridor)	Minimal impact expected on PEC and HIC transfers. Existing voltage limits are present in the Mid North of SA for outages on the Robertstown to Davenport corridor	SA: Local impact only, effectively the same as current limits NSW & VIC: Minimal impact expected	
NW Victoria transmission line (not on PEC and HIC corridor)	Minimal impact on PEC	VIC: Some impact depending on location / anti-islanding schemes SA & NSW: Minimal impact expected	
Any one SVC in South Australia	Expected to be less than 50 MW reduction	SA: No system strength impact anticipated NSW: No pre-contingent disconnection of existing renewable generators in south west VIC: No impact on Vic gens anticipated	
Any one synchronous condenser at Davenport or Robertstown	Expected to be less than 50 MW reduction	SA: SA instantaneous IBR generation limit reduced from 2,500 to 2,200 MW NSW & VIC: Minimal impact expected	

Expected impact of prior outages following PEC-2 (2/3)

The MW values quoted are based on limited studies and are indicative only

Prior Outage	Expected impact on transfer capability	Expected impact on generators (in addition to transfer capability, mainly system strength)	Comment
Any one synchronous condenser at Buronga or Dinawan	About 50 MW reduction	SA: Minimal impact expected NSW: No pre-contingent disconnection of existing renewable generators in south west NSW VIC: No impact on Vic gens anticipated	
Buronga to Red Cliffs Line X1	Expected to be less than 50 MW reduction	Balranald renewable generation can remain in service; Broken Hill renewable generation can remain in service	Line OX1 trip scheme to be modified
Buronga to Balranald Line X3	Expected to be less than 50 MW reduction	Balranald 220 kV renewable generation to be disconnected as per existing arrangements; Broken Hill renewable generation can remain in service	Line X3 trip scheme to be modified
Balranald to Darlington Point Line X5	About 50 – 100 MW reduction	Balranald renewable generation can remain in service; Broken Hill renewable generation can remain in service	Line X5 trip scheme to be modified

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Expected impact of prior outages following PEC-2 (3/3)

The MW values quoted are based on limited studies and are indicative only

Prior Outage	Expected impact on transfer capability	Expected impact on generators (in addition to transfer capability, mainly system strength)	Comment
Darlington Point to Wagga Line 63	Expected to be less than 50 MW reduction	Darlington Point renewable generation to be disconnected as per existing arrangements; Balranald renewable generation can remain in service; Broken Hill renewable generation can remain in service; Line X5 to be opened as per existing arrangements	Line 63 trip scheme to be modified
Lower Tumut to Wagga Line O51; or Wagga to Jindera Line 62; or Jindera to Wodonga Line O60; or Dederang to Wodonga 330 kV Line	PEC 330 kV may need to be opened at Wagga depending on south west NSW load and generation; PEC transfers could be limited to less than 100 - 200 MW at these times	Renewable generation in Wagga – Darlington Point area to be disconnected; Balranald and Broken Hill renewable generation can remain in service	Humelink will resolve

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Anticipated construction outages

- Key outages expected to have a material market impact

Stage	Outage	Expected impact	Timing	Length
PEC-1	HIC outages, one circuit at a time (Line End Open signals)	Same reduction as currently, HIC transfers reduced to 50-100 MW	Completed	
PEC-1	Buronga to Balranald Line X3, Buronga – Red Cliffs Line OX1	Approx 1,200 MW of renewable generation curtailed	Feb 2024	40 hrs
PEC-2	OX1 (Buronga – Red Cliffs) and Red Cliffs 220 kV Busbar	Approx 900 MW renewable generation curtailed	May 2024	2 days
PEC-2	Wagga to Jindera Line 62 - Relocation onto temporary pole	Approx 1,900 MW renewable generation curtailed	May or Sep 2024	2 days
PEC-2	Wagga to Jindera Line 62 - Cutover into its new switchbays	Approx 1,900 MW renewable generation curtailed	May or Sep 2024	3 days
PEC-2	Darlington Point to Wagga Line 63, Wagga No.3 Transformer, Wagga B Bus No.2 section	Approx 1,300 MW of renewable generation curtailed	May or Sep 2024	5 days

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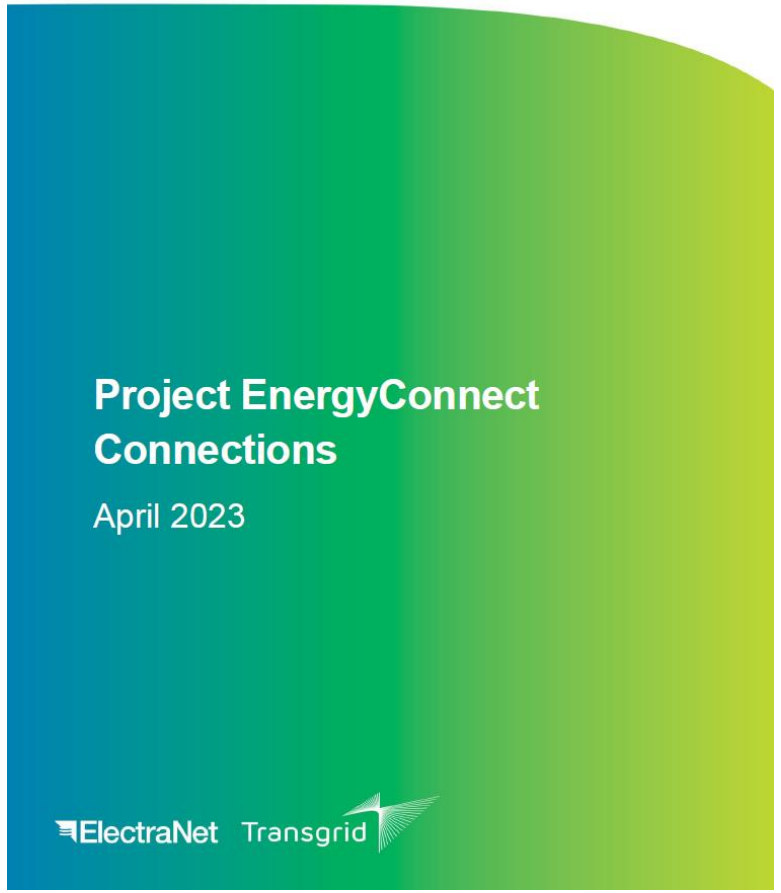
Managing connection interest

John Hele - Transgrid

Managing connection interest

- Staged approach to progressing connections to PEC:
  - A connections framework outlining pre-requisites for each connection project phase relative to PEC milestones to be shared on Project EnergyConnect website.
  - Expected to be published in December 2023.
- A connections update was published on the PEC website in April 2023 when the project achieved Considered Project status, allowing Connection Enquiries to be accepted
- A further connections update will be published on the PEC website when the connections framework is published
- Connections to certain sections of PEC network infrastructure in NSW may be subject to South-West REZ access arrangements (for details see: https://www.energyco.nsw.gov.au/sw-rez)
- The key Connection Assessment Transition Framework consists of the following milestones:
  - Connection enquiry pre-requisites
  - Connection application pre-requisites
  - 5.3.4A/B approval pre-requisites
  - Registration and commissioning pre-requisites



Draft connection assessment transition framework

Milestones	Connection Enquiry pre-requisites	Connection Application pre-requisites	5.3.4A/B approval pre-requisites	Registration and Commissioning pre-requisites
Status	**Achieved in March 2023**	**In Progress – earliest expected by Q1 2024**		
PEC milestone	• PEC formally achieves Considered status	• PEC detailed design complete (design data available including functional requirements of South Australia Intertrip Remedial Action Scheme (SAIT RAS))	• Detailed design of SAIT RAS finalised and complete	• SAITRAS commissioned and in service (including impact assessment on Heywood Interconnector) • PEC internetwork testing completed, and 500 MW transfer capacity released across PEC
PEC model maturity	• PEC planning models (PSS/E) available via AEMO data request • PEC PowerFactory model available	• Standard or Detailed (S/D) data for Buronga and Dinawan synchronous condensers (syncons) available	• PEC R1 dynamic models (PSS/E and PSCAD) available (including Buronga and Dinawan syncons)	• PEC R2 dynamic models (PSS/E and PSCAD) available (including Buronga and Dinawan syncons)
PEC limit advice, Special Protection Schemes (SPS) and other considerations	• Preliminary PEC Limit advice available	• Preliminary PEC limit advice available • Preliminary limit advice available for nearby key transmission lines • For connections to the NSW end of PEC, updated NSW SPS details (including preliminary impact on existing SPS in NSW) • SAIT RAS functional requirements available	• AEMO PEC constraint equations available. AEMO constraint equations available for nearby key transmission lines • For connections to the NSW end of PEC, updated NSW SPS details (including impact on existing SPS in NSW) • SAIT RAS impact assessment and coordination of any new control schemes by newly proposed connecting plant completed	• AEMO constraint equations for PEC and nearby key transmission lines available and active • SAIT RAS, NSW SPS details and limit advice updated based on connecting plant impacts

Note – Final connection assessment transition framework expected to be published on PEC website in Dec 2023.

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Thank You!

System Integration Steering Committee:

Hugo Klingenberg, ElectraNet

Kasia Kulbacka, Transgrid

Luke Robinson, AEMO

Nicola Falcon, AEMO Victorian Planning

Andrew Linnie, AusNet Services

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Governance of System Integration activities

- System Integration Steering Committee (SISC) has responsibility for system integration activities, including stakeholder engagement as required
- The SISC is overseen by an Executive SISC comprising relevant ElectraNet, AEMO, Transgrid, AEMO Victorian Planning and AusNet Services Executives and Project Directors

Key objectives of PEC System Integration Steering Committee

- Collaboration across AEMO, ElectraNet, Transgrid, AEMO Victorian Planning and AusNet Services to coordinate timely PEC integration into the National Electricity Market (NEM)
- Provide governance and reporting in accordance with National Electricity Rules (NER) frameworks and meet all requirements of clause 5.7.7 of the NER
- Achieve combined transfer limit across both the Heywood and PEC interconnectors of 1,300 MW import into South Australia and 1,450 MW export. The project is designed to achieve these transfer levels with consideration of non-credible loss of either interconnector

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- PEC is a geographically diverse second Alternating Current (AC) interconnector that will significantly increase the transfer capability between South Australia and the rest of the National Electricity Market
- This will increase access to other regions and increase competition in the wholesale electricity market putting downward pressure on electricity prices

Interconnector	Nominal Limit (MW)	Nominal Combined Limit (MW)	Combined Transfer Limit[1]
Heywood Interconnector (HIC)	+/-[2] 650	+/- 1450	+ 1300 - 1450
Project EnergyConnect (PEC)	+/- 800		

1. Combined transfer limit dependent on transient system stability and sufficient loads and generators in the SAIT RAS
2. + import into SA
   - export from SA
3. Current transfer limit is SA-VIC: 550 MW, VIC-SA: 600 MW
4. Transmission augmentation information: https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/transmission-augmentation-information

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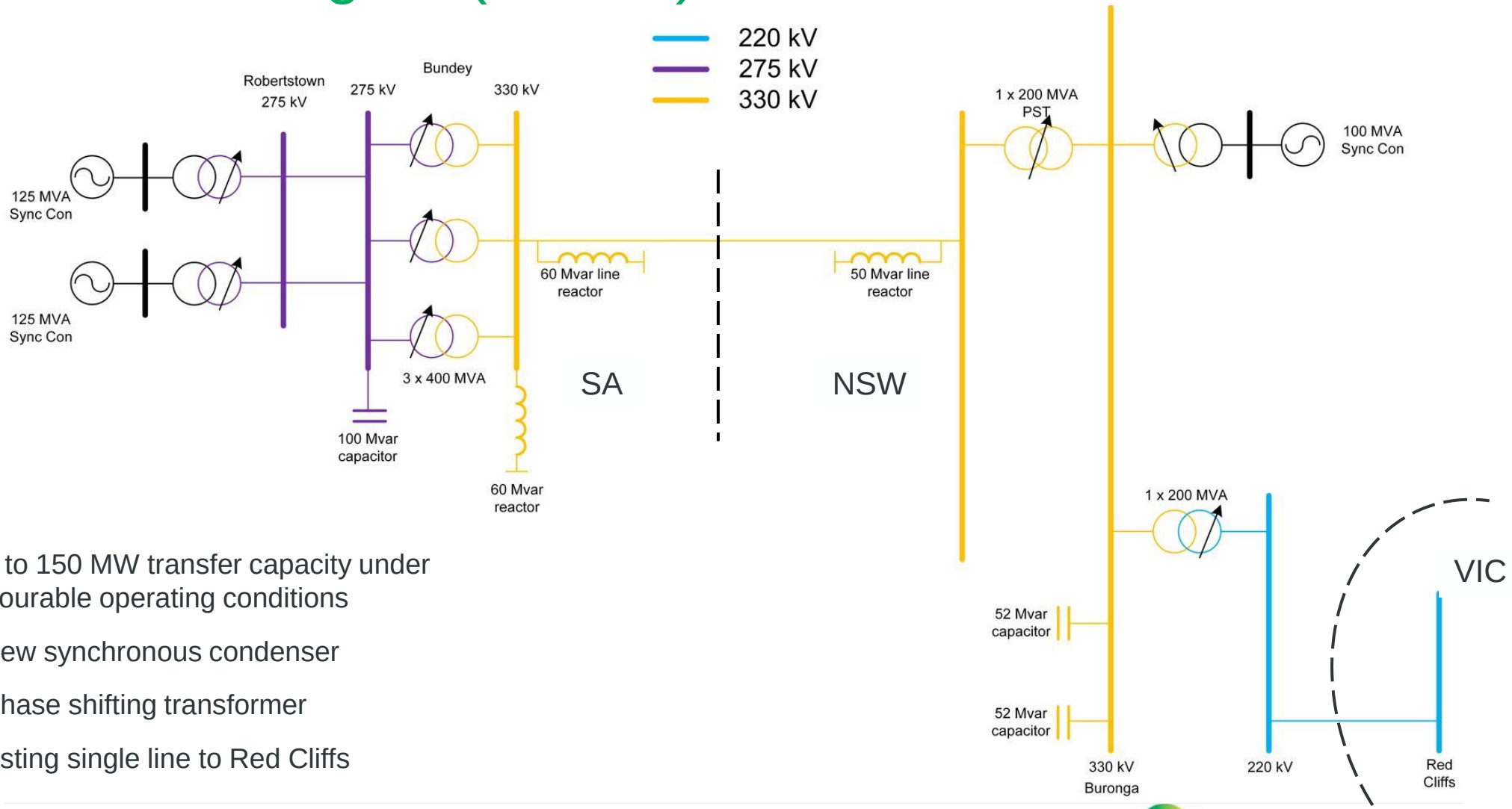
Scope - PEC stage 1 (PEC-1)



- Up to 150 MW transfer capacity under favourable operating conditions
- 1 new synchronous condenser
- 1 phase shifting transformer
- Existing single line to Red Cliffs

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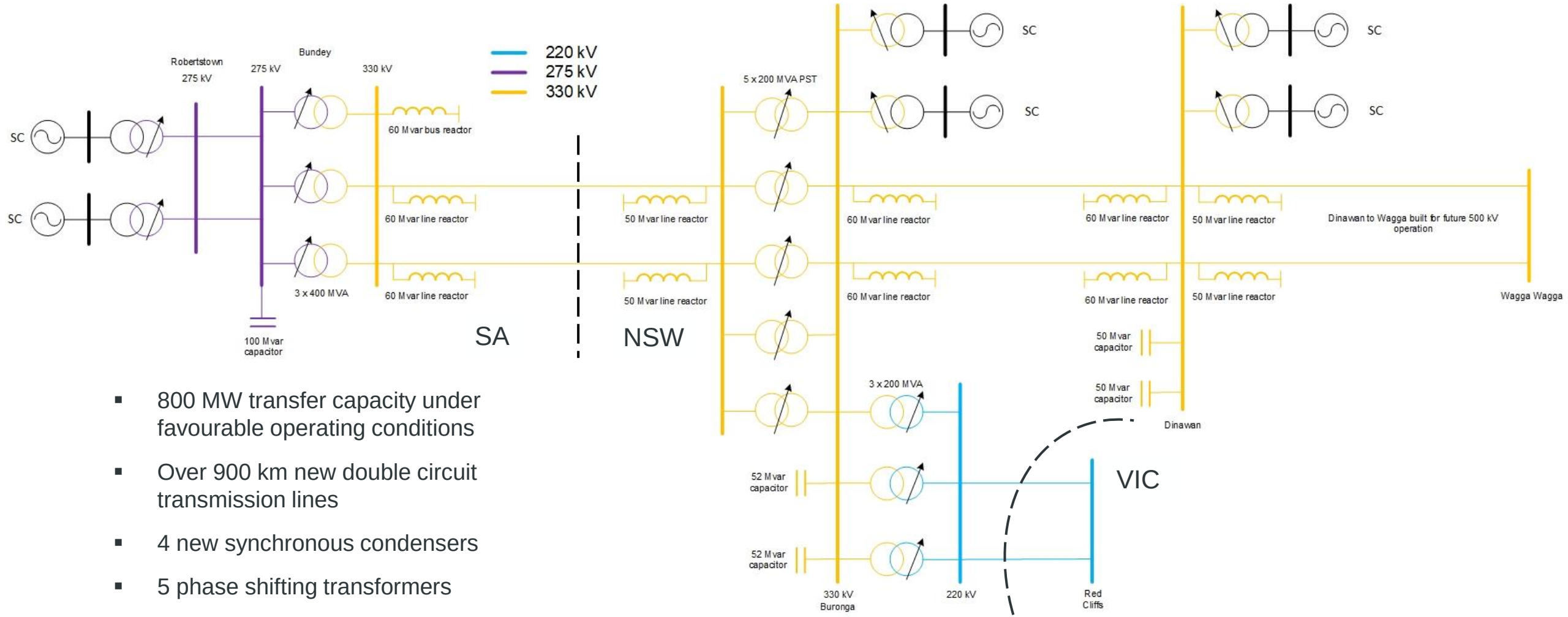
Scope - PEC stage 2 (PEC-2)



- 800 MW transfer capacity under favourable operating conditions
- Over 900 km new double circuit transmission lines
- 4 new synchronous condensers
- 5 phase shifting transformers

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PEC-2 – Managing non-credible events

- Electricity transmission networks are designed and operated to withstand credible contingencies
- It would be prohibitively expensive to design and build a transmission system that can withstand non-credible contingencies without impacting on loads and/ or generators
- Instead, Emergency Control Schemes are used to keep the system connected and stable if non-credible contingencies happen
- The South Australian Interconnector Trip Remedial Action Scheme (SAIT RAS) is being developed to prevent SA being separated from the NEM
- Other RASs may be required to cater for non-credible events 'out of scope' for SAIT RAS, e.g.
  - Non-credible loss of the Buronga – Red Cliffs 220 kV lines
  - Non-credible loss of Moorabool - Sydenham 500 kV lines with significant generation connecting on that corridor
  - Non-credible loss of Buronga – Dinawan – Wagga 330 kV lines if significant generation connects on that corridor
- Number of impacted SPSs being reviewed
  - SA: 7 ; NSW: 7 ; VIC: 4

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SAIT RAS

Indicative concept design

Inputs Monitored

- Line End Open on PEC corridor into NSW, up to Wagga Wagga
- Line End Open on HIC corridor into Victoria, up to Moorabool
- Synchrophasor (PMU) measurements
- SA inertia
- Response resource availability

Central Control Unit

Monitors inputs shown and determines in real time the MW response required if one of the interconnectors was to trip or remedial action is required due to another non-credible event.

If remedial action is required automatically sends signals to deploy the required resources.

Resource Action

Very fast proportional response in SA - up to 600 MW

Potential actions:

- Trip load
- Trip generation
- Charge or discharge BESSs

Telecommunications requirements

- **Duplicated high-speed communications into Victoria and NSW**
- **Duplicated high-speed communications to resource response sites**

HIC – Heywood Interconnector **BESS** – Battery Energy Storage System

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Revocation of the existing SA protected event

The Reliability Panel published its final determination on AEMO's request on 14 September 2023.

The revocation of the SA protected event will take effect on 30 March 2024 in advance of the expected synchronisation and testing of PEC Stage 1 in April 2024.

Impact of proposed revocation of Protected Event to coincide with PEC-1:

- Wide Area Protection Scheme (WAPS) upgrade (S5.1.8) to cater for multiple loss of generators in SA
- Constraints associated with destructive wind conditions will be managed under the Power System Security Guidelines with the associated limits published in AEMO's interconnector capabilities document
- AEMO is completing studies to confirm destructive wind condition limits with consideration of PEC-1
- Destructive wind limit for HIC is currently 250 MW. Revision is subject to further studies
- Updates to limits to be covered in AEMO's annual General Power System Risk Review

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