WEM Procedure: Dispatch Algorithm Formulation

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Version	Effective Date	Summary of Changes
0.1		First draft prepared for consultation

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IMPORTANT NOTICE - EXPLANATORY NOTES

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1. Introduction

1.1. Purpose and scope

1.1.1. This WEM Procedure: Dispatch Algorithm Formulation (Procedure) is made in accordance with AEMO's functions under clause 2.1A.2(h) of the Wholesale Electricity Market Rules (WEM Rules).

1.1.2. The *Electricity Industry Act 2004* (WA), the WEM Regulations and the WEM Rules prevail over this Procedure to the extent of any inconsistency.

1.1.3. In this Procedure, where obligations are conferred on a Rule Participant, that Rule Participant must comply with the relevant obligations in accordance with clause 2.9.7A, 2.9.7D or 2.9.8 of the WEM Rules, as applicable.

1.1.4. The purpose of this Procedure is to document:

(a) the Dispatch Algorithm used by AEMO for the purpose of the Central Dispatch Process and setting Market Clearing Prices and the mathematical formulation of the Dispatch Algorithm, including **[clause 7.2.5(a)]**:

(i) the calculation of the required quantity of Contingency Reserve Raise **[clause 7.2.5(a)(iii)]**;

In a form that:

(ii) sets out the form, scope and construction of each type of Constraint Equation **[clause 7.2.5(a)(v)]**;

(iii) describes and quantifies the mechanism by which different Constraints are taken into account and prioritised, including in accordance with clauses 3.12.2 and 7.6.25 **[clause 7.2.5(a)(vi)]**; and

(iv) AEMO reasonably considers will enable a third party, such as the Market Auditor or the Economic Regulation Authority, to replicate the results of the Dispatch Algorithm by using the same inputs **[clause 7.2.5(a)(vii)]**;

(b) the processes to be followed by AEMO and Market Participants in accounting for Inflexible Facilities **[clause 7.2.5(c)]**;

(c) the methodology AEMO will use, and any assumptions it may be required to make, to determine the Market Clearing Prices during AEMO Intervention Events under clauses 7.11C.7, 7.11C.8 and 7.11C.10. The methodology must, wherever reasonably practicable **[clause 7.11C.11]**:

(i) be consistent with the principles for the determination of Market Clearing Prices set out in section 7.11A **[clause 7.11C.11(a)]**; and

(ii) enable AEMO to determine and publish such prices in accordance with the applicable timeframes for the publication of the Market Clearing Prices under these WEM Rules **[clause 7.11C.11(b)]**;

(d) the processes to be followed by AEMO for the relaxation of Constraints under clause 7.2.6 **[clause 7.2.8]**; and

(e) the process to be followed by AEMO when issuing Dispatch Instructions that override the output of the Dispatch Algorithm for Dispatch Intervals where the Dispatch Algorithm determines a Degenerate Solution pursuant to clause 7.6.23 **[clause 7.6.27(a)]**.

(f) Situations that are deemed significant for the purposes of clause 7.6.24(b) **[clause 7.6.27(b)]**.

1.1.5. Appendix A of this Procedure outlines the head of power clauses that this Procedure is made under, as well as other obligations in the WEM Rules covered by this Procedure.

1.2. Definitions

1.2.1. Terms defined in the *Electricity Industry Act 2004* (WA), the WEM Regulations and the WEM Rules have the same meanings in this Procedure unless the context requires otherwise.

1.2.2. The following definitions apply in this Procedure unless the context requires otherwise.

Table 1 Definitions

Term	Definition
Active Fast Start Facility	A Fast Start Facility which contains a valid Dispatch Inflexibility Profile in its effective Real Time Market Submission for the relevant Dispatch Interval.
Constraint Violation Quantity	Variables introduced with a high objective function cost to ensure that a feasible solution can be found to a dispatch run, which are also often known as 'slack variables'.
Defined Facility Risk Constraint	A Constraint Equation that represents the Credible Contingency Event associated with a single Registered Facility that differs from the standard Constraint Equation in paragraph 2.4.7.
Dynamic Frequency Control Model	The Dynamic Frequency Control Model (DFCM) is computer simulation of the SWIS system frequency that uses an ESS System Configuration as an input, and for a given quantity of RoCoF Control Service calculates the quantity of: (a) Contingency Reserve Raise in response to the Largest Credible Supply Contingency; and (b) Contingency Reserve Lower in response to the Largest Credible Load Contingency, required to maintain the frequency of the SWIS within the Contingency Event Frequency Band.
Dispatch Run	The first Dispatch Interval in the Dispatch Schedule at a given time. That is, the Dispatch Interval for which Dispatch Instructions are being issued, and prices for Market Services are being determined.
Essential System Service Trapezium	The set of Constraint Equations formed by WEMDE using the Enablement Minimum, Low Breakpoint, High Breakpoint, Enablement Maximum, and maximum available quantity of a given Essential System Service.
Fast Start Second Pass Run	The iteration of the Dispatch Algorithm where Dispatch Inflexibility Profiles for Fast Start Facilities are respected.
Fast Start Mode	The modes available to a Fast Start Facility as set out in Appendix E , which can be used by the Fast Start Current Mode or Fast Start Target Mode parameters.
Fast Start Current Mode	The current Fast Start Mode for a Fast Start Facility. Unless otherwise specified in this Procedure, this will be the same as the Fast Start Target Mode from the first Dispatch Interval of the Dispatch Schedule immediately prior to the current Dispatch Schedule.
Generic Constraint	A Constraint calculated under paragraph 2.4.27. This includes any Constraint Equations included in the Dispatch Algorithm for the purposes of clauses 7.2.4(e) and 7.2.4(f).
Intervention Pricing Run	The methodology used in Appendix D to determine Market Clearing Prices during AEMO Intervention Events.

Term	Definition
Normally On Load	A Registered Facility, for which the forecast quantity of Withdrawal is already accounted for in the Forecast Operational Demand.
Over-Constrained Dispatch Run	The mechanism that AEMO uses to resolve the presence of penalty prices in dispatch solutions, so that the effect of Constraint Violation Quantities is removed, as per Appendix C.
Price Tied Tranche	For a Dispatch Interval, for a Market Service, where the absolute value of the difference between the Loss-Factor Adjusted Prices of two or more Price-Quantity Pairs is less than 1e-6 and the Price-Quantity Pairs are, therefore, deemed price tied.
$\mathbb{R}$	The set of real numbers.
RHS	Means the right hand side of a Constraint Equation.
Supervisory Control and Data Acquisition	A system used to describe telemetry and associated real-time control/indication functions.
SCADA-telemetered Downward Ramp Rate Limit	Values provided by a Registered Facility to AEMO via SCADA (or another medium approved by AEMO), indicating the Maximum Downwards Ramp Rate of the Registered Facility in real-time.
SCADA-telemetered High Limit	A value provided by a Registered Facility to AEMO via SCADA (or another medium approved by AEMO), indicating the maximum dispatchable quantity in MW of the Registered Facility in real-time.
SCADA-telemetered Low Limit	A value provided by a Registered Facility to AEMO via SCADA (or another medium approved by AEMO), indicating the minimum dispatchable quantity in MW of the Registered Facility in real-time.
SCADA-telemetered Upward Ramp Rate Limit	Values provided by a Registered Facility to AEMO via SCADA (or another medium approved by AEMO), indicating the Maximum Upwards Ramp Rate of the Registered Facility in real-time.
System Inertia	AEMO’s estimate of total Inertia on the SWIS, including contributions from Registered Facilities, Loads, and other unregistered equipment.
WEMDE	The software that AEMO uses to solve the Dispatch Algorithm.
$\mathbb{Z}$	The set of integers.

1.2.3. Other terms are defined in this Procedure for the purpose of defining elements of the Dispatch Algorithm and are used throughout the Procedure.

1.3. Interpretation

1.3.1. The following principles of interpretation apply in this Procedure unless the context requires otherwise.

(a) Clauses 1.3 to 1.5 of the WEM Rules apply in this Procedure.

(b) References to time are references to Australian Western Standard Time.

(c) Terms that are capitalised, but not defined in this Procedure, have the meaning given in the WEM Rules.

(d) A reference to the WEM Rules or WEM Procedures includes any associated forms required or contemplated by the WEM Rules or WEM Procedures.

(e) Words expressed in the singular include the plural and vice versa.

(f) A reference to a paragraph refers to a paragraph of this Procedure.

(g) A reference to an appendix refers to an appendix of this Procedure.

(h) A reference to a clause refers to a clause or section of the WEM Rules.

(i) References to WEM Rules in this Procedure in bold and square brackets **[Clause XXX]** are included for convenience only, and do not form part of this Procedure.

(j) Text located in boxes and headed as Explanatory Note X in this Procedure is included by way of explanation only and does not form part of this Procedure. The Procedure prevails to the extent of any inconsistency with the explanatory notes contained within it.

(k) The body of this Procedure prevails to the extent of any inconsistency with the figures, diagrams, appendices, schedules, annexures or attachments contained within this document.

(l) Text appearing in bold italics at the beginning of sub-paragraphs in paragraphs 2.1, 2.2, 2.3, 2.4, and 2.5 of this Procedure is provided to indicate the name of an input of the Dispatch Algorithm formulation to which that paragraph applies.

(m) Mathematical notation used to represent sets, parameters, variables, and equations in this Procedure is set out immediately following the paragraph that defines the relevant set, parameter, variables, or equation.

(n) In paragraph 2.4, "SKIP CONSTRAINT" indicates that no Constraint Equation is entered into the model when the stated conditions are present.

(o) Measurements are specified using the International System of Units with the following symbols:

- (i) MW: Megawatt
- (ii) MWs: Megawatt-second
- (iii) MWh: Megawatt-hour

1.4. Related documents

1.4.1. The documents in Table 2 are associated with this Procedure.

Table 2 Related documents

Reference	Title	Location
WEM Procedure	WEM Procedure: Facility Dispatch Process	AEMO Website
WEM Procedure	WEM Procedure: Adjustment of Real-Time Inputs	AEMO Website
WEM Procedure	WEM Procedure: Essential System Service Quantities	AEMO Website
WEM Procedure	Credible Contingency Events	AEMO Website
WEM Procedure	Participant Submissions	AEMO Website

2. Optimisation Problem Formulation

Preamble:

This paragraph 2 outlines the elements that comprise the optimisation problem, which is AEMO's formulation of the Dispatch Algorithm.

This paragraph is divided into subparagraphs defining the sets (paragraph 2.1), parameters (paragraph 2.2), variables (paragraph 2.3), Constraints (paragraph 2.4), and the objective function (paragraph 2.7) that make up the optimisation problem. This paragraph 2 also defines some particular data pre-processing steps that occur whenever the Dispatch Algorithm is solved (paragraphs 2.5 and 2.6).

2.1. Sets

2.1.1. ***Dispatch Period Set*:** The period for which the Dispatch Algorithm is calculated and dispatch quantities are produced. For Dispatch Intervals in the Dispatch Schedule, this equates to five minute periods, and for Pre-Dispatch Intervals in the Pre-Dispatch Schedule or Week-Ahead Schedule, this equates to 30 minute periods.

$$\boldsymbol{I} = \{i \,|\, i \in \mathbb{Z}, i \geq 0\}$$

2.1.2. ***Market Service Set:*** Each Market Service, as defined in the WEM Rules, uses the notation below and in Table 3 for the purpose of this Procedure.

$$\boldsymbol{M} = \{energy, contingency\_raise, contingency\_lower,$$
$$regulation\_raise, regulation\_lower, rocof\}$$

Table 3 Market Service Set notation

Symbol	Name	Units
energy	Energy	MW
contingency_raise	Contingency Reserve Raise	MW
contingency_lower	Contingency Reserve Lower.	MW
regulation_raise	Regulation Raise	MW
regulation_lower	Regulation Lower	MW
rocof	Rate of Change of Frequency Control Service	MWs

2.1.3. ***Registered Facility Set:*** The notation below indicates the set of Registered Facilities participating in the Central Dispatch Process for the relevant Dispatch Interval or Pre-Dispatch Interval.

$$\boldsymbol{F} \; where \; |\boldsymbol{F}| > 0$$

2.1.4. ***Offer Set:*** The Price-Quantity Pairs for each Market Service, up to the maximum allowable number, which, is set to 10 by AEMO in accordance with clause 7.2.5(a)(iv).

$$\boldsymbol{OS} = \{t \mid t \in \mathbb{Z}, t \in [1..10]\}$$

2.1.5. ***Generic Constraint Set***: The set of Generic Constraints included in the Dispatch Algorithm.

$$\boldsymbol{G} \text{ } where \text{ } |\boldsymbol{G}| \geq 0$$

2.1.6. ***System Inertia Set:*** The set of System Inertia levels considered by the Dispatch Algorithm, as per the DFCM determined under the WEM Procedure: Essential System Service Quantities.

$$\boldsymbol{H} = \{s_h \cdot h \mid h \in \mathbb{Z}, s_h \in [a_h..b_h]\}$$
$$where \text{ } s_h, a_h, b_h, h \geq 0$$

2.1.7. ***Largest Contingency Size Set:*** The set of Largest Credible Supply Contingency quantity levels used by the Dispatch Algorithm, as per the DFCM determined under the WEM Procedure: Essential System Service Quantities.

$$\boldsymbol{L} = \{ s_l \cdot l \mid l \in \mathbb{Z}, s_l \in [a_l..b_l]\}$$
$$where \text{ } s_l, a_l, b_l, l \geq 0$$

2.1.8. ***Tau Set:*** The set of Facility Speed Factors values used by the Dispatch Algorithm, as per the DFCM determined under the WEM Procedure: Essential System Service Quantities.

$$\boldsymbol{T} = \{ s_\tau \mid s_\tau \in \mathbb{R}, s_\tau \in [a_\tau..b_\tau]\}$$
$$where \text{ } s_\tau, b_\tau \geq 0$$
$$a_\tau = 0.2$$

2.1.9. ***Constraint Violation Penalty Set:*** The set of Constraint Violation Penalty values (described in paragraph 2.2.22) used by the Dispatch Algorithm, and as listed in Appendix B, as well as any Constraint Violation Penalties for Generic Constraints.

$$\boldsymbol{CVP} \text{ } where \text{ } |\boldsymbol{CVP}| \geq 0$$

2.1.10. ***Defined Contingency Set:*** The set of Credible Contingency Events for Injection identified by AEMO in accordance with the WEM Procedure: Credible Contingency Events, in addition to any Credible Contingency Events that could occur due to Injection from an individual Registered Facility.

$$\boldsymbol{D} \text{ } where \text{ } |\boldsymbol{D}| \geq 0$$

2.1.11. ***Contingency Set:*** The set of all Credible Contingency Events for Injection considered by the Dispatch Algorithm, which is the union of the Registered Facility Set, described in paragraph 2.1.3,, and the Defined Contingency Set described in paragraph 2.1.10.

$$\boldsymbol{C} = \boldsymbol{F} \cup \boldsymbol{D}$$

2.2. Parameters

2.2.1. ***Tranche Upper Bound:*** The upper bound of a given Tranche Quantity, where:

(a) this is greater than or equal to zero for Price-Quantity Pairs for Injection;

(b) this is zero for Price-Quantity Pairs for Withdrawal; and

(c) this is greater than or equal to zero for Price-Quantity Pairs for Essential System Service provision.

$$TrancheUB_{f,m,t} \ for \ f \ in \ \boldsymbol{F}, m \ in \ \boldsymbol{M}, t \ in \ \boldsymbol{OS}$$

$$where \ \ TrancheUB_{f,m,t} \ \geq 0$$

2.2.2. ***Tranche Lower Bound:*** The upper bound of a given Tranche Quantity, where:

(a) this is be zero for Price-Quantity Pairs for Injection;

(b) this is less than or equal to zero for Price-Quantity Pairs for Withdrawal; and

(c) this is zero for Price-Quantity Pairs for Essential System Service provision.

$$TrancheLB_{f,m,t} \ for \ f \ in \ \boldsymbol{F}, m \ in \ \boldsymbol{M}, t \ in \ \boldsymbol{OS}$$

$$where \ \ TrancheLB_{f,m,t} \ \leq 0$$

2.2.3. ***Tranche Price:*** The Loss Factor Adjusted Price associated with a given Tranche Quantity, as derived from the relevant Price-Quantity Pair, where:

(a) AEMO treats this as the price at or above which the Registered Facility is willing to generate energy associated with a Price-Quantity Pair for Injection;

(b) AEMO treats this as the price at or below which the Registered Facility is willing to consume energy associated with a Price-Quantity Pair for Withdrawal; and

(c) AEMO treats this as the price at or above which the Registered Facility is willing to provide the quantity of the Essential System Service associated with this Price-Quantity Pair for Essential System Service provision.

$$TranchePrice_{f,m,t} \ for \ f \ in \ \boldsymbol{F}, m \ in \ \boldsymbol{M}, t \ in \ \boldsymbol{OS}$$

$$where \ \ TranchePrice_{f,m,t} \ \in \mathbb{R}$$

2.2.4. ***Initial MW:*** The measured or estimated MW Injection or Withdrawal of each Registered Facility at the start of a Dispatch Interval or Pre-Dispatch Interval.

$$EnergyInitialMW_f \; for \; f \; in \; \boldsymbol{F}$$

$$where \; EnergyInitialMW_f \in \mathbb{R}$$

2.2.5. ***Ramp Up Rate:*** The Maximum Upwards Ramp Rate for a Registered Facility, as a MW per minute value.

$$RampUpRate_f \; for \; f \; in \; \boldsymbol{F}$$

$$where \; RampUpRate_f \in \mathbb{R}, \geq 0$$

2.2.6. ***Ramp Down Rate:*** The Maximum Downwards Ramp Rate for a Registered Facility, as a MW per minute value.

$$RampDownRate_f \; for \; f \; in \; \boldsymbol{F}$$

$$where \; RampDownRate_f \in \mathbb{R}, \geq 0$$

2.2.7. ***Facility Tau Factor:*** The Tau Value, as defined in the WEM Procedure: Essential System Services Accreditation, associated with a Registered Facility in respect to its Contingency Reserve Raise provision.

$$FacTau_f \; for \; f \; in \; \boldsymbol{F}$$

$$where \; FacTau_f \in \boldsymbol{T}$$

2.2.8. ***Essential System Service Maximum Provision Percentage:*** For an Essential System Service, the percentage of the total Essential System Service Enablement Quantity that any single Registered Facility can provide.

$$ESSMaximumProvisionPercentage_m \; for \; m \; in \; \boldsymbol{M}$$

$$where \; m \neq energy$$

$$where \; ESSMaximumProvisionPercentage_m \in [0, 1.0]$$

2.2.9. ***System Inertia:*** AEMO's estimate of the total Inertia in the SWIS, including contributions for Registered Facilities, Loads, and other Network elements.

$$SystemInertia$$

$$where \; SystemInertia_r \in \mathbb{R}, \geq 0$$

2.2.10. ***Demand:*** The Forecast Unscheduled Operational Demand as prepared by AEMO under clause 7.3.1(a) or 7.3.1(b).

$$Demand$$

$$where\ Demand \in \mathbb{R}, \geq 0$$

2.2.11. ***Normally-On Load Demand:*** The quantity of demand associated with Registered Facilities that are treated by AEMO as Normally-On Load. For a Dispatch Interval or Pre-Dispatch Interval, this is calculated as the absolute value of the sum of offered Withdrawal for all Registered Facilities that are Normally-On Load.

$$NOLDemand$$

$$where\ NOLDemand \in \mathbb{R}, \geq 0$$

2.2.12. ***Essential System Service Requirement:*** The exogenously defined quantity to be procured for the given Essential System Service, as determined under the WEM Procedure: Essential System Service Quantities, excluding Contingency Reserve Raise.

$$ESSRequirement_m$$

$$for\ m\ in\ \boldsymbol{M}$$

$$where\ m\ \neq energy, contingency\_raise$$

$$where\ ESSRequirement_m \in \mathbb{R}, \geq 0$$

2.2.13. ***Contingency Raise Offset:*** The parameter indicating the difference between the size of the Largest Credible Supply Contingency, and the quantity of Contingency Reserve Raise that must be procured by AEMO in order to maintain Power System Security, as determined via the DFCM.

$$ContingencyRaiseOffset_{l,h}$$

$$for\ l\ in\ \boldsymbol{L}, h\ in\ \boldsymbol{H}$$

$$where\ ContingencyRaiseOffset_{l,h} \in \mathbb{R}$$

2.2.14. ***Contingency Raise Performance Factor:*** The parameter between zero and one indicating a Registered Facility's capability to provide Contingency Reserve Raise relative to a Tau Value for the given system conditions, as determined via the DFCM.

$$ContingencyRaisePF_{l,h,f}$$

$$for\ l\ in\ \boldsymbol{L}, for\ h\ in\ \boldsymbol{H}, for\ f\ in\ \boldsymbol{F}$$

$$where\ ContingencyRaisePF_{l,h,f} \in [0, 1.0]$$

E[A] Note on Facility Performance Factors and Contingency Lower Offsets

This Dispatch Algorithm treats Facility Performance Factors for Regulation Raise, Regulation Lower, Contingency Reserve Lower, and RoCoF Control Service as equal to one for all Registered Facilities in all power system conditions. The Dispatch Algorithm also treats the Contingency Lower Offset as zero. As such, these parameters are not dealt with explicitly in this Procedure, as they have no impact on the Dispatch Algorithm at this time.

2.2.15. ***Enablement Minimum Value:*** The Enablement Minimum value for a Registered Facility providing an Essential System Service.

$$EnablementMin_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ m\ \neq energy$$

$$where\ EnablementMin_{f,m} \in \mathbb{R}$$

2.2.16. ***Low Breakpoint Value:*** The Low Breakpoint value for a Registered Facility providing an Essential System Service.

$$LowBP_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ m\ \neq energy$$

$$where\ LowBP_{f,m} \in \mathbb{R}$$

2.2.17. ***High Breakpoint Value:*** The High Breakpoint value for a Registered Facility providing an Essential System Service.

$$HighBP_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ m\ \neq energy$$

$$where\ HighBP_{f,m} \in \mathbb{R}$$

2.2.18. ***Enablement Maximum Value:*** The Enablement Maximum value for a Registered Facility providing an Essential System Service.

$$EnablementMax_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ m\ \neq energy$$

$$where\ EnablementMax_{f,m} \in \mathbb{R}$$

2.2.19. ***Generic Constraint Coefficient:*** The coefficient associated with the relevant Tranche Sum variable (as described in paragraph 2.3.2) within a Generic Constraint.

$$GenericConstraintCoeff_{g,f,m}$$

$$for\ g\ in\ \boldsymbol{G}, for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ GenericConstraintCoeff_{g,f,m} \in \mathbb{R}$$

2.2.20. ***Generic Constraint RHS:*** The value of the right hand side of a Generic Constraint, which resolves to a constant value for a given Dispatch Interval or Pre-Dispatch Interval.

$$GenericConstraintRHS_{g}$$

$$for\ g\ in\ \boldsymbol{G}$$

$$where\ GenericConstraintRHS_{g} \in \mathbb{R}$$

2.2.21. ***Generic Constraint Type:*** The form the Constraint Equation takes, which is one of:

(a) less than or equal to;

(b) greater than or equal to; or

(c) equal to.

$$GenericConstraintType_{g}$$

$$for\ g\ in\ \boldsymbol{G}$$

$$where\ GenericConstraintType_{g} \in \{\mathrm{LE}, \mathrm{GE}, \mathrm{EQ}\}$$

2.2.22. ***Constraint Violation Penalty:*** The penalties for each Constraint Equation outlined under paragraph 2.4, where these values are specified in Appendix B.

$$CVP$$

2.2.23. ***Facility Storage Constraint Flag:*** A Boolean indicator as to whether a Registered Facility incorporating an Electric Storage Resource has opted into Energy Storage Constraints under clause 7.5.10.

$$FacilityStorageConstraintFlag_{f}$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FacilityStorageConstraintFlag_{f} = TRUE \veebar FALSE$$

2.2.24. ***Facility Available Storage MWh:*** The Charge Level of a Registered Facility incorporating an Electric Storage Resource that is available to be dispatched.

$$FacilityAvailStorageMWh_{f}$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FacilityAvailStorageMWh_f \in \mathbb{R} \geq 0$$

2.2.25. ***Load Inertia:*** AEMO's estimate of the quantity of System Inertia that is contributed by equipment other than Registered Facilities.

$$LoadInertia$$

$$where\ LoadInertia \in \mathbb{R}, \geq 0$$

2.2.26. ***Defined Contingency Coefficient:*** The coefficient defining the contribution of energy, Contingency Reserve Raise, or Regulation Raise from a given Registered Facility towards a Credible Contingency Event in the Defined Contingency Set.

$$DefinedContingencyCoefficient_{d,f}$$

$$for\ d\ in\ \boldsymbol{D}, for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \{energy, contingency\_raise, regulation\_raise\}$$

$$where\ DefinedContingencyCoefficient_{d,f} \in \mathbb{R}$$

2.2.27. ***Defined Contingency Constant:*** For each Credible Contingency Event in a Defined Contingency Set, a constant offset that is applied.

$$DefinedContingencyConstant_d$$

$$for\ d\ in\ \boldsymbol{D}$$

$$where\ DefinedContingencyCoefficient_d \in \mathbb{R}$$

2.2.28. ***Interval Length:*** The length of the Dispatch Interval or Pre-Dispatch Interval in minutes, where this is equal to:

(a) five minutes for a Dispatch Interval; or

(b) 30 minutes for a Pre-Dispatch Interval.

$$IntervalLength$$

2.2.29. ***Fast Start Current Mode:*** The current Fast Start Mode for a Fast Start Facility. Unless otherwise specified in this Procedure, this will be the same as the Fast Start Target Mode from the first Dispatch Interval of the Dispatch Schedule immediately prior to the current Dispatch Schedule.

$$FSIPCurrentMode_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FSIPCurrentMode_f \in \mathbb{Z}, \in [0..5]$$

2.2.30. ***Fast Start Current Mode Time:*** The time in minutes that a Fast Start Facility has been in its current Fast Start Mode at the start of the Dispatch Interval. Unless otherwise specified, this will be the same as the Fast Start Target Mode Time described in paragraph 2.2.41 from the first Dispatch Interval of the Dispatch Schedule immediately prior to the current Dispatch Schedule.

$$FSIPCurrentModeTime_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FSIPCurrentModeTime_f \in \mathbb{R}, \geq 0$$

2.2.31. ***Dispatch Inflexibility Profile Mode Time:*** The Dispatch Inflexibility Profile parameters T1, T2, T3, and T4 as per clause 7.4.44(a), 7.4.44(b), 7.4.44(c), and 7.4.44 (d).

$$FSIPTTime_{f,t}$$

$$for\ f\ in\ \boldsymbol{F}, for\ t\ in\ \{t \mid t \in \mathbb{Z}, t \in [1,4]\}$$

$$where\ FSIPTTime_{f,t} \in \mathbb{R}, \geq 0$$

2.2.32. ***Dispatch Inflexibility Profile Minimum Load:*** The quantity as provided under clause 7.4.44(e), where:

(a) For Injection, this quantity is positive; and

(b) For Withdrawal, this quantity is negative.

$$FSIPMinLoading_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FSIPMinLoading_f \in \mathbb{R}$$

2.2.33. ***Fast Start Threshold:*** The value that determines whether a Fast Start Facility is considered committed for a solve of the Dispatch Algorithm.

$$FastStartThreshold$$

$$where\ FastStartThreshold \in \mathbb{R}, \geq 0$$

2.2.34. ***Inflexibility Flag:*** A Boolean indicator as to whether a Registered Facility has informed AEMO via its effective Real-Time Market Submission that it is Inflexible for the relevant Dispatch Interval or Pre-Dispatch Interval.

$$InflexibleFlag_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ InflexbileFlag_f \in \{FALSE, TRUE\}$$

2.2.35. ***ESS Flag:*** A Boolean indicator as to whether a Registered Facility is capable of providing a given Essential System Service in a Dispatch Interval or Pre-Dispatch Interval, as per the logic set out in paragraph 2.5.

$$ESSFlag_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ ESSFlag_{f,m} \in \{FALSE, TRUE\}$$

2.2.36. ***Fast Start Flag:*** A Boolean indicator as to whether a Registered Facility is participating as a Fast Start Facility in the Dispatch Interval. This is inferred from the Dispatch Inflexibility Mode Time parameters for a Fast Start Facility as follows:

(a) Where all Dispatch Inflexibility Profile Mode Time parameters are zero, then Fast Start Flag is false;

(b) Otherwise, Fast Start Flag is true.

$$FastStartFlag_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FastStartFlag_f \in \{FALSE, TRUE\}$$

2.2.37. ***Time After Mode 2:*** The time in minutes since a Fast Start Facility entered Fast Start Current Mode 2 (as outlined in Appendix E). This parameter is only used in a Fast Start Second Pass Run. This is a parameter that can be derived for a Fast Start Facility as follows:

(a) Where the Fast Start Target Mode, is 0, 1, 2, or 5, then this parameter is null, and not used in calculations;

(b) Where the Fast Start Target Mode is 3, this parameter equals the Fast Start Target Mode Time described in paragraph 2.2.41;

(c) Where the Fast Start Target Mode is 4, this parameter equals the Fast Start Target Mode Time plus the time T3 contained in the Dispatch Inflexibility Profile for the Fast Start Facility as per clause 7.4.44(c),

$$TimeSinceMode2_f$$

$$where\ TimeSinceMode2_f \in \mathbb{R}, \geq 0$$

2.2.38. ***Unconstrained Injection Forecast Value:*** The value representing the Unconstrained Injection Forecast (UIF) of a Semi-Scheduled Facility (SSF) or Non-Scheduled Facility (NSF).

$$UIF_f\ for\ f\ in\ \boldsymbol{F}$$

$$where\ UIF_f \in \mathbb{R}, \geq 0$$

2.2.39. ***Unconstrained Withdrawal Forecast Value:*** The value representing the Unconstrained Withdrawal Forecast (UWF) of a SSF or NSF.

$$UWF_f\ for\ f\ in\ \boldsymbol{F}$$

$$where\ UWF_f \in \mathbb{R}, \leq 0$$

2.2.40. ***Fast Start Target Mode:*** The Fast Start Mode that a Fast Start Facility will be in at the end of a Dispatch Interval, based on its Dispatch Inflexibility Profile. This can be determined by taking the Fast Start Current Mode Time, adding the length of the Dispatch Interval, and comparing it against the Dispatch Inflexibility Profile for the Fast Start Facility. Two special cases exist:

(a) If the Fast Start Current Mode is 0, then the Fast Start Target Mode is 0; or

(b) If the Fast Start Current Mode is 5, then the Fast Start Target Mode is 5.

$$FSIPTargetMode_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FSIPTargetMode_f \in \mathbb{Z}, \in [0..5]$$

2.2.41. ***Fast Start Target Mode Time:*** The time in minutes that a Fast Start Facility will have been in its current Fast Start Target Mode at the end of the Dispatch Interval, based on its Dispatch Inflexibility Profile.

$$FSIPTargetModeTime_f$$

$$for\ f\ in\ \boldsymbol{F}$$

$$where\ FSIPTargetModeTime_f \in \mathbb{R}, \geq 0$$

2.3. Variables

2.3.1. ***Tranche Quantity:*** A variable representing the quantity dispatched for a Registered Facility, for a Market Service, for a Price-Quantity Pair, where:

(a) For energy, this represents the quantity of Injection or Withdrawal allocated to the Price Quantity Pair in MW; or

(b) For a Regulation Raise, Regulation Lower, Contingency Reserve Raise, and Contingency Reserve Lower, this represents the Essential System Service Enablement Quantity allocated to the Price-Quantity Pair in MW; or

(c) For RoCoF Control Service, this represents the Essential System Service Enablement Quantity allocated to the Price-Quantity Pair in MWs.

$$TrancheQuantity_{f,m,t}\ for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}, for\ t\ in\ \boldsymbol{OS}$$

$$where\ TrancheQuantity_{f,m,t} \in \mathbb{R}$$

2.3.2. ***Tranche Sum***: For each Market Service, for each Registered Facility, a variable representing the sum of the Tranche Quantities where this relationship is enforced by the Constraint Equation in paragraph 2.4.35.

$$TrancheSum_{f,m}, for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

$$where\ TrancheQuantity_{f,m} \in \mathbb{R}$$

E[B] Tranche Sum and Dispatch Instructions

For each Registered Facility, the Tranche Sum for energy after a solve of the Dispatch Algorithm represents the Dispatch Target or Dispatch Cap to be issued. For Essential System Services, the Tranche Sum represents the Essential System Service Enablement Quantity to be issued.

2.3.3. ***Largest Contingency:*** A variable representing the Largest Credible Supply Contingency for the Dispatch Interval or Pre-Dispatch Interval.

$$LargestContingency$$

$$where\ LargestContingency \in \mathbb{R}, \geq 0$$

2.3.4. ***DFCM Binary:*** A binary variable representing each combination of the Largest Contingency Size Set and System Inertia Set.

$$DFCMBinary_{l,h}$$

$$for\ l\ in\ \boldsymbol{L}, for\ h\ in\ \boldsymbol{H}$$

$$where\ DFCMBinary_{l,h} = \{0,1\}$$

2.3.5. ***Contingency:*** A variable representing each Credible Contingency Event for Injection.

$$Contingency_c\ for\ c\ in\ \boldsymbol{C}$$

$$where\ Contingency_c \in \mathbb{R}, \geq 0$$

2.3.6. ***Constraint Violation Quantities:*** Variables included in Constraint Equations in paragraph 2.4 to resolve infeasible dispatch solutions as permitted by clause 7.2.6, where these individual variables are listed in Appendix B.

2.3.7. ***Tie-Breaking Variables:*** Variables included, as permitted under clause 7.6.23, to override the output of the Dispatch Algorithm and avoid Degenerate Solutions in the case of Price-Quantity Pairs with identical Loss Factor Adjusted Prices.

$$TBSlack1_{i,j}, TBSlack2_{i,j}$$

$$where\ TBSlack1_{i,j}\ , TBSlack2_{i,j} \in \mathbb{R}, \geq 0$$

E[C] Tie-Breaking Variables

Note that the *i* and *j* subscripts for the Tie-Breaking Variables are members of the ordered set S_k as outlined in paragraphs 2.4.33 and 2.4.34.

2.3.8. ***Contingency Raise Requirement Variable:*** This variable represents the Contingency Reserve Raise quantity that is determined endogenously in the Dispatch Algorithm and must be procured for the Dispatch Interval or Pre-Dispatch Interval.

$$ContingencyRaiseRequirement$$

$$where\ ContingencyRaiseRequirement \in \mathbb{R}, \geq 0$$

2.3.9. ***RoCoF Control Service Requirement Variable:*** This variable represents the RoCoF Control Service quantity that is determined endogenously in the Dispatch Algorithm and must be procured for the Dispatch Interval or Pre-Dispatch Interval.

$$RoCoFRequirement$$

$$where\ RoCoFRequirement \in \mathbb{R}, \geq 0$$

2.4. Constraints

2.4.1. ***Energy Balance Constraint***:

$$\sum_{f \in F} (TrancheSum_{f,energy}) + EnergyDeficit - EnergySurplus = Demand - NOLDemand$$

E[D] Energy Balance Constraint

This Constraint Equation requires that the total sum of Tranche Quantities must equal the demand for energy. Note that the Tranche Sum is the net of Injection and Withdrawal, so any Withdrawal by Registered Facilities is accounted for in that way. Normally On Loads are subtracted to avoid double counting.

2.4.2. Tranche Quantity Upper Bound Constraint:

$$TrancheQuantity_{f,m,t} - TrancheQuantitySurplus_{f,m,t} \leq TrancheUB_{f,m,t}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}, for\ t\ in\ \boldsymbol{OS}$$

E[E] Tranche Quantity Upper Bound Constraint

This Constraint Equation implements the upper bound on the Tranche Quantity variable. This is done as an explicit Constraint as opposed to a variable bound so that it can have a Constraint Violation Quantity associated with it.

2.4.3. Tranche Quantity Lower Bound Constraint:

$$TrancheQuantity_{f,m,t} + TrancheQuantityDeficit_{f,m,t} \geq TrancheLB_{f,m,t}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}, for\ t\ in\ \boldsymbol{OS}$$

E[F] Tranche Quantity Lower Bound Constraint

This Constraint Equation implements the lower bound on the Tranche Quantity variable. This is done as an explicit Constraint as opposed to a variable bound so that it can have a Constraint Violation Quantity associated with it.

2.4.4. Largest Contingency Constraint:

$$Contingency_c - LargestContingency \leq 0$$

$$for\ c\ in\ \boldsymbol{C}$$

E[G] Largest Contingency Constraint

This Constraint Equation requires that the Contingency variable is greater than or equal to the individual Contingency variables. As this formulation is a minimisation problem, this means that the Largest Contingency variable will be equal to the Largest Contingency in an optimal solution.

2.4.5. DFCM Binary to Largest Contingency Constraint:

$$LargestContingency - \sum_{l \in \boldsymbol{L}, h \in \boldsymbol{H}} (DFCMBinary_{l,h} * l) \leq 0$$

E[H] DFCM Binary to Largest Contingency Constraint

This Constraint Equation ensures consistency between the size of the Largest Contingency, and the DFCM Binary variable in use.

2.4.6. DFCM Binary to Inertia Level Constraint:

$$RoCoFRequirement - \sum_{l \in \boldsymbol{L}, h \in \boldsymbol{H}} (DFCMBinary_{l,h} * h) \geq -LoadInertia$$

E[I] DFCM Binary to Inertia Level Constraint

This Constraint Equation ensures consistency between the RoCoF Control Requirement, and the DFCM Binary variable in use. It also sets the requirement and price for RoCoF Control Service.

2.4.7. Facility Contingency Constraint:

$IF\ a\ Defined\ Facility\ Risk\ Constraint\ is\ present\ as\ part\ of\ the\ set\ of\ Defined\ Contingencies\ for\ Facility\ F$

$$SKIP\ CONSTRAINT$$

$ELSE$

$$Contingency_f - TrancheSum_{f,energy} - TrancheSum_{f,regulation_{raise}} - TrancheSum_{f,contingency_{raise}} = 0$$

$$for\ f\ in\ \boldsymbol{F}$$

E[J] Facility Contingency Constraint

This Constraint Equation requires that the Contingency variable associated with each Facility is greater than or equal to the energy Dispatch Target plus any Regulation

Raise provision from the relevant Facility. As this is a minimisation problem, the Contingency variable will equal the RHS.

This Constraint Equation is not activated where an alternative Defined Facility Risk Constraint is provided.

2.4.8. Defined Contingency Constraint:

$$Contingency_d - \sum_{f \in \boldsymbol{F}, m \in \widehat{M}} \left(DefinedContingencyCoefficient_{d,f,m} * TrancheSum_{f,m}\right) + DefinedContingencyDeficit - DefinedContingencySurplus = DefinedContingencyConstant_d$$

$$for\ d\ in\ \boldsymbol{D}$$

$$where\ \widehat{\boldsymbol{M}} = \{energy, regr, conr\}$$

E[K] Defined Contingency Constraint

These Constraint Equations require that the Contingency variable associated with each member of the Defined Contingency Set is greater than or equal to a linear combination of Energy, Regulation Raise, and Contingency Reserve Raise.

A Defined Contingency Constraint may be either represent a Facility Risk or a Network Risk.

2.4.9. Essential System Service Maximum Provision Percentage Constraint:

$$IF\ ESSFlag_{f,m} = True$$

$$TrancheSum_{f,m} - ESSMaximumProvisionPercentage_m * ESSRequirement_m - MaxESSProvisionPercentageSurplus_{f,m} \le 0$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ m\ in\ \boldsymbol{M}, \quad for\ f\ in\ \boldsymbol{F}$$

$$where\ m\ \neq energy, conr, rocof$$

E[L] Essential System Service Maximum Provision Percentage Constraint

This Constraint Equation requires that the provision of an ESS by a Facility is no more than a given percentage of the total ESS requirement.

2.4.10. Essential System Service Requirement Constraint:

$$\sum_{f \in \boldsymbol{F}} (TrancheSum_{f,m}) + ESSDeficit_m \geq ESSRequirement_m$$

$$for\ m\ in\ \boldsymbol{M}, where\ m\ \notin \{energy, conr, rocof\}$$

E[M] ESS Requirement Constraint

This Constraint Equation requires that the total procured Essential System Service is equal to or greater than the ESS requirement for each market, other than Energy and Contingency Reserve Raise, which have separate requirements in paragraphs 2.4.1 and 2.4.12 respectively. Any Contingency Lower Offset is assumed incorporated into the ESS Requirement Constraint value for Contingency Reserve Lower.

Note that $ESSDeficit_m$ indicates the relevant Constraint Violation Quantity deficit variable for each Essential System Service as per Appendix B.

2.4.11. Contingency SOS1 Constraint:

$$\sum_{l \in \boldsymbol{L}, h \in \boldsymbol{H}} (DFCMBinary_{l,h}) = 1$$

E[N] Contingency SOS1 Constraint

This Constraint Equation ensures that the DFCM Binary variables form a special ordered set of type 1 (SOS1). As the variables in the DFCM Binary are binary variables, this means that only one of these variables can be non-zero in a given solution.

2.4.12. Contingency Reserve Raise Requirement Constraint:

Indicator:

$$DFCMBinary_{l,h} = 1$$

Indicated Constraint:

$$\sum_{f \in \boldsymbol{F}} (ContingencyRaisePF_{h,l,f} * TrancheSum_{f,conr}) - ContingencyRaiseRequirement + ContingencyRaiseDeficit \geq 0$$

$$for\ l\ in\ \boldsymbol{L}, for\ h\ in\ \boldsymbol{H}$$

E[O] Contingency Reserve Raise Requirement Constraint

This Constraint Equation ensures that the quantity of procured Contingency Reserve Raise is greater than or equal to the requirement, reduced by the pre-calculated Contingency Raise Offset (see paragraph 2.2.13). This Constraint Equation makes use of an indicator Constraint, which is a functionality that can be found in commercial optimisation software, including FICO® Xpress.

2.4.13. Ramp Up Constraint:

$$TrancheSum_{f,energy} - RampRateUpSurplus_f \leq EnergyInitialMW_f + RampUpRate_f * IntervalLength$$

$$for\ f\ in\ \boldsymbol{F}$$

2.4.14. Ramp Up Constraint Alternative:

This Constraint Equation applies, in place of the Ramp Up Constraint outlined in paragraph 2.4.13, to a Fast Start Facility that is transitioning from Fast Start Modes 1 or 2 to Fast Start Modes 3 or 4 (outlined in Appendix E) during the Dispatch Interval.

$$TrancheSum_{f,energy} - RampRateUpSurplus_f \leq FSIPMinLoading_f + RampUpRate_f * TimeAfterMode2_f$$

$$for\ f\ in\ \boldsymbol{F}$$

E[P] Ramp Up Constraint and Ramp Up Constraint Alternative

These Constraint Equations require that a Registered Facility's Dispatch Target for energy is within its Ramp Rate Limit based on the Facility's Initial MW quantity. Note that these Constraint Equations are applied differently depending on the status of a Fast Start Facility. See paragraph 3.1 for information on the application of these Constraint Equations.

2.4.15. Ramp Down Constraint:

$$TrancheSum_{f,energy} + RampRateDownDeficit_f \geq EnergyInitialMW_f - RampDownRate_f * IntervalLength$$

$$for\ f\ in\ \boldsymbol{F}$$

2.4.16. Ramp Down Constraint Alternative:

This Constraint Equation applies to Fast Start Facilities in place of the Ramp Up Constraint in paragraph 2.4.13, for a Fast Start Facility that is transitioning from Fast Start Modes 1 or 2 to Fast Start Modes 3 or 4 (outlined in Appendix E) during the Dispatch Interval.

$$TrancheSum_{f,energy} + RampRateDownDeficit_f \geq FSIPMinLoading_f - RampDownRate_f * TimeAfterMode2_f$$

$$for\ f\ in\ \boldsymbol{F}$$

E[Q] Ramp Down Constraint and Ramp Down Constraint Alternative

These Constraint Equations require that a Registered Facility's Dispatch Target for energy is within its Ramp Rate Limit based on the Registered Facility's Initial MW quantity. Note that these Constraint Equations are applied differently depending on the status of a Fast Start Facility. See paragraph 3.1 for information on the application of these Constraint Equations.

2.4.17. Essential System Service Enablement Constraint:

$IF\ ESSFlag_{f,m} = True$

$$SKIP\ CONSTRAINT$$

$ELSE$

$$TrancheSum_{f,m} = 0$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m \neq energy$$

E[R] Essential System Service Enablement Constraint

This Constraint Equation only allows Essential System Service provision for the given service if the relevant Registered Facility passes the ESS pre-processing conditions in paragraph 2.5 and the Registered Facility is between its Enablement Minimum and its Enablement Maximum for the given Essential System Service.

2.4.18. Essential System Service Enablement Minimum Constraint:

$$IF\ ESSFlag_{f,m} = False$$

$$SKIP\ CONSTRAINT$$

$$ELSE$$

$$TrancheSum_{f,energy} + EnablementMinDeficit_{f,m} \geq EnablementMin_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m \neq energy$$

E[S] Essential System Service Enablement Minimum Constraint

For Registered Facilities that pass the ESS pre-processing conditions in paragraph 2.5, this Constraint Equation requires that these Registered Facilities are not dispatched for less than their Enablement Minimum for the relevant ESS. If this Constraint's marginal value is non-zero, it indicates that a Registered Facility is "trapped" at its Enablement Minimum for energy quantity .

2.4.19. Essential System Service Enablement Maximum Constraint:

$$IF\ ESSFlag_{f,m} = False$$

$$SKIP\ CONSTRAINT$$

$$ELSE$$

$$TrancheSum_{f,energy} - EnablementMaxSurplus_{f,m} \leq EnablementMax_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m \neq energy$$

E[T] Essential System Service Enablement Maximum Constraint

For Registered Facilities that pass the ESS pre-processing conditions in paragraph 2.5, this Constraint Equation requires that they are not dispatched for more than the Enablement Maximum for the relevant ESS. If this Constraint's marginal value is non-zero, it indicates that a Registered Facility is "trapped" at its Enablement Maximum for energy quantity.

2.4.20. Essential System Service Joint Ramping Up Constraint:

$$IF\ ESSFlag_{f,regulation\_raise} = False$$

$$SKIP\ CONSTRAINT$$

$$ELSE$$

$$TrancheSum_{f,energy} + TrancheSum_{f,regr} - JointRampingSurplus_{f,m} \leq EnergyInitialMW_{f} + (RampUpRate_{f} * IntervalLength)$$

$$for\ f\ in\ \boldsymbol{F}$$

E[U] Essential System Service Joint Ramping Up Constraint

For Registered Facilities that are providing both energy and Regulation Raise, the combination of the dispatched quantities for these services cannot be greater than the Maximum Upwards Ramp Rate for the Registered Facility. That is, if a Registered Facility is already moving at its Maximum Upwards Ramp Rate for energy dispatch, it leaves no additional upwards capacity for Regulation Raise.

2.4.21. Essential System Service Joint Ramping Down Constraint:

$$IF\ ESSFlag_{f,regulation\_lower} = False$$

$$SKIP\ CONSTRAINT$$

$$ELSE$$

$$TrancheSum_{f,energy} - TrancheSum_{f,regl} + JointRampingDeficit_{f,m} \geq EnergyInitialMW_f - (RampDownRate_f * IntervalLength)$$

$$for\ f\ in\ \boldsymbol{F}$$

E[V] Essential System Service Joint Ramping Down Constraint

For Registered Facilities that are providing both energy and Regulation Lower, the combination of the dispatched quantities for these services cannot be less than the Maximum Downwards Ramp Rate for the Registered Facility. That is, if a Registered Facility is already moving at its Maximum Downwards Ramp Rate for energy dispatch, it leaves no additional downwards capacity for Regulation Lower.

2.4.22. Essential System Service Joint Capacity Constraint 1:

$$IF\ ESSFlag_{f,m} = False$$

$$SKIP\ CONSTRAINT$$

$$ELSE$$

$$TrancheSum_{f,energy} + TrancheSum_{f,regulation\_raise} + usc * TrancheSum_{f,m} - JointCapacitySurplus_{f,m} \leq EnablementMax_{f,m}$$

$$where\ usc = \frac{EnablementMax_{f,m} - HighBP_{f,m}}{\sum_{t \in \boldsymbol{OS}} TrancheUB_{f,m,t}}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \{contingency\_raise, contingency\_lower\}$$

E[W] Essential System Service Joint Capacity Constraint 1

This Constraint Equation requires that a Registered Facility that is providing Regulation Raise, and one or both of Contingency Reserve Raise and/or Contingency Reserve Lower, is dispatched such that it can provide all Essential System Services concurrently.

2.4.23. Essential System Service Joint Capacity Constraint 2:

$IF\ ESSFlag_{f,m} = False$

$$SKIP\ CONSTRAINT$$

$ELSE$

$$TrancheSum_{f,energy} - TrancheSum_{f,regulation\_lower} - lsc * TrancheSum_{f,m} + JointCapacityDeficit_{f,m} \geq EnablementMin_{f,m}$$

$$where\ lsc = \frac{LowBP_{f,m} - EnablementMin_{f,m}}{\sum_{t \in OS} TrancheUB_{f,m,t}}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \{contingency\_raise, contingency\_lower\}$$

E[X] Essential System Service Joint Capacity Constraint 2

This Constraint Equation requires that a Registered Facility that is providing Regulation Lower, and one or both of Contingency Reserve Raise and/or Contingency Reserve Lower is dispatched such that it can provide all Essential System Services concurrently.

2.4.24. Essential System Service Energy and Regulation Constraint 1:

$IF\ ESSFlag_{f,m} = False$

$$SKIP\ CONSTRAINT$$

$ELSE$

$$TrancheSum_{f,energy} + usc * TrancheSum_{f,m} - ERSurplus_{f,m} \leq EnablementMax_{f,m}$$

$$where\ usc = \frac{EnablementMax_{f,m} - HighBP_{f,m}}{\sum_{t \in \boldsymbol{OS}} TrancheUB_{f,m,t}}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \{regulation\_raise, regulation\_lower\}$$

2.4.25. Essential System Service Energy and Regulation Constraint 2:

$$IF\ ESSFlag_{f,m} = False$$

$$SKIP\ CONSTRAINT$$

$$ELSE$$

$$TrancheSum_{f,energy} - lsc * TrancheSum_{f,m} + ERDeficit_{f,m} \geq EnablementMin_{f,m}$$

$$where\ lsc = \frac{LowBP_{f,m} - EnablementMin_{f,m}}{\sum_{t \in \boldsymbol{os}} TrancheUB_{f,m,t}}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \{regulation\_raise, regulation\_lower\}$$

E[Y] Essential System Service Energy and Regulation Constraints

These Constraint Equations require that the dispatch of a Registered Facility that provides Regulation Raise and/or Regulation Lower together with energy occurs within bounds specified by the Regulation Raise and Regulation Lower Essential System Service Trapezium.

2.4.26. Pure Storage Constraint:

$$IF\ FacilityStorageConstraintFlag_f = True$$

$$\frac{5}{60} TrancheSum_{f,energy} + \frac{5}{60} TrancheSum_{f,regulation\_raise} + \frac{15}{60} TrancheSum_{f,contingency\_raise} - StorageSurplus \leq FacilityAvailStorageMWh_f$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[Z] Pure Storage Constraint

A Constraint Equation that requires Registered Facilities with Electric Storage Resources to limit energy and Essential System Service provision subject to their charge level. It is intended that this Constraint will be an opt-in requirement. Facilities will need to manage their charge level and bids accordingly.

2.4.27. Generic Constraints:

$$\sum_{f \in \boldsymbol{F}, m \in \boldsymbol{M}} (GenericConstraintCoeff_{g,f,m} * TrancheSum_{f,m}) - GCSurplus_g \leq GenericConstraintRHS_g$$

$$OR$$

$$\sum_{f \in \boldsymbol{F}, m \in \boldsymbol{M}} (GenericConstraintCoeff_{g,f,m} * TrancheSum_{f,m}) + GCDeficit_g \geq GenericConstraintRHS_g$$

$$OR$$

$$\sum_{f \in \boldsymbol{F}, m \in \boldsymbol{M}} (GenericConstraintCoeff_{g,f,m} * TrancheSum_{f,m}) - GCSurplus_g + GCDeficit_g = GenericConstraintRHS_g$$

$$for\ g\ in\ \boldsymbol{G}$$

E[AA] Generic Constraints

These Constraint Equations represent all forms of Constraints that may be activated and de-activated by AEMO to represent various system and Network conditions. Certain Generic Constraints may be tagged as Intervention Constraints for the purpose of the intervention pricing methodology in accordance with Appendix D.

2.4.28. Fast Start Inflexibility Profile Mode 1 Constraint:

$$IF\ FastStartFacility_f\ AND\ (FSIPTargetMode_f = 0\ OR\ FSIPTargetMode_f = 1)$$

$$TrancheSum_{f,energy} + FSProfileDeficit_f - FSProfileSurplus_f = 0$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

2.4.29. Fast Start Inflexibility Profile Mode 2 Constraint:

$$IF\ FastStartFacility_f\ AND\ FSIPTargetMode_f = 2$$

$$TrancheSum_{f,energy} + FSProfileDeficit_f - FSProfileSurplus_f = \frac{FSIPTargetModeTime_f * FSIPMinLoading_f}{FSIPTTime_{f,2}}$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

2.4.30. Fast Start Inflexibility Profile Mode 3 Constraint:

$$IF\ FastStartFacility_f\ AND\ (FSIPTargetMode_f = 3)\ AND\ (FSIPMinLoading_f \geq 0):$$

$$TrancheSum_{f,energy} + FSProfileDeficit_f \geq FSIPMinLoading_f$$

$$ELSE\ IF\ FastStartFacility_f\ AND\ (FSIPTargetMode_f = 3)\ AND\ (FSIPMinLoading_f < 0):$$

$$TrancheSum_{f,energy} - FSProfileSurplus_f \leq FSIPMinLoading_f$$

$$ELSE:$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

2.4.31. Fast Start Inflexibility Profile Mode 4 Constraint:

$$IF\ FastStartFacility_f\ AND\ \left(FSIPTargetMode_f = 4\right) AND \left(FSIPTargetModeTime_f < FSIPTTime_{f,4}\right) AND\ (FSIPMinLoading_f \geq 0):$$

$$TrancheSum_{f,energy} + FSProfileDeficit_f \geq \frac{FSIPMinLoading_f * (FSIPTTime_{f,4} - FSIPTargetModeTime_f)}{FSIPTTime_{f,4}}$$

$$IF\ FastStartFacility_f\ AND\ \left(FSIPTargetMode_f = 4\right) AND \left(FSIPTargetModeTime_f < FSIPTTime_{f,4}\right) AND\ (FSIPMinLoading_f < 0):$$

$$TrancheSum_{f,energy} - FSProfileSurplus_f \leq \frac{FSIPMinLoading_f * (FSIPTTime_{f,4} - FSIPTargetModeTime_f)}{FSIPTTime_{f,4}}$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[BB] Fast Start Inflexibility Profile Constraints

These Constraint Equations give effect to Dispatch Inflexibility Profiles for Fast Start Facilities, requiring that the times provided for T1, T2, T3, and T4 in the effective Real Time Market Submission are respected.

2.4.32. Inflexibility Constraint:

$$IF\ InflexibleFlag_f = TRUE\ AND\ FacilityClass \neq NSF$$

$$TrancheSum_{f,energy} - InflexibleFlagSurplus_f + InflexibleFlagDeficit_f = \sum_{t \in \boldsymbol{OS}} (TrancheUB_{f,energy,t}) + \sum_{t \in \boldsymbol{OS}} (TrancheLB_{f,energy,t})$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[CC] Inflexibility Constraint

This Constraint Equation indicates that a Facility cannot move from the total energy quantity offered in its effective Real Time Market Submission. This can be a single Constraint as, if there are two right hand side parameters, only one will be non-zero at a time. AEMO's implementation of this Constraint relies on upstream systems ensuring that there is only a single offered tranche for a Facility using the Inflexibility Flag Constraint.

2.4.33. Tie-Breaking Constraint 1:

$$Let\ \boldsymbol{S}\ be\ the\ set\ of\ price\text{-}tied\ tranches\ within\ a\ Market\ Service\ m$$

$$s.t.\ the\ absolute\ value\ of\ the\ difference\ in\ TranchePrices\ within\ a\ unique\ tranche\ pair\ k\ is\ within\ 1e^{-6}\ in\ value$$

$$where\ any\ k = \{s_{1k}, s_{2k}\},\ s_{1k}, s_{2k} \in \boldsymbol{S}$$

$$and\ where\ both\ TrancheLB\ and\ the\ TrancheUB\ associated\ with\ the\ TranchePrice\ are\ non\ zero$$

$$TBSlack1_{k\_UB} - TBSlack2_{k\_UB} = TrancheUB_{s1k} * TrancheQuantity_{s2k} - TrancheUB_{s2k} * TrancheQuantity_{s1k}$$

$$for\ each\ k$$

$$for\ each\ Market\ Service$$

2.4.34. Tie-Breaking Constraint 2:

$$Let\ \boldsymbol{S}\ be\ the\ set\ of\ price\text{-}tied\ tranches\ within\ a\ Market\ Service\ m$$

$$s.t.\ the\ absolute\ value\ of\ the\ difference\ in\ TranchePrices\ within\ a\ unique\ tranche\ pair\ k\ is\ within\ 1e^{-6}\ in\ value$$

$$where\ any\ k = \{s_{1k}, s_{2k}\},\ s_{1k}, s_{2k} \in \boldsymbol{S}$$

$$and\ where\ both\ TrancheLB\ and\ the\ TrancheUB\ associated\ with\ the\ TranchePrice\ are\ non\ zero$$

$$TBSlack1_{k\_LB} - TBSlack2_{k\_LB} = TrancheLB_{s1k} * TrancheQuantity_{s2k} - TrancheLB_{s2k} * TrancheQuantity_{s1k}$$

$$for\ each\ k$$

$$for\ each\ Market\ Service$$

E[DD] Tiebreaking Constraints

The result of Constraint Equations 2.4.33 and 2.4.34 is that the Dispatch Algorithm attempts to minimise the sum of the values of TBSlack1 and TBSlack2, subject to other Constraints. TBSlack1 and TBSlack2 are penalised in the objective function with sufficiently small coefficients such that the price-tied pairs will be dispatch in proportion, unless it has a material impact on the value of the objective function, including where it would result in another Constraint violating.

The Dispatch Algorithm is required to apportion price ties for all Market Services, not just energy.

2.4.35. Tranche Sum Constraint:

$$\sum_{t \in \boldsymbol{OS}} \left(TrancheQuantity_{f,m,t}\right) = TrancheSum_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}$$

E[EE] Tranche Sum Constraint

This Constraint Equation ensures that Tranche Sum variable is equal to the sum of the Tranche Quantity variables for a given Registered Facility and Market Service.

2.4.36. Contingency Raise Requirement Auxiliary Constraint:

Indicator:

$$DFCMBinary_{l,h} = 1$$

Indicated Constraint:

$$ContingencyRaiseRequirement - LargestContingency \geq -ContingencyRaiseOffset_{h,l}$$

$$for\ l\ in\ \boldsymbol{L}, for\ h\ in\ \boldsymbol{H}$$

E[FF] Contingency Raise Requirement Auxiliary Constraint

This Constraint Equation requires that the Contingency Raise Requirement Variables is greater than all of the Contingency variables, with an allowance for any Contingency Raise Offset determined by AEMO.

2.4.37. Contingency Raise Maximum Provision Percentage Constraint:

$$IF\ ESSFlag_{f,conRaise} = True$$

$$\begin{aligned} TrancheSum_{f,contingency\_raise} &- ESSMaximumProvisionPercentage_{contingency\_raise} \\ &* ContingencyRaiseRequirement \\ &- MaxESSProvisionPercentageSurplus_{f,contingency_{raise}} \leq 0 \end{aligned}$$

$$ELSE$$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[GG] Contingency Raise Maximum Provision Percentage Constraint

This Constraint Equation can be used to limit the maximum Contingency Reserve Raise procured from a single Registered Facility as a percentage of the sum of the dispatched total energy or a given ESS.

2.4.38. RoCoF Control Service Requirement Constraint:

$$\sum_{f \in \boldsymbol{F}} (TrancheSum_{f,rocof}) + RCSDeficit \geq RoCoFRequirement$$

E[HH] RoCoF Control Service Requirement Constraint

This Constraint Equation requires that the total quantity of procured RoCoF Control Service is greater than the RoCoF Control Requirement, which is determined by the combination of the Constraints in paragraphs 2.4.6 and 2.4.40.

2.4.39. RoCoF Control Service Maximum Provision Percentage Constraint:

$IF\ ESSFlag_{f,RoCoF} = True$

$$TrancheSum_{f,rocof} - ESSMaximumProvisionPercentage_{rocof} * RoCoFRequirement - MaxESSProvisionPercentageSurplus_{f,rocof} \leq 0$$

$ELSE$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[II] RoCoF Control Service Maximum Provision Percentage Constraint

This Constraint Equation can be used to restrict the maximum contribution of a single Registered Facility towards the RoCoF Control Requirement where this is considered necessary for Power System Security.

2.4.40. RoCoF Control Minimum Requirement Constraint:

$$RoCoFRequirement \geq ESSRequirement_{rocof}$$

E[JJ] RoCoF Control Service Minimum Requirement Constraint

This Constraint Equation can be used to set an exogenous minimum requirement for RoCoF Control Service where this considered necessary to meet Power System Security, in accordance with the WEM Procedure: Essential System Service Quantities. Note that this is not necessarily the same as the Minimum RoCoF Control Requirement.

2.4.41. Unconstrained Injection Forecast Constraint:

$IF\ FacilityClass = SSF$

$$TrancheSum_{f,energy} - UIFSurplus_f \leq UIF_f$$

$ELSE$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[KK] Unconstrained Injection Forecast Constraint

This Constraint Equation restricts the energy dispatch of SSF to no more than their forecast UIF.

2.4.42. Unconstrained Withdrawal Forecast Constraint:

$IF\ FacilityClass = SSF$

$$TrancheSum_{f,energy} + UWFDeficit_f \geq UWF_f$$

$ELSE$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[LL] Unconstrained Withdrawal Forecast Constraint

This Constraint Equation restricts the energy dispatch of SSF to no less than their UWF.

2.4.43. NSF Constraint

$IF\ FacilityClass = NSF$

$IF\ UIF = 0\ AND\ UWF < 0$

$$TrancheSum_{f,energy} + NSFDeficit_f - NSFSurplus_f = UWF_f$$

$IF\ UWF = 0\ AND\ UIF \geq 0$

$$TrancheSum_{f,energy} + NSFDeficit_f - NSFSurplus_f = UIF_f$$

$ELSE$

$$TrancheSum_{f,energy} + NSFDeficit_f - NSFSurplus_f = 0$$

$ELSE$

$$SKIP\ CONSTRAINT$$

$$for\ f\ in\ \boldsymbol{F}$$

E[MM] NSF Constraint

This Constraint Equation treats Non-Scheduled Facilities as Inflexible, by fixing their Dispatch Quantities to the submitted UIF or Unconstrained Withdrawal Forecast, as applicable.

2.5. Essential System Service Pre-Processing Conditions

E[NN] Note on ESS-Only Facilities

Where a Registered Facility does not have energy offers (that is, it only provides one or more Essential System Services), the Initial MW quantity for energy, the sum of the Tranche Upper Bound, and the sum of the Tranche Lower Bound (as defined in paragraph 2) used in the ESS Flag Constraint are assumed to be zero. As such, the flags in paragraph 2.4.43 will pass for Registered Facilities with no energy offers if, and only if, the Enablement Minimum, Low Breakpoint, High Breakpoint, and Enablement Maximum for the Essential System Service are all equal to zero.

2.5.1. Constraint Equations in paragraphs 2.4.17 through to 2.4.25 inclusive contain an ESS Flag parameter, where, for a Registered Facility, for Regulation Raise, Regulation Lower, Contingency Reserve Raise, and Contingency Reserve Lower:

(a) the ESS Flag is set to true if:

(i) the conditions in paragraphs 2.5.3, 2.5.4, 2.5.5, and 2.5.6 are met; and

(ii) the Inflexibility Flag from paragraph 2.2.34 is false; and

(b) otherwise, the ESS Flag is set to false.

2.5.2. Constraint Equations in paragraphs 2.4.17 through to 2.4.25 inclusive contain an ESS Flag parameter, where, for a Registered Facility, for RoCoF Control Service:

(a) the ESS Flag is set to true if the conditions in paragraphs 2.5.3, 2.5.4, 2.5.5, and 2.5.6 are met; or

(b) otherwise, the ESS Flag is set to false.

2.5.3. ESS Flag Condition 1:

$$EnablementMin_{f,m} \leq EnergyInitialMW_f \leq EnablementMax_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m\ \neq energy$$

2.5.4. ESS Flag Condition 2:

$$\sum_{t \in \boldsymbol{OS}} TrancheUB_{f,energy,t} \geq EnablementMin_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m\ \neq energy$$

2.5.5. ESS Flag Condition 3:

$$\sum_{t \in \boldsymbol{OS}} TrancheLB_{f,energy,t} \leq EnablementMax_{f,m}$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m\ \neq energy$$

2.5.6. ESS Flag Condition 4:

$$\sum_{t \in \boldsymbol{OS}} TrancheUB_{f,m,t} > 0$$

$$for\ f\ in\ \boldsymbol{F}, for\ m\ in\ \boldsymbol{M}\ where\ m\ \neq energy$$

2.6. Pre-processing of Fast Start Facility Parameters

E[OO] Note on Fast Start Pre-processing

This paragraph discusses the use and pre-processing of Fast Start Facility parameters where they are used in accordance with paragraph 3. Pre-processing of Fast Start Facility parameters consists of processing the necessary information in the appropriate format for committing and dispatching Fast Start Facilities. In standard Fast Start operation, the Dispatch Algorithm needs to know:

- the mode that a fast start unit is operating in; and
- how long it has been in that mode?

This paragraph discusses three non-standard scenarios for Fast Start Facilities where the Fast Start Current Mode and Fast Start Current Mode Time need to be reset.

The details of each Fast Start Current Mode can be found in Appendix E

2.6.1. For the first Dispatch Interval of a Dispatch Schedule, for a Fast Start Facility, where:

(a) all of the times T1, T2, T3, and T4 as described in clauses 7.4.44(a) to 7.4.44(d) are zero or null, then the Fast Start Facility Flag as per paragraph 2.2.36 will be set to false; or

(b) at least one of the times T1, T2, T3, and T4 as described in clauses 7.4.44(a) to to 7.4.44(d) is not zero, then the Fast Start Facility Flag as per paragraph 2.2.36 will be set to true.

2.6.2. Where a Fast Start Facility's Fast Start Facility Flag as per paragraph 2.2.36 was set to false for the first Dispatch Interval of the Dispatch Schedule immediately prior to the current Dispatch Schedule, and for the first Dispatch Interval of the current Dispatch Schedule, the Fast Start Facility's Fast Start Facility Flag is set to true;

(a) where the Fast Start Facility's Initial MW value as per paragraph 2.2.4 is less than 1 MW, the Fast Start Facility's Fast Start Current Mode will be set to 0, and the Fast Start Current Mode Time will be set to 0;

(b) where the Fast Start Facility's Initial MW value as per paragraph 2.2.4 is greater than or equal to 1 MW, the Fast Start Facility's Fast Start Current Mode will be set to 5, and the Fast Start Current Mode Time will be set to time T4 as per clause 7.4.44(d).

2.6.3. Where a Fast Start Facility's Fast Start Facility Flag was set to true for the first Dispatch Interval of the Dispatch Schedule immediately prior to the current Dispatch Schedule, and for the first Dispatch Interval of the current Dispatch Schedule, as per paragraph 2.2.36, the Fast Start Facility's Fast Start Facility Flag is set to false:

(a) where the Fast Start Facility's Initial MW value as per paragraph 2.2.4 is less than 1 MW, and the Fast Start Facility's Fast Start Current Mode is zero, then the Fast Start Current Mode Time will be set to 0.

(b) otherwise, the Fast Start Facility's Fast Start Current Mode will be set to 5, and the Fast Start Current Mode Time will be set to time T4 as per clause 7.4.44(d).

2.6.4. The Fast Start Current Mode Time of each Fast Start Facility will be capped in accordance with its Dispatch Inflexibility Profile.

2.7. Objective Function

2.7.1. The objective function of the Dispatch Algorithm is:

$$Minimise$$

$$Objective = \sum_{t \in \boldsymbol{OS}} \left(TrancheQuantity_{f,m,t} * TranchePrice_{f,m,t} \right) + \sum_{j \in \boldsymbol{CVP}} \left(CVP_j * CVQ_j \right)$$

$$where\ CVQ_j\ represents\ each\ of\ the\ CVQ\ variables\ listed\ in\ Appendix\ B$$

3. Dispatch Algorithm Solution Process

Preamble:

This paragraph 3 sets out the process for solving the Dispatch Algorithm for each Market Schedule, and accounts for certain conditions where alternative logic paths may be required for a particular Dispatch Interval or Pre-Dispatch Interval.

AEMO accounts for Inflexible Facilities via the application of the Constraints in paragraphs 2.4.28, 2.4.29, 2.4.30, 2.4.31, 2.4.32, and 2.4.43. The relevant parameters are provided by Market Participants for a Facility as set out in the WEM Procedure: Participant Submissions.

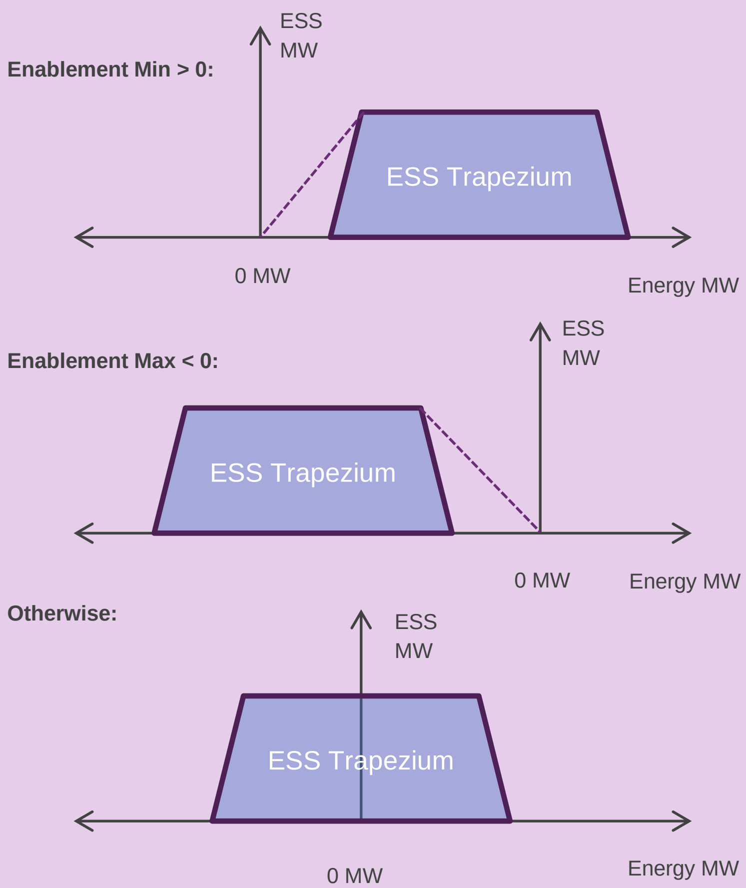
AEMO achieves the priority order required by clause 7.6.23 of the WEM Rules via the application of the Constraints in paragraph 2.3.7, 2.4.33, and 2.4.34.

AEMO has not identified any situations it deems significant for the purpose of clause 7.6.24(b) of the WEM Rules, and as a consequence has not implemented Oscillation Control Constraints as part of the Dispatch Algorithm at this time.

E[PP] Adjustment of Enablement Limits for RoCoF Control Service

For all instances of the Dispatch Algorithm, except the first Dispatch Interval in a Dispatch Schedule, the Enablement Limits of the RoCoF Control Service Essential System Service Trapezium are relaxed. This allows for the forecast commitment and decommitment of Registered Facilities for RoCoF Control Service in future Dispatch Intervals and Pre-Dispatch Intervals, where they would otherwise be disabled or enabled due to the Essential System Service pre-processing conditions. The effects of the modifications made in this paragraph are shown below visually for reference:

Figure E[1]. Trapezia adjustments for RoCoF Control Service



3.1. Primary Dispatch Interval

3.1.1. The steps in this paragraph 3.1 layout the steps to be completed to produce a solution from the Dispatch Algorithm for the first Dispatch Interval in a Dispatch Schedule, including logic for Fast Start Facilities, Intervention Pricing Runs, and Over-Constrained Dispatch Runs.

3.1.2. Where a solve of an optimisation problem is required in this paragraph 3.1, the optimisation problem will use the same set of Constraint Equations applied to the step immediately prior to it, unless otherwise specified.

3.1.3. **Step 1:** Solve the optimisation problem defined in paragraph 2, with the following modifications:

(a) Constrain the RoCoF Control Service Requirement variable from paragraph 2.3.9 to be less than or equal to the greater of:

(i) the Essential System Service Requirement parameter for RoCoF Control Service from paragraph 2.2.12; and

(ii) the System Inertia parameter from paragraph 2.2.9.

(b) For any Active Fast Start Facilities, do not apply the Constraint Equations outlined in paragraphs 2.4.13, 2.4.14, 2.4.15, 2.4.16, 2.4.28, 2.4.29, 2.4.30, and 2.4.31; and

(c) For Active Fast Start Facilities with a Fast Start Current Mode of 0, 1, or 2 at the start of the Dispatch Interval, do not apply the Constraint Equations outlined in paragraphs 2.4.20 and 2.4.21 to these Facilities;

(d) Update the Active Fast Start Facilities' Fast Start Target Mode and Fast Start Target Mode Times based on their Fast Start Current Mode, Fast Start Current Mode Time, and Dispatch Inflexibility Profiles.

then progress to Step 2 of this paragraph.

3.1.4. **Step 2:** In the solution to the optimisation problem in Step 1:

(a) If any Active Fast Start Facility has a Fast Start Target Mode of 5, and the Tranche Sum variable for energy for the Active Fast Start Facility is less than the Fast Start Threshold variable, change the Fast Start Current Mode to 0 and reset the Fast Start Current Mode Time to 0;

(b) For any Active Fast Start Facilities with a Fast Start Current Mode of 0 where the Tranche Sum variable for energy for the Active Fast Start Facility is greater than or equal to the Fast Start Threshold variable, change the Fast Start Current Mode to 1 and Fast Start Current Mode Time to 0;

(c) Update each Active Fast Start Facility's Fast Start Target Mode and Fast Start Target Mode Time based on the Fast Start Current Mode and Fast Start Current Mode Time as updated in Step 1(d) in paragraph 3.1.3 and Dispatch Inflexibility Profiles.

If following these modifications, one or more Active Fast Start Facilities has a Fast Start Current Mode of 1, 2, 3, or 4; then progress to Step 3B in paragraph 3.1.6. Otherwise, progress to Step 3A in paragraph 3.1.5.

3.1.5. **Step 3A:** If in the solution produced in the previous step (step 2 or step 3B as relevant) Intervention Constraints are invoked, progress to Step 4 in paragraph 3.1.7. Otherwise progress to Step 5 in paragraph 3.1.8.

3.1.6. **Step 3B:** Solve the optimisation problem defined in section 2 with the following modifications:

(a) For any Active Fast Start Facilities that have a Fast Start Current Mode of 1 or 2, and a Fast Start Target Mode of 3 or 4, exclude the Constraint Equations outlined in paragraphs 2.4.13 and 2.4.15 and use the Constraint Equations in paragraphs 2.4.14 and 2.4.16 in their place;

(b) For all Active Fast Start Facilities that do not meet the conditions in paragraph 3.1.6(a), exclude the Constraint Equations outlined in paragraphs 2.4.14 and 2.4.16 and use the Constraint Equations outlined in paragraphs 2.4.13 and 2.4.15 in their place;

(c) If the Fast Start Target Mode for an Active Fast Start Facility is Fast Start Mode 0 or Fast Start Mode 1, then AEMO will apply the Fast Start Inflexibility Profile Mode 1 Constraint Equation outlined in paragraph 2.4.29 to the Fast Start Facility;

(d) If the Fast Start Target Mode for an Active Fast Start Facility is Fast Start Mode 2, then AEMO will apply the Fast Start Inflexibility Profile Mode 2 Constraint Equation outlined in paragraph 2.4.30 to the Fast Start Facility;

(e) If the Fast Start Target Mode for an Active Fast Start Facility is Fast Start Mode 3, then AEMO will apply the Fast Start Inflexibility Profile Mode 3 Constraint Equation outlined in section 2.4.30 to the Fast Start Facility;

(f) If the Fast Start Target Mode for an Active Fast Start Facility is Fast Start Mode 4, then AEMO will apply the Fast Start Inflexibility Profile Mode 4 Constraint Equation, outlined in section 2.4.31 to the Fast Start Facility;

then progress to Step 3A of this section.

3.1.7. **Step 4:** Solve the optimisation problem with the modifications applied in Step 3, ignoring any Intervention Constraints, then progress to Step 5 in paragraph 3.1.8.

3.1.8. **Step 5:** If any of the Constraint Violation Quantities are greater than zero in the solution produced in the previous step, perform an Over-Constrained Dispatch Run on that solution, using the logic in Appendix C.

3.1.9. **Step 6:** Produce final results as follows, applying any conditions from paragraph 3.1.10 or 3.1.11, if relevant:

(a) If a Fast Start Second Pass Run under step 3B in paragraph 3.1.6 was performed, use the results of this run;

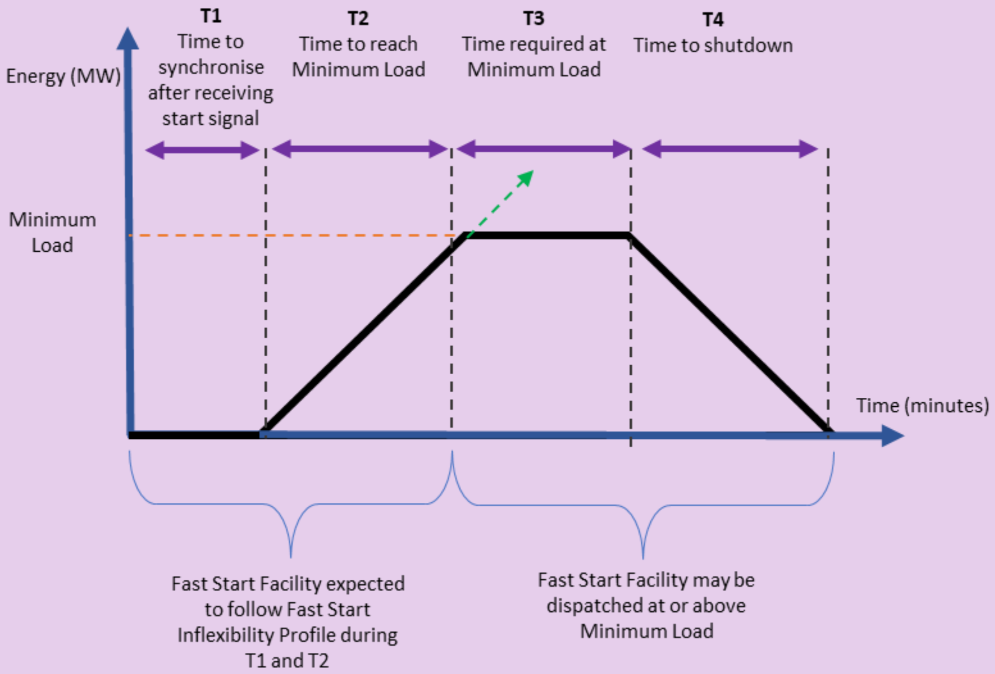
(b) If a Fast Start Second Pass Run under step 3B in paragraph 3.1.6 was not performed, use the results of the first run conducted under step 1 in paragraph 3.1.3.

3.1.10. If an Intervention Pricing Run was conducted, use prices determined in this run in preference to other runs for the purpose of setting Market Clearing Prices, except where the conditions in paragraph 3.1.11 are met.

3.1.11. If an Over-Constrained Dispatch Run was conducted, use prices determined in this run in preference to other runs for the purpose of setting Market Clearing Prices.

E[QQ] A visual representation of a Dispatch Inflexibility Profile

Figure E[2]. A visual representation of a Dispatch Inflexibility Profile



3.2. All other Dispatch Intervals in the Dispatch Schedule

3.2.1. This paragraph 3.2 lays out the steps to be completed to produce a forecast solution from the Dispatch Algorithm for the Dispatch Intervals in a Dispatch Schedule excluding the first Dispatch Interval.

3.2.2. Where a solve of an optimisation problem is required in this paragraph 3.2, the optimisation problem will use the same set of Constraint Equations applied to the step immediately prior to it, unless otherwise specified.

3.2.3. Fast Start Current Mode, Fast Start Current Mode Time, Fast Start Target Mode, and Fast Start Target Mode Time are not relevant to the Dispatch Intervals in this paragraph, and so do not need to be calculated.

3.2.4. **Step 1:** Solve the optimisation problem defined in paragraph 2, with the following modifications:

(a) Fast Start Facility considerations do not apply to these runs, and so do not apply the Constraint Equations outlined in paragraphs 2.4.14, 2.4.16, 2.4.28, 2.4.29, 2.4.30, and 2.4.31;

(b) Where a Registered Facility's Enablement Minimum and Enablement Maximum for RoCoF Control Service are both greater than zero, set the Registered Facility's Enablement Minimum for RoCoF Control Service to zero;

(c) Where a Registered Facility's Enablement Minimum and Enablement Maximum for RoCoF Control Service are both less than zero, set the Registered Facility's Enablement Maximum for RoCoF Control Service to zero;

(d) Pure Storage Constraints, as outlined in paragraph 2.4.26, are not projected forward, so do not apply to this Step 1 (paragraph 3.2.4);

then progress to Step 2 in paragraph 3.2.5

3.2.5. **Step 2:** If the solution produced in the previous step (Step 1) has Intervention Constraints invoked, progress to Step 3 in paragraph 3.2.6. Otherwise progress to Step 4 in paragraph 3.2.7.

3.2.6. **Step 3:** Solve the optimisation problem created for the previous step, ignoring any Intervention Constraints, then progress to Step 4 in paragraph 3.2.7.

3.2.7. **Step 4:** If any of the Constraint Violation Quantities are greater than zero in the solution produced in the previous step, perform an Over-Constrained Dispatch Run, using the logic in Appendix C.

3.2.8. **Step 5:** Produce results for the relevant Dispatch Interval, applying any relevant conditions from paragraph 3.2.9 or 3.2.10.

3.2.9. If an Intervention Pricing Run was conducted, use prices determined in this run in preference to other runs for the purpose of setting forecast Market Clearing Prices, except where the conditions in paragraph 3.2.10 are met.

3.2.10. If an Over-Constrained Dispatch Run was conducted, use prices determined in this run in preference to other runs for the purpose of setting forecast Market Clearing Prices.

3.3. Pre-Dispatch Intervals in the Pre-Dispatch Schedule and Week-Ahead Schedule

3.3.1. This paragraph 3.3 outlines the steps to be completed to produce a forecast solution from the Dispatch Algorithm for the Pre-Dispatch Intervals in a Pre-Dispatch Schedule or Week-Ahead Schedule.

3.3.2. Where a solve of an optimisation problem is required in this paragraph 3.3, the optimisation problem will use the same set of Constraint Equations applied to the step immediately prior to it, unless otherwise specified.

3.3.3. Fast Start Current Mode, Fast Start Current Mode Time, Fast Start Target Mode, and Fast Start Target Mode Time are not relevant to these Dispatch Intervals, and do not need to be calculated.

3.3.4. **Step 1:** Solve the optimisation problem defined in paragraph 2, with the following modifications:

(a) Fast Start Facility considerations do not apply to these runs, and so do not apply to the Constraint Equations outlined in paragraphs 2.4.14, 2.4.16, 2.4.28, 2.4.29, 2.4.30, and 2.4.31;

(b) Where a Registered Facility's Enablement Minimum and Enablement Maximum for RoCoF Control Service are both greater than zero, set the Registered Facility's Enablement Minimum for RoCoF Control Service to zero;

(c) Where a Registered Facility's Enablement Minimum and Enablement Maximum for RoCoF Control Service are both less than zero, set the Registered Facility's Enablement Maximum for RoCoF Control Service to zero;

(d) Pure Storage Constraints, outlined in paragraph 2.4.26, are not projected forward, so are not applied in this step;

then progress to Step 2 in paragraph 3.3.5.

3.3.5. **Step 2:** If the solution produced in the previous step (Step 1) has Intervention Constraints invoked, progress to Step 3 in paragraph 3.3.6. Otherwise, progress to Step 4 in paragraph 3.3.7.

3.3.6. **Step 3:** Solve the optimisation problem created for the previous step, ignoring any Intervention Constraints, then progress to Step 4 in paragraph 3.3.7.

3.3.7. **Step 4:** If any of the Constraint Violation Quantities are greater than zero in the solution produced in the previous step, perform an Over-Constrained Dispatch Run, using the logic in Appendix C.

3.3.8. **Step 5:** Produce results for the relevant Pre-Dispatch Interval, applying any conditions from paragraphs 3.3.9 or 3.3.10, if relevant.

3.3.9. If an Intervention Pricing Run was conducted, use prices determined in this run in preference to other runs for the purpose of setting forecast Market Clearing Prices, except where the conditions in clause 3.3.10 are met.

3.3.10. If an Over-Constrained Dispatch Run was conducted, use prices determined in this run in preference to other runs for the purpose of setting forecast Market Clearing Prices.

3.4. Calculation of Market Clearing Prices

3.4.1. Market Clearing Prices and forecast Market Clearing Prices are determined as follows:

(a) The price for energy is determined as the marginal value of the Energy Balance Constraint in paragraph 2.4.1;

(b) The price for Contingency Reserve Raise is determined as the marginal value of the actively indicated Contingency Reserve Raise Requirement Constraint in paragraph 2.4.12;

(c) The price for Contingency Reserve Lower is determined as the marginal value of the Essential System Service Requirement Constraint in paragraph 2.4.10 as implemented for Contingency Reserve Lower;

(d) The price for Regulation Raise is determined as the marginal value of the Constraint Equation in paragraph 2.4.10 as implemented for Regulation Raise;

(e) The price for Regulation Lower is determined as the marginal value of the Constraint Equation in paragraph 2.4.10 as implemented for Regulation Lower; and

(f) The price for RoCoF Control Service is determined as the marginal value of the RoCoF Control Service Minimum Requirement Constraint in paragraph 2.4.38.

E[RR] Constraint Relaxation

Appendix C and its applications in this Procedure are the mechanisms that AEMO uses to relax Constraints as permitted under clause 7.2.6.

3.4.2. Where a price or forecast price for any Market Service determined in paragraph 3.1 or 3.2 is greater than the Alternative Maximum STEM Price, AEMO will instead set the Market Clearing Price for the Market Service to the Alternative Maximum STEM Price.

3.4.3. Where a price or forecast price for energy determined under this paragraph 3 is less than the Minimum STEM Price, AEMO will instead set the Market Clearing Price for the Market Service to the Minimum STEM Price.

3.4.4. Where a price or forecast price for a Market Service, other than energy, determined under this paragraph 3 is less than the zero, AEMO will instead set the Market Clearing Price for the Market Service to zero.

Appendix A. Relevant clauses of the WEM Rules

Table 4 details:

(a) the head of power clauses in the WEM Rules under which the Procedure has been developed; and

(b) each clause in the WEM Rules requiring an obligation, process or requirement be documented in a WEM Procedure, where the obligation, process or requirement has been documented in this Procedure.

Table 4 Relevant clauses of the WEM Rules

Clause
7.2.5(a)(iii)
7.2.5(a)(iv)
7.2.5(a)(v)
7.2.5(a)(vi)
7.2.5(a)(vii)
7.2.5(c)
7.2.8
7.3.1(a)
7.3.1(b)
7.5.10
7.6.24
7.6.27(a)
7.6.27(b)
7.11C.7
7.11C.8
7.11C.10

Appendix B.Constraint Violation Quantities and Constraint Violation Penalty Values

B.1 Constraint Violation Quantity Variables and Associated Constraint Violation Penalty Values

B.1.1 The list of Constraint Violation Quantity variables for the purpose of paragraph 2.3.6, and the associated Constraint Violation Penalty values for the purposes of paragraph 2.2.22 are listed in Table 5.

B.1.2 The value of a Constraint Violation Penalty in Table 5 is expressed as a multiplier to be applied to the Alternative Maximum STEM Price in the relevant Dispatch Interval or Pre-Dispatch Interval.

Table 5 Schedule of Constraint Violation Quantities and associated Constraint Violation Penalties

Constraint Violation Quantity variable name	Section references	Set membership	CVP Value
NSFDeficit	2.4.44	Registered Facility	1175
NSFSurplus	2.4.44	Registered Facility	1175
RampRateDeficit	2.4.15, 2.4.16	Registered Facility	1155
RampRateSurplus	2.4.13, 2.4.14	Registered Facility	1155
StorageSurplus	2.4.27	Registered Facility	1150
TrancheUBDeficit	2.4.2	Registered Facility, Market Service	1135
TrancheLBDeficit	2.4.3	Registered Facility, Market Service	1135
FSProfileDeficit	2.4.28, 2.4.29, 2.4.30, 2.4.31	Registered Facility	1130
FSProfileSurplus	2.4.28, 2.4.29, 2.4.30, 2.4.31	Registered Facility	1130
UIFSurplus	2.4.41	Registered Facility	385
UWFDeficit	2.4.42	Registered Facility	385
InflexibleFlagDeficit	2.4.32	Registered Facility, Market Service	380
InflexibleFlagSurplus	2.4.32	Registered Facility, Market Service	380
GCDeficit	2.4.27	Generic Constraint Set	300
GCSurplus	2.4.27	Generic Constraint Set	300
DefinedContingencyDeficit	2.4.8	Defined Contingency	160
DefinedContingencySurplus	2.4.8	Defined Contingency	160
JointRampDeficit	2.4.21	Registered Facility, Market Service	155
JointRampSurplus	2.4.20	Registered Facility, Market Service	155
JointCapacityDeficit	2.4.22	Registered Facility, Market Service	155

Constraint Violation Quantity variable name	Section references	Set membership	CVP Value
JointCapacitySurplus	2.4.23	Registered Facility, Market Service	155
ERDeficit	2.4.25	Registered Facility, Market Service	155
ERSurplus	2.4.24	Registered Facility, Market Service	155
EnergySurplus	2.4.1	-	150
EnergyDeficit	2.4.1	-	150
EnablementMinDeficit	2.4.18	Registered Facility, Market Service	70
EnablementMaxSurplus	2.4.19	Registered Facility, Market Service	70
RCSDeficit	2.4.6	-	12
RegulationRaiseDeficit	2.4.10	-	10
RegulationLowerDeficit	2.4.10	-	10
ContingencyRaiseDeficit	2.4.10	-	8
ContingencyLowerDeficit	2.4.10	-	8
MaxESSProvisionPercentageSurplus	2.4.9	Registered Facility	4
TBSlack1	2.4.33, 2.4.34	Tie-Break Set(s)	1e-9
TBSlack2	2.4.33, 2.4.34	Tie-Break Set(s)	1e-9

Appendix C. Over-Constrained Dispatch Run Process

E[SS] Over-constrained Dispatch Background

WEMDE's objective when solving the Dispatch Algorithm is to minimise the total cost of Injection and Withdrawal, subject to any Constraints. Most Constraints in the optimisation problem in paragraph 2 have slack variables and associated penalty coefficients. In the case of an infeasible solution, it is possible for these Constraint Violation Penalties to dominate the value of the objective function, thus obscuring real price information.

When this happens, the resulting Market Clearing Price is either below the Minimum STEM Price or above the Alternative Maximum STEM Price. While the solution itself may be close to acceptable, it is necessary to:

1) recover the actual price information by removing the Constraint Violation Penalty values from the objective function based on offer price; and
2) notify Market Participants of the price outcome. This is important because the dispatch solution prices are needed for settlement of the STEM.

The process of recovering the price information from a solution like this is called the Over-Constrained Dispatch Run process.

Note that a typical approach used in linear programming, where the solution is infeasible, is to relax Constraints and re-solve. That is not being done here because the Constraints themselves are not being relaxed. Instead, the only objective here is to recover the offer price information, accepting that the Constraints are too restrictive to allow a feasible solution.

C.1 Method

C.1.1 **Step 1:** From the original solution of the Dispatch Algorithm, retain the constructed model.

C.1.2 **Step 2:** Apply an upper bound Constraint to each Constraint Violation Quantity, equal to its value from the original solution of the Dispatch Algorithm, to the retained version of the Dispatch Algorithm.

C.1.3 **Step 3:** Change the Constraint Violation Penalty values for all Constraint Violation Quantities in the retained version of the Dispatch Algorithm initialised in Step 2 in paragraph C.1.2 of this Appendix to equal 1e-3, so as to not affect the price outcome.

C.1.4 **Step 4:** Solve this modified version of the Dispatch Algorithm using the basis of the original solution from Step 1 in paragraph C.1.1 of this Appendix as the starting point for the solve.

C.1.5 **Step 5:** Determine prices from the solution of the modified version of the Dispatch Algorithm determined in Step 4 in paragraph C.1.4 of this Appendix as per paragraph 3.4.1.

Appendix D. Intervention Pricing Run Process

E[TT] Intervention Pricing Logic

Clause 7.11C.11 of the WEM Rules requires AEMO to determine a methodology for determing Market Clearing Prices during AEMO Intervention Events.

The method in this Appendix D allows the Dispatch Algorithm to ignore ramp rate Constraints to allow the movement of Registered Facilities to levels of Injection or Withdrawal that would have occurred without Intervention Constraints. In practice, this can result in some price suppression where a ramp rate Constraint is genuinely binding in dispatch during an AEMO Intervention Event.

D.1 Assumptions

D.1.1 A truly accurate counterfactual is impossible to create, and therefore it is more important to focus on a simple, repeatable approach for pricing during AEMO Intervention Events, based on a reasonable scenario that could have occurred if Intervention Constraints were not applied in a Dispatch Interval.

D.1.2 All other input data to the Dispatch Algorithm except the relevant Intervention Constraints should not change for the purpose of pricing during AEMO Intervention Constraints.

D.1.3 The effect of Constraints that limit Facility output based on Maximum Upwards Ramp Rates or Maximum Downward Ramp Rates do not typically persist for extended periods of time, and so can be reasonably ignored for the purpose of shifting dispatch outcomes from a different set of initial conditions in the real system, where the Intervention Constraints are active.

D.2 Method

D.2.1 **Step 1:** Where it is determined in this Procedure that AEMO must conduct an Intervention Pricing Run, AEMO will retain the model used for the previous iteration, and apply the following modifications:

(a) disable any active Intervention Constraints;

(b) disable any ramp rate Constraints created under paragraphs 2.4.13, 2.4.14, 2.4.15, and 2.4.16; and

(c) disable joint ramping Constraints created under paragraphs 2.4.20 and 2.4.21.

D.2.2 **Step 2:** Run the optimisation problem, including the modifications applied under Step 1 in paragraph D.1.1 of this Appendix.

D.2.3 **Step 3:** Using the solution generated in Step 2 of this Appendix, apply the price determination logic under paragraph 3.4, and use the most recently determined prices in place of any previously determined prices.

Appendix E. Fast Start Modes

E.1.1 Table 6 lists the Fast Start modes used by the Dispatch Algorithm, as well as a description of each mode.

Table 6 Fast Start Modes

Mode	Mode Number	Description
Off-Line Mode	0	The Fast Start Facility is offline.
Synchronising Mode	1	The Fast Start Facility has been committed as a result of the dispatch process, and is starting, but has not yet synchronised. This mode lasts for T_1.
Start-up Mode	2	The Fast Start Facility has synchronised, but has not reached its Minimum Load, and is therefore on a fixed-dispatch trajectory. This mode lasts for T_2.
Minimum Loading Constrained Operation Mode	3	The Fast Start Facility has reached its Minimum Load, but has not operated at or above this level for the required period of time. This mode lasts for T_3.
Shutdown Bounded Mode	4	The Fast Start Facility has been running above its Minimum Load level for more than the required period of time, T_3, but has not been running longer than ($T_2 + T_3 + T_4$). In this mode, the energy dispatch for this Fast Start Facility is lower bounded by the MW value as calculated from its shut-down inflexibility profile and the length of time it has been in this mode.
Normal Operation	5	After $T_2 + T_3 + T_4$ minutes, the Fast Start Facility is eligible for shut down. The unit is dispatched the same way as any other regular unit until the MW target becomes zero and the Fast Start Facility is placed into Off-Line Mode.

Appendix F. Price-Setter Functionality

E[UU] Price-Setter Functionality

To assist in the analysis of dispatch outcomes, AEMO has included functionality within its implementation of the Dispatch Algorithm that shows which variables contributed to the Market Clearing Price for each Market Service. This mechanism is not required by the WEM Rules, and should be taken as informational only. AEMO does not guarantee that this mechanism will be accurate in all scenarios. Additionally, this functionality will not be accurate where a price has been overridden either due to it exceeding a price cap, or by another mechanism (such as an Over-Constrained Dispatch Run) outlined in this Procedure.

E[UU1] Method

For a linear program **D** of the form:

Min $\boldsymbol{CX}$

s.t. $Ax = b$

which can be written as:

Min $c_B^T x_B + c_N^T x_N$

s.t. $Bx_B + Nx_N = b$

where B are the basic columns of the A matrix.

N are the non-basic columns of the A matrix.

then **(1)** $x_B = B^{-1}b - B^{-1}Nx_N$

For a solution where Constraint n is binding, an increase in its RHS value is equivalent to increasing the non-basic slack variable of this Constraint Equation. Equation (1) in this Appendix can then be used to find the increase in the basic variables brought about by an increase in the RHS.

For example, if we are interested in the third Constraint:

$$x_B = B^{-1}b - B^{-1}Nx_N$$

$$= B^{-1}b - B^{-1}\begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 1 \end{bmatrix}\begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ \dots \\ 0 \end{bmatrix}$$

So a change in x_B is the third column of $-B^{-1}$.

Taking energy price, for example, at the optimal solution, the Energy Balance Constrained (outlined in paragraph 2.4.1) is binding. Using the above technique, we can find basic variable changes caused by a marginal increase in the RHS of this Constraint Equation. The basic variables returned are typically (but not exclusively) one of those listed in Table 7 below:

Table 7 Basic variables with the price-setting output

Variable	Description
energy_Tranche	An energy offer tranche associated with a price.
*ESS*_Tranche	An ESS offer tranche associated with a price, where *ESS* could be any ESS co-optimised with energy.
EnergyBalance_SlackDeficit	The energy shortfall CVQ.
EnergyBalance_SlackEnergySurplus	The energy surplus CVQ.
GenericConstraint_SlackDeficit	A deficit variable (CVQ) from a Generic Constraint.
GenericConstraint_SlackSurplus	A surplus variable (CVQ) from a Generic Constraint.
Product_Deficit	An ESS Deficit (CVQ).

Similar analysis can be conducted in relation to the Constraint Equation in paragraph 2.4.10 for each Essential System Service price.