# WEMP: RCM Constraint Formulation

WEM Reform Implementation Group (WRIG) 24th February 2022

# RCM Constraint Formulation

## Background and purpose

- Transitional Procedure published under WEMR 1.33.1.iv
- Head of Power under WEMR 2.27A.10
- Processes and methodology AEMO must use in
  - selecting the equations to represent Network Constraints
  - determining terms and coefficients are determined
  - using RCM Limit Advice & Non-Thermal Network Limits to formulate RCM Constraint Equations
  - applying an Operating Margin
  - assigning a unique identifier to the equations and sets
- Processes and methodology AEMO may use in verifying the equations
- Notes:
  - Unless specifically mentioned, all items apply to both Preliminary RCM Constraint Equations and RCM Constraint Equations
    - Facilities
    - Peak demand assumptions

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# RCM Constraint Formulation

## Selecting RCM Constraint Equations for peak demand

- Thermal
  - Develop for constraints applicable under Peak Demand conditions.
  - May develop for only the worst-case if results in the highest power transfer in all scenarios
  - To determine above, power system models consider:
    - Preliminary Peak Demand or Peak Demand
    - RCM Facilities
    - Information provided under 4.4B.5
    - The matters under 4.15.8
    - Facilities Dispatch Scenarios most likely to result in constraint
- Non-Thermal
  - As advised in Limit Advice
  - May not formulate if considered not applicable under peak demand by AEMO
    - E.g. due to application of RLM for intermittent generation

# RCM Constraint Formulation

## Determining terms and coefficients of an RCM Thermal Constraint Equation

2.2.4. For each Thermal RCM Constraint Equation, AEMO must determine the Sensitivity Factor for each relevant Facility, the Sensitivity Factor for the SWIS demand term, and the constant value, by following the steps below:

(a) removing the contingent element, and all consequential elements from service;

(b) identifying the power flow in MW on the monitored element;

(c) using load flow simulation and assigning the Swing Bus to be the Reference Node in the power system model, determine the Sensitivity Factor for each RCM Facility as:

**Equation 3**

$$S_i = \Delta P_M / \Delta P_i$$

Where:

- $S_i$ is the Sensitivity Factor for Facility $i$;
- $\Delta P_i$ is an Injection of MW exclusively by Facility $i$, or in the case of Demand Side Programmes a Withdrawal of MW exclusively.
- $\Delta P_M$ is the change in power flow in MW through the monitored element following $\Delta P_i$; and

(d) using load flow simulation, identifying the Sensitivity Factor for the SWIS demand term by increasing SWIS demand at all relevant locations, including relevant Electrical Locations, and calculating the difference in power flow on the monitored element with respect to the difference in SWIS demand:

**Equation 4**

$$S_{SWIS} = (\mathrm{ME}' - ME) \ / \ (PD' - PD)$$

Where:

- $ME'$ is the power flow on the monitored element after increasing SWIS demand;
- $ME$ is the power flow on the monitored element under Peak Demand conditions;
- $PD'$ is the SWIS demand after increasing demand above Peak Demand;
- $PD$ is the SWIS Peak Demand; and
- $S_{SWIS}$ is the Sensitivity Factor for the SWIS demand term;

(e) returning the SWIS demand at relevant locations in paragraph 2.2.4(d) to the initial value;

(f) returning the contingent element in paragraph 2.2.4(a) to service; and

(g) calculating a constant value as the error between the sum of all Scheduled Facilities, Semi-Scheduled Facilities, Non-Scheduled Facilities and Demand Side Programmes and Peak Demand multiplied by their respective Sensitivity Factors, and the flow on the monitored element measured at paragraph 2.2.4(b):

**Equation 5**

$$Constant = Monitored\ Element\ Flow\ - (\sum_{i=1}^{n} SiPi + S_{SWIS} * PD)$$

where:

- $Si$ is the Sensitivity Factor for Facility $i$
- $Pi$ is the output (MW) for Facility $i$.

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# RCM Constraint Formulation

## Formulating RCM Constraint Equations

## Thermal

### E[D] Example

Formulating initial LHS and RHS:

**Equation 6**

$$LHS = (a * A + b * B + c * C + d * D + x * PD) + 1 * Constant$$

where:

- Lower case letters ($a$ through $d$) and upper case letters ($A$ through $D$) denote the Sensitivity Factor and term for each Facility, respectively;
- Lower case $x$ denotes the Sensitivity Factor for SWIS demand;
- $PD$ denotes the Peak Demand considered for a Reserve Capacity Cycle; and
- $Constant$ is the constant value calculated in paragraph 2.2.4.

**Equation 7**

$$RHS = Conversion\ Factor * Rm$$

where:

- $Rm$ is the Rating of the monitored element; and
- $Conversion\ Factor$ is the Conversion Factor specified in paragraph 2.5.3.

Substituting initial LHS and RHS to $LHS \leq RHS$:

**Equation 8**

$$a * A + b * B + c * C + d * D + x * PD + 1 * Constant \leq Conversion\ Factor * Rm$$

Assuming terms A, B, C are Scheduled Facilities and term D is a Non-Scheduled Facility, Thermal RCM Constraint Equation in Equation 8 is rearranged as shown in :

**Equation 9**

$$a * A + b * B + c * C \leq Conversion\ factor * Rm - 1 * Constant - x * PD - d * D$$

# RCM Constraint Formulation

## Formulating RCM Constraint Equations

## Non-Thermal

- Based Non-Thermal Network Limits available to AEMO
- Similar to SCED Non-Thermal Constraint Equations, AEMO may:
  - Add Operating Margin if required
  - Assign terms to LHS and RHS as appropriate
  - Re-orient a Limit Equation to the Reference Node
  - Re-express a Limit Equation as multiple Constraint Equations
- Including an RCM Facility in a Non-Thermal Network Limits
  - 'Shadow Generator' approach
    - Apply the same or similar coefficient as relevant existing Facility ('Shadow Generator')
  - If not appropriate, exclude the Facility:
    - *Location wise, one contributes to a specific power flow, one does not*
    - *Large distance between RCM Facility & Shadow Generator*
    - *Considerable differences in the capacity (e.g. reactive power capability)*
    - *Non-Thermal network Limit relates to a specific Facility Technology Type*

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## Formulating RCM Constraint Equations

## Operating Margin

- Within NAQ Model, not exposed to real-time operational errors
- Thermal
    - To account for MVA to MW Conversion, assume 0.95 power factor
    - By default, 0.95.
- Non-Thermal
    - Power transfer limits in Limit Advice represented in MW
    - By default, none.
- If found not appropriate, deviation permitted
    - Examples:
        - *Invalid assumption of 0.95 power factor on a specific element*
        - *Some terms dependent on voltage and MVAr assumptions in the studied scenarios*

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# RCM Constraint Formulation

## Publication

- All requirements are specified in WEMR
- Preliminary RCM Constraint Equations
  - Information under 4.4B.5
  - 6 Dec 2022 & (20 May for subsequent cycles)
- RCM Constraint Equations
  - 28 June 2023 (30 Sept for subsequent cycles)

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# RCM Constraint Formulation

## Naming convention: RCM Constraint Sets

$$\overbrace{\text{RCM}}^{A}\text{-}\overbrace{\text{RCC22}}^{B}\text{-}\underbrace{\text{CY24}}_{C}\text{-}\overbrace{\text{S3}}^{D}$$

- A: P-RCM or RCM
- B: Reserve Capacity Cycle
- C: Reserve Capacity year
    - Early CRC applicants have different applicable Capacity Years
- D: Applicable step in WEMR Appendix 3
    - Step 3, Step 4 and Step 13

# RCM Constraint Formulation

## Naming convention: RCM Constraint Equations

$$\overbrace{\text{RCM}}^{A}\text{-}\overbrace{\text{RCC22}}^{B}\text{-}\underbrace{\text{CY24}}_{C}\text{-}\overbrace{\text{S3}}^{D}\underbrace{>}_{E}\overbrace{\{\text{NBT-WNO81}\}}^{F}\underbrace{[\text{CKN-YP81}]}_{G}$$

- A: P-RCM or RCM
- B: Reserve Capacity Cycle
- C: Reserve Capacity year
  - Early CRC applicant applicable for a different Capacity Year
- D: Applicable step in WEMR Appendix 3
- E: Cause ID
  - Thermal (>), Transient (:), Voltage (^), Others (*)
- F: Contingency
- G: Monitored element

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# RCM Constraint Formulation

## Verifying RCM Constraint Equations

## Thermal

5.1.2. When assessing the formulation of a Thermal RCM Constraint Equation, AEMO may:

(a) prepare several Facility Dispatch Scenarios, each of which result in the LHS and RHS of the Constraint Equation having equal values. This indicates that the power system is operating at the limit defined by the Thermal RCM Constraint Equation;

(b) use the power system models prepared under paragraph 2.1.3, and for each Facility Dispatch Scenario prepared under paragraph 5.1.2(a), calculate the power transfer on the relevant monitored element being protected by Thermal RCM Constraint Equation when the contingent element is removed from service; and

(c) compare the power transfer on the monitored element (in MVA) with its rating (in MVA) and:

(i) if the difference is within or equal to the error tolerance for all considered Facility Dispatch Scenarios under paragraph 5.1.2(a), the Thermal RCM Constraint Equation is considered acceptable;

(ii) if the difference is outside the error tolerance for one or more of the Facility Dispatch Scenarios under paragraph 5.1.2(a), an alternative formulation may be required for the Thermal RCM Constraint Equation.

5.1.3. Where AEMO determines a Thermal RCM Constraint Equation is not accurate and an alternative formulation is required, including under circumstances specified in paragraph 5.1.2(c)(ii), AEMO may deviate from the processes specified under paragraphs 2.2 and 2.3 by applying one or more of the following:

(a) using a different Operating Margin;

(b) applying an additional static constant values to the RHS of the RCM Constraint Equation;

(c) adding additional logic to the RHS of the RCM Constraint Equation so that a dynamic constant value is calculated dependent on the status of one or more Facilities in a particular Facility Dispatch Scenario;

(d) applying different assumptions to the model of the power system prepared under paragraph 2.2.2 to calculate alternative Sensitivity Factors for one or more Facilities; or

(e) using multiple RCM Constraint Equations to control power transfer on the monitored element, but with only one version invoked at any one time, based on the actual Facility Dispatch Scenario under consideration.

# RCM Constraint Formulation

## Verifying RCM Constraint Equations

## Non-Thermal

5.1.4. When assessing the formulation of a Non-Thermal RCM Constraint Equation, AEMO may:

(a) prepare several Facility Dispatch Scenarios, each of which result in the LHS and RHS of the Constraint Equation having equal values. This indicates that the power system is operating at the Non-Thermal Network Limits defined by the Non-Thermal RCM Constraint Equation;

(b) with the aid of the Non-Thermal Limit Advice provided by the relevant Network Operator, determine the non-thermal power transfer limit for each Facility Dispatch Scenario under paragraph 5.1.4(a);

(c) use the power system models prepared under paragraph 2.1.3, and for each Facility Dispatch Scenario prepared under paragraph 5.1.4(a), calculate the power transfer on the relevant monitored element being protected by the Non-Thermal RCM Constraint Equation when the contingent element is removed from service;

(d) compare the power transfer on the monitored element calculated at paragraph 5.1.4(c) with the non-thermal power transfer limit calculated at paragraph 5.1.4(b) and:

  (i) if the difference is within or equal to the error tolerance, for all considered Facility Dispatch Scenarios under paragraph 5.1.4(a), the Non-Thermal RCM Constraint Equation is considered acceptable; and

  (ii) if the difference is outside the error tolerance, for one or more of the Facility Dispatch Scenarios under paragraph 5.1.4(a), an alternative formulation may be required for the Non-Thermal RCM Constraint Equation.

5.1.5. Where AEMO determines a Non-Thermal RCM Constraint Equation is not accurate and an alternative formulation is required, including under circumstances specified in paragraph 5.1.4(d)(ii), AEMO may:

(a) apply one or more options in paragraph 5.1.3;

(b) apply a different coefficient under paragraphs 2.4.2 and (b); or

(c) apply the approach in paragraph 2.4.2(b).

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## Next steps

- Publish for consultation early March
- Additional comments or questions can be directed to AEMO by email to WA.ETS@aemo.com.au.