WEM Reform Program

Constraint Formulation

WRIG – 1 October 2020

Relationship to the Rules

Existing:

- the processes to be followed by AEMO and the matters it must consider in formulating and updating Constraint Equations, including:
  - the approach to be taken by AEMO in applying:
    - an Operating Margin; and
    - the principles described in clause 2.27A.9; and
  - the conventions for assigning a unique identifier to Constraint Equations and Constraint Sets [Clause 2.27A.10(b)];
- the processes to be followed by AEMO in developing and updating the Constraints Library and notifying Market Participants of updates to the Constraints Library [Clause 2.27A.10(c)];
- Any other processes or procedures relating to Constraints or Network congestion that AEMO considers are reasonably required to enable it to carry out its functions under the Market Rules [Clause 2.27A.10(d)].

Upcoming:

- the processes to be followed and the methodology to be used by AEMO in determining Constraint Equation terms and coefficients for Network Constraints, including the methodology for determining whether the exclusion of a variable from a Fully Co-optimised Network Constraint Equation would have a material effect on Power System Security due to the size of its coefficient [Clause 2.27A.10(cA)];
- the processes to be followed and the methodology to be used by AEMO in selecting one or more Constraint Equations to respond to a Network Constraint, including in respect of the location of terms on each side of the Constraint Equation [Clause 2.27A.10(cB)];
- the processes and timeframes to be followed by AEMO for creating new Constraint Equations and Constraint Sets in response to a Non-Credible Contingency Event [Clause 2.27A.10(cC)];

Speculative

- the process to be used by AEMO for selecting, applying, invoking and revoking Constraint Equations or Constraint Sets in response to Network Constraints for use in the Dispatch Algorithm [Clause 7.5.4 (a)];
- the circumstances in which AEMO will use Fully Co-optimised Network Constraint Equations and Alternative Network Constraint Equations in the Dispatch Algorithm [Clause 7.5.4 (b)]; and

Explanatory Content

- Aim to improve clarity and comprehension
- Various purposes:
  - Technical background information
  - Linkage to other sections / documents
  - Example applications
  - Rationale for specific values or thresholds
  - Annotations vs. Stand-alone sections
- Seeking industry feedback on presentation and/or alternatives

4.1. Thermal Network Constraints

Equation Selection

4.1.1. The network combinatorial strategy is a methodology for the selection of Constraint Equations to ensure appropriate coverage of Network Constraints. It consists of a single Constraint Equation per combination of:

(a) network configuration;

(b) Thermal Network Limit; and

(c) Credible Contingency.

E[E] NETWORK MODELLING

E[E1] Network Coverage

Constraint Equations can be mathematically expressed in different ways to achieve secure outcomes in the dispatch process and physical system.

Under the network combinatorial strategy:

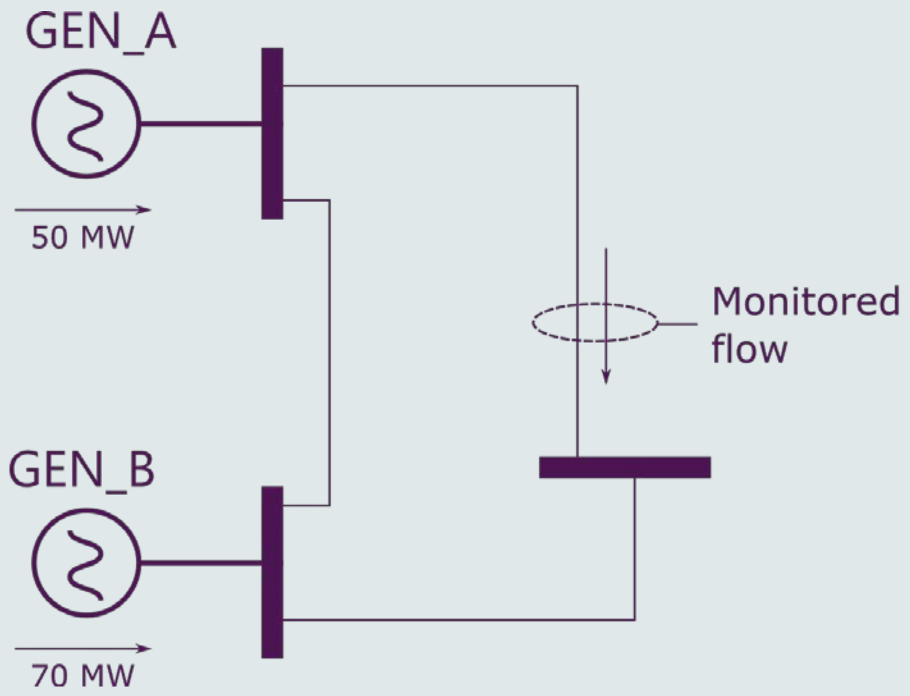
(a) Each network element requires multiple Constraint Equations to protect against different contingencies; and

(b) a network outage (change in configuration) requires reconsideration of all contingency and monitored element combinations.

Format of Constraint Equations (Explanatory)

- Left-Hand Side:
  - Controllable terms
- Right-Hand Side
  - Everything else

- Examples:
  - $LHS < RHS$
  - $LHS = a_1 G_A + a_2 G_B$
  - $= (0.75 * 50) + (0.50 * 70) = 72.50$

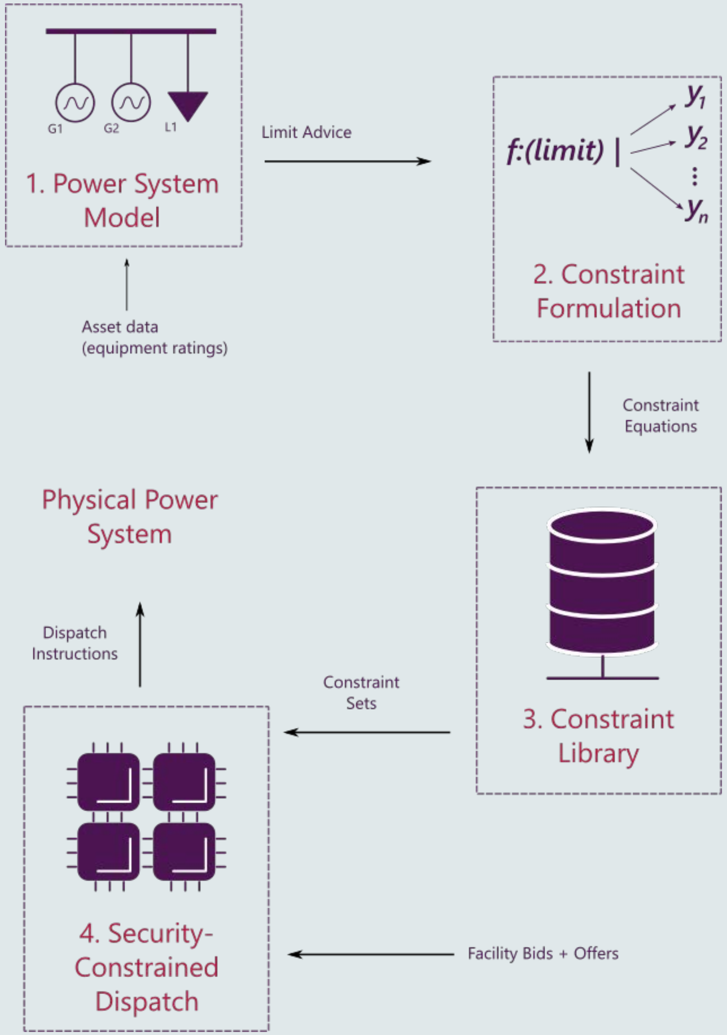


Equation (2) Coefficients

a_1	0.75
a_2	0.50

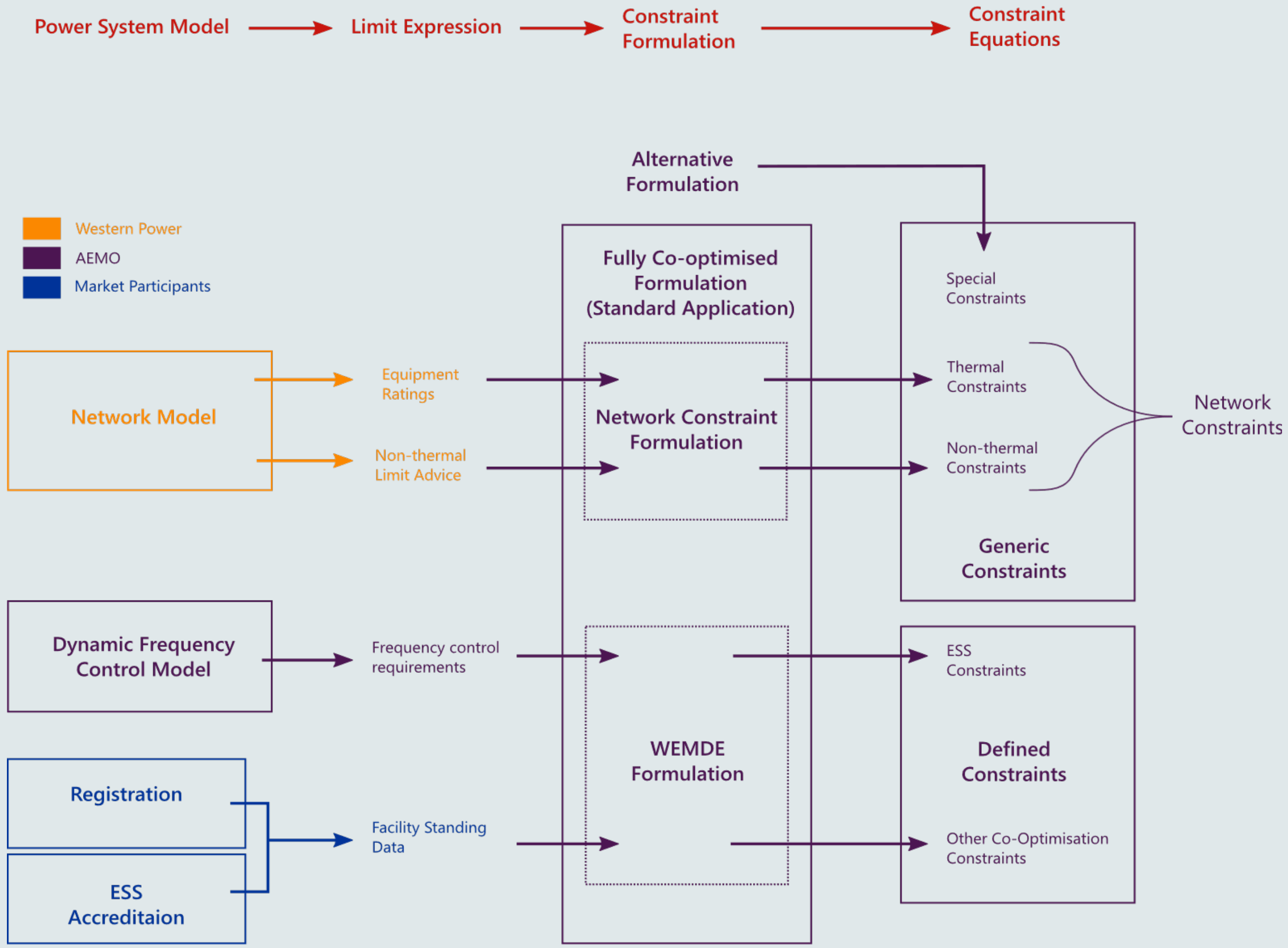
Standard Methodology

- Development of "Fully Co-optimized Constraint Equations"
  - Facilitate secure, economic, predictable dispatch outcomes
- AEMO must follow where practicable, in as far in advance
- "Alternative Formulation" described later



Constraint Equation classification

(Explanatory)



Operating Margins

Operating Margin applied to ALL Constraint Equations

AEMO must develop with consistent process:

- Identification of error sources
- Statistical estimation of error distribution
- Identification of risk consequences
- Selection of margin consistent with risk appetite

Operating Margins

AEMO principles (Explanatory)

Preference for:

- The use of measured data and statistical analysis
- Linkage with relevant policy or statements of risk appetite
- Efficient allocation of engineering analysis and development resources to relieve market congestion
- Simplicity, robustness and clarity over mathematical sophistication or purity.

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Operating Margins

Application strategy

- AEMO may default to applying conservative Operating Margins
- AEMO may use real time environment for optimisation
- Revise margins following new information:
  - Live operating experience
  - Change in industry risk appetite

Operating Margins

Error sources

- Modelling errors + assumptions
  - E.g. MW vs MVA
- Real time error
  - E.g. dispatch drift
- Non-operational error – NOT included
  - e.g. equipment ratings

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Operating Margins

Likelihood

LIKELIHOOD	ANNUAL PROBABILITY	QUALITATIVE DESCRIPTION
Almost Certain	>90%	Will occur in most circumstances; statistical record of several occurrences
Likely	51% - 90%	Can be expected to occur in most circumstances; statistical record of multiple occurrences
Possible	11% - 50%	May occur, but not expected in most circumstances; statistical record of a few occurrence
Unlikely	1% - 10%	Conceivable but unlikely to occur in any given year; statistical record of at least one occurrence
Rare	<1%	Will only occur in exceptional circumstances; no history of occurrence

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Operating Margins

Consequence (Speculative)

Extreme	AEMO cannot restore Satisfactory operation
Major	AEMO can restore a Satisfactory state only through multiple directions and not within 15 minutes.
Moderate	AEMO can restore a Satisfactory state through single intervention or direction within 15 minutes
Minor	Satisfactory state restored within next Dispatch Interval by Market Dispatch (<10 minutes)
Immaterial	Satisfactory state restored automatically within 1 Dispatch Interval (<5 minutes)

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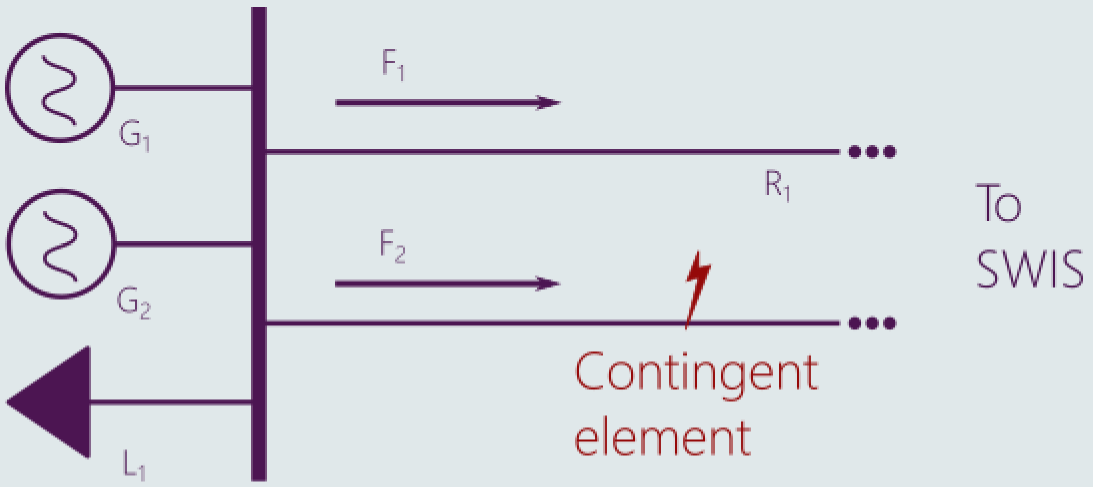
Operating Margins
Risk appetite

		CONSEQUENCE				
		Immaterial	*Minor*	*Moderate*	*Major*	*Extreme*
LIKELIHOOD	*Almost Certain*	Medium	Medium	High	Critical	Critical
	Likely	Low	Medium	High	Critical	Critical
	Possible	Low	Medium	High	High	Critical
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Medium	Medium	High

Network Constraint Formulation Network coverage

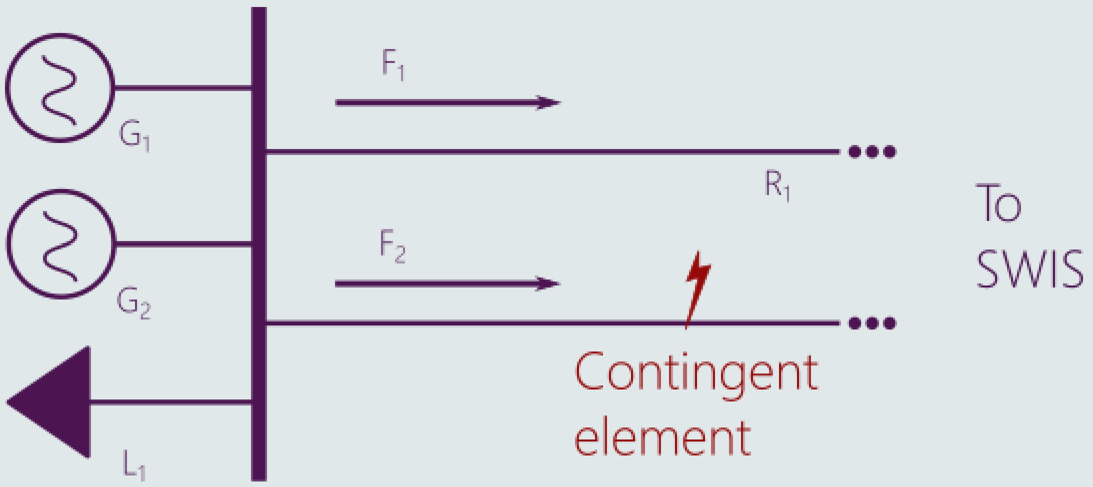
- 1x equation per combination of:
  - Network configuration
  - Limit
  - Credible Contingency

- Many (theoretical) equations to manage
  - Filter based on coefficient size



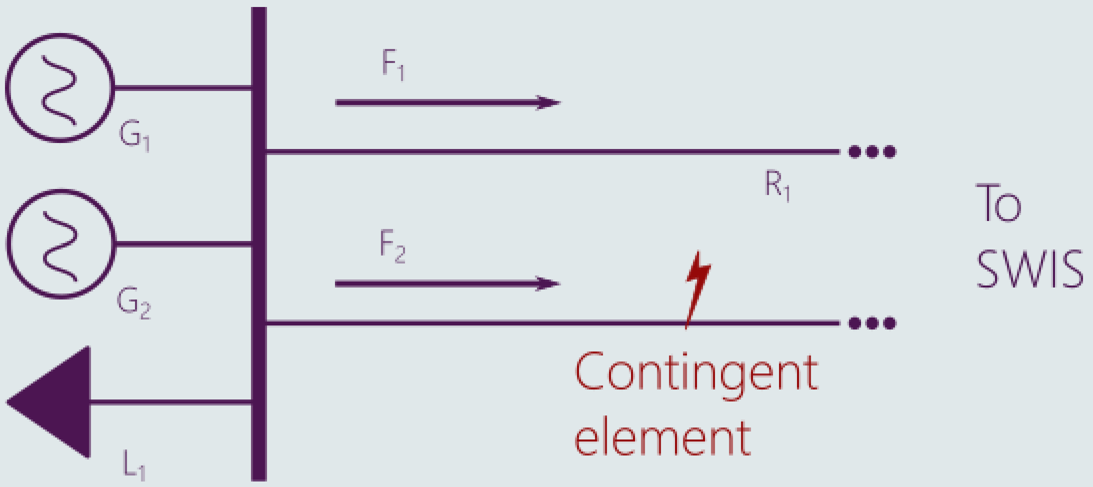
Network Constraint Formulation
"Open-loop" formulation (explanatory)

- $F_1 < R_1$
- $RDF \times F_2 + a_1 G_1 + a_2 G_2 - b_1 L_1 < R_1$
- Operating Margin of 8%
- $1G_1 + 1G_2 < 1(1 - 0.08)R_1 - F_2 + 1L_1$



Network Constraint Formulation
Open loop weaknesses (explanatory)

- Issues with open loop equations:
  - Linearization error
  - Requirements detailed model and many measurements
  - Limited applicability over system conditions



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Feedback formulation (explanatory)

$$\mathrm{a}_1 \Delta G_1 + a_2 \Delta G_2 + \cdots a_n \Delta G_n < (1 - \epsilon) R_m - F_m - \mathrm{RDF} \times F_c$$

$$\mathrm{a}_1 G_{1,\mathrm{DI}} + a_2 G_{2,\mathrm{DI}} + \cdots a_n G_{n,DI} < (1 - \epsilon) R_m - F_m - \mathrm{RDF} \times F_c + \mathrm{a}_1 G_{1,\mathrm{t0}} + a_2 G_{2,\mathrm{t0}} + \cdots a_n G_{n,t0}$$

Constraint Library

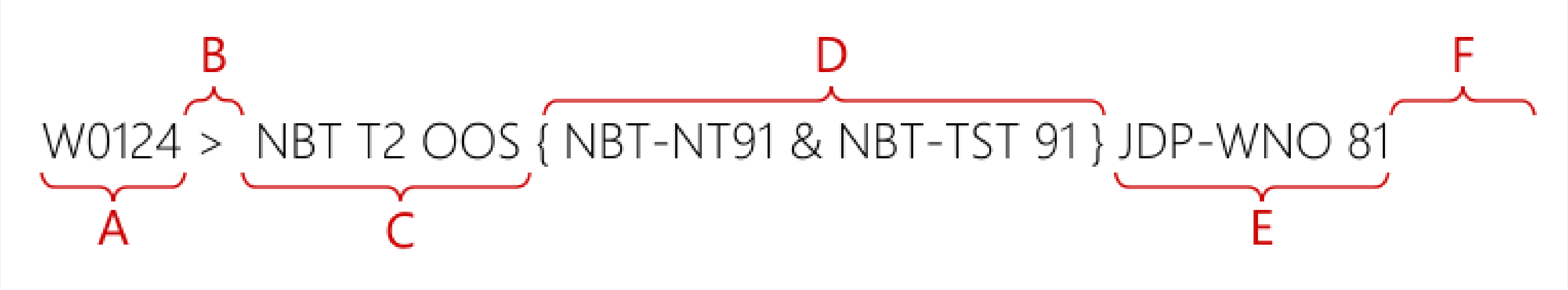
- Repository and source of truth of all Constraint Equations
  - Current and archived
- Record of all Constraint Equation changes
  - Notification to Participants (implementation TBD)
- Publicly available online in the Congestion Information Resource (alongside suite of other useful information)

Alternative constraint formulation (Speculative)

- Discretionary Constraints:
  - Developed in real-time to manage unexpected or extreme operating conditions
  - E.g.: Non-conformance, Constraint Deficiency

- Stop-Gap Constraints:
  - Temporary Constraint Equations to bridge unexpected circumstances through to fully co-optimised formulation
  - E.g.: Non-Credible contingency event, unanticipated system limit

Constraint naming conventions



- A: prefix
- B: cause ID
- C: configuration
- D: contingency
- E: monitored element
- F: postfix

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Quality Control (Appendix)

- Playback analysis
  - Shallow, wide-reaching “sanity check” of Constraint Equation action and forecasting
- Simulation environment
  - High detail, low-level testing
- Real time monitoring
  - Primary means of testing and optimisation
  - Used to prioritise “Efficiency review”

Questions

- Additional comments or questions can be provided to AEMO
  - WA.ETS@aemo.com.au
  - AEMO Contact – Leon Kwek