Business Requirements Specification

Flexible Ramp Product: Deliverability

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Current Version Date: 8/19/2022

Disclaimer

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Revision History

Date	Version	Description
1/28/2021	1.0	Initial Document release

07/29/2022	1.1	Updated Document release
		• Minor formatting changes throughout the document.
		• Section 2 (Details of Business Need/Problem)
		  o Changed project release date.
		• Section 5.1 (Manage RTM)
		  o Added some notes.
		  o Added FRPDY-BRQ104 through FRPDY-BRQ111C.
		• Section 5.2 (Manage Billing & Settlements)
		  o Added FRPDY-BRQ112 thru FRPDY-BRQ112B, FRPDY-BRQ117A, FRPDY-BRQ122A.
		  o Edited the following BRQs: FRPDY-BRQ112D, FRPDY-BRQ113, FRPDY-BRQ115, FRPDY-BRQ116, FRPDY-BRQ117, FRPDY-BRQ118 thru FRPDY-BRQ122.
		• Section 5.3 (Manage OASIS)
		  o Added FRPDY-BRQ124, FRPDY-BRQ124A.
		  o Deleted some BRQs.
		  o Edited the following BRQs: FRPDY-BRQ125 thru FRPDY-BRQ131, FRPDY-BRQ137, FRPDY-BRQ138, FRPDY-BRQ138A.
		• Deleted PCA requirements.
		• Section 5.4 (Manage CMRI)
		  o Added FRPDY-BRQ138B.
		• Section 5.5 (Market/Business Simulation)
		  o Added a note.

Date	Version	Description
		• Appendix A ○ Made minor updates to graphs in section 6.4.2 (Flex Ramp Capacity Model).

08/19/2022	1.2	• Section 3.1 (BPM)
		  ○ Updated to add Demand Response BPM impact.
		• FRPDY-BRQ004, FRPDY-BRQ005, FRPDY-BRQ014, FRPDY-BRQ015, FRPDY-BRQ016, FRPDY-BRQ017, FRPDY-BRQ019, FRPDY-BRQ020, FRPDY-BRQ021, FRPDY-BRQ022, FRPDY-BRQ024, FRPDY-BRQ025, FRPDY-BRQ026, FRPDY-BRQ027, FRPDY-BRQ028, FRPDY-BRQ029
		  ○ Updated the formulation to reverse the sign of S and W terms.
		• FRPDY-BRQ006, FRPDY-BRQ018, FRPDY-BRQ023, , FRPDY-BRQ030
		  ○ Updated the formulation
		  ○ Updated note, as applicable.
		• FRPDY-BRQ017
		  ○ Corrected BRQ ID from FRPDY-BRQ117 to FRPDY-BRQ017.
		• FRPDY-BRQ026, FRPDY-BRQ029, FRPDY-BRQ070, FRPDY-BRQ071, FRPDY-BRQ072, FRPDY-BRQ073, FRPDY-BRQ080, FRPDY-BRQ081, FRPDY-BRQ101A, FRPDY-BRQ137, FRPDY-BRQ138
		  ○ Updated.
		• FRPDY-BRQ070 thru FRPDY-BRQ103
		  ○ Updated BRQ ID.

Date	Version	Description

		• FRPDY-BRQ073A, FRPDY-BRQ101B, FRPDY-BRQ109, FRPDY-BRQ111D, FRPDY-BRQ111E, FRPDY-BRQ111F
		  ○ Added.
		• FRPDY-BRQ080, FRPDY-BRQ081, FRPDY-BRQ108
		  ○ Changed Requirement Types to Existing System Functionality.
		• FRPDY-BRQ24, FRPDY-BRQ124A, FRPDY-BRQ127, FRPDY-BRQ128
		  ○ Updated BPM info.
		• FRPDY-BRQ138A, Appendix-B
		  ○ Deleted.
		• FRPDY-MKT001, FRPDY-MKT002
		  ○ Added CMRI as sink system.

Table of Contents

1 Introduction

1.1 Purpose

With regards to FRP Deliverability, the procurement of Flexible ramping product (FRP) is based on opportunity costs that arises from trade-offs between the need for energy and the need for ramping capability. The current market does not consider the locational constraints when procuring the flexible ramping product. This results in procuring flexible ramp awards that may not be fully deliverable. Nodal procurement ensures that both energy and flexible ramp awards are transmission feasible. This nodal approach addresses operational concerns that flexible ramping capacity may not be dispatchable and more accurately prices individual resource's flexible ramp capacity. The goal of this initiative is to not eliminate stranded ramping capability when system conditions change.

The scope of the FRP Deliverability is:

1. Procurement of FRP for BAA's that fails the flex test is separate for each BAA.
2. Procurement of FRP for BAA's that pass the flex test for the entire group of BAA.
3. Transmission constraints and transfer limits are enforced in FRP deployment scenarios.
4. Distributing the uncertainty requirement in each BAA load and VER locations versus just load.
5. Distributing the demand curve surplus variable as a decision variable at load aggregation points (LAP) versus Balancing Authority Areas (BAA).
6. To establish the Locational Marginal Capacity Prices (LMCP) for FRP.

1.2 References

Information related to this Flexible Ramping Product: Deliverability can be found on the following CAISO web page at:

http://www.caiso.com/InitiativeDocuments/DraftFinalProposal-FlexibleRampingProductRefinements.pdf

2 Details of Business Need/Problem

2.1 Description

Business Opportunity/Problem Statement:	
What:	Procurement of flexible ramping product (FRP) is based on opportunity costs that arises from trade-offs between the need for energy and the need for ramping capability. The current market does not consider the locational constraints when procuring the flexible ramping product. This results in procuring flexible ramp awards that may not be fully deliverable. Nodal procurement ensures that both energy and flexible ramp awards are transmission feasible. This nodal approach addresses operational concerns that flexible ramping capacity may not be dispatchable and more accurately prices individual resource's flexible ramp capacity.
When:	Fall 2022
Why do we have this opportunity/problem:	The flexible ramping product secures additional ramping capability that can be dispatched in the subsequent market runs to cover uncertainty in forecasted net load.

3 Business Impacts

3.1 Business Practice Manual (BPM)

BPM	Description of Impact(s)
Demand Response	Updated to change the default election from 5 minute to 60 minute for the bid dispatchable election. Tariff §4.13.3
Market Operations	Yes
Market Instruments	Yes

3.2 Other

Impact:	Description:
Market Simulation	Yes • Market sim needed for calculation of FRP requirements & demand curve (FRP Requirements Enhancements) • Nodal FRP procurement (FRP Deliverability)
Market Participant Impact	Yes • To improve the FRP requirements to be more accurate based on historical information • Nodal FRP procurement and efficient FRP Deployment scenarios
External Training	Yes
Policy Initiative	Yes

4 Acronyms and Terms Definition

Acronym	Definition
FRP	Flexible Ramping Product
BAA	Balancing Authority Area
LMP	Locational Marginal Pricing
LMCP	Locational Marginal Corrective Capacity
LAP	Load Aggregation Point Group
VER	Variable Energy Resource
FRU	Flex Ramp up
FRD	Flex Ramp Down
ETSR	Energy Transfer System resource
GHG	Green House Gas
SMEC	System marginal Energy Cost
ITC/ISL	Intertie Transmission Constraint / Interchange Scheduling Limit

5 Business Requirements

The sections below describe the Business processes and the associated business requirements involved in the project. These may represent high-level functional, non-functional, reporting, and/or infrastructure requirements. These business requirements directly relate to the high-level scope items determined for the project.

5.1 Business Process: Manage Real Time Market

5.1.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ001	The system shall be capable of identifying BAA groups and their BAA membership.	Core	RTBS STUC RTPD RTD
FRPDY-BRQ002	The system shall receive the following 5min data for each Trading Hour in the Trading Day for each BAA in the EIM Area and for the entire EIM Area: • the 5min High Percentile net demand forecast uncertainty histogram ($ND_5^{H97.5}$) • the 5min High Percentile demand forecast uncertainty histogram ($D_5^{H97.5}$) • the 5min High Percentile adjusted solar forecast uncertainty histogram ($S_5^{H97.5}$) • the 5min High Percentile adjusted wind forecast uncertainty histogram ($W_5^{H97.5}$) • the 5min Low Percentile net demand forecast uncertainty histogram ($ND_5^{H2.5}$) • the 5min Low Percentile demand forecast uncertainty histogram ($D_5^{H2.5}$)	Core Tariff §44.2.4.2	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	• the 5min Low Percentile adjusted solar forecast uncertainty histogram ($S_5^{H2.5}$) • the 5min Low Percentile adjusted wind forecast uncertainty histogram ($W_5^{H2.5}$) • the second-order polynomial coefficients ($A_5^{D97.5}, B_5^{D97.5}, C_5^{D97.5}$) of the High Percentile quadratic quantile regression of 5min demand forecast uncertainty • the second-order polynomial coefficients ($A_5^{S97.5}, B_5^{S97.5}, C_5^{S97.5}$) of the High Percentile quadratic quantile regression of 5min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_5^{W97.5}, B_5^{W97.5}, C_5^{W97.5}$) of the High Percentile quadratic quantile regression of 5min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_5^{D2.5}, B_5^{D2.5}, C_5^{D2.5}$) of the Low Percentile quadratic quantile regression of 5min demand forecast uncertainty • the second-order polynomial coefficients ($A_5^{S2.5}, B_5^{S2.5}, C_5^{S2.5}$) of the Low Percentile quadratic quantile regression of 5min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_5^{W2.5}, B_5^{W2.5}, C_5^{W2.5}$) of the Low Percentile quadratic quantile regression of 5min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_5^{M97.5}, B_5^{M97.5}, C_5^{M97.5}$) of the High Percentile quadratic quantile regression of 5min MOSAIC forecast uncertainty • the second-order polynomial coefficients ($A_5^{M2.5}, B_5^{M2.5}, C_5^{M2.5}$) of the Low Percentile quadratic quantile regression of 5min MOSAIC forecast uncertainty • the 5min High Percentile Threshold net demand forecast uncertainty histogram (ND_5^{H99}) • the 5min Low Percentile Threshold net demand forecast uncertainty histogram (ND_5^{H1})		

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ003	The system shall receive the following 15min data for each Trading Hour in the Trading Day for each BAA in the EIM Area and for the entire EIM Area: • the 15min High Percentile net demand forecast uncertainty histogram ($ND_{15}^{H97.5}$) • the 15min High Percentile demand forecast uncertainty histogram ($D_{15}^{H97.5}$) • the 15min High Percentile adjusted solar forecast uncertainty histogram ($S_{15}^{H97.5}$) • the 15min High Percentile adjusted wind forecast uncertainty histogram ($W_{15}^{H97.5}$) • the 15min Low Percentile net demand forecast uncertainty histogram ($ND_{15}^{H2.5}$) • the 15min Low Percentile demand forecast uncertainty histogram ($D_{15}^{H2.5}$) • the 15min Low Percentile adjusted solar forecast uncertainty histogram ($S_{15}^{H2.5}$) • the 15min Low Percentile adjusted wind forecast uncertainty histogram ($W_{15}^{H2.5}$) • the second-order polynomial coefficients ($A_{15}^{D97.5}, B_{15}^{D97.5}, C_{15}^{D97.5}$) of the High Percentile quadratic quantile regression of 15min demand forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{S97.5}, B_{15}^{S97.5}, C_{15}^{S97.5}$) of the High Percentile quadratic quantile regression of 15min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{W97.5}, B_{15}^{W97.5}, C_{15}^{W97.5}$) of the High Percentile quadratic quantile regression of 15min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{D2.5}, B_{15}^{D2.5}, C_{15}^{D2.5}$) of the Low Percentile quadratic quantile regression of 15min demand forecast uncertainty	Core Tariff §44.2.4.2	RTBS STUC RTPD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	• the second-order polynomial coefficients ($A_{15}^{S2.5}, B_{15}^{S2.5}, C_{15}^{S2.5}$) of the Low Percentile quadratic quantile regression of 15min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{W2.5}, B_{15}^{W2.5}, C_{15}^{W2.5}$) of the Low Percentile quadratic quantile regression of 15min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{M97.5}, B_{15}^{M97.5}, C_{15}^{M97.5}$) of the High Percentile quadratic quantile regression of 15min MOSAIC forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{M2.5}, B_{15}^{M2.5}, C_{15}^{M2.5}$) of the Low Percentile quadratic quantile regression of 15min MOSAIC forecast uncertainty • the 15min High Percentile Threshold net demand forecast uncertainty histogram (ND_{15}^{H99}) • the 15min Low Percentile Threshold net demand forecast uncertainty histogram (ND_{15}^{H1})		
FRPDY-BRQ004	The system shall calculate the 15min FRU requirement for each 15min interval of the next Trading Hour for each BAA in the EIM Area and for the entire EIM Area, as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_{15} = A_{15}^{M97.5}\left(M_{15}^{P97.5}\right)^2 + B_{15}^{M97.5}\, M_{15}^{P97.5} + C_{15}^{M97.5}$$ Where: $M_{15}^{P97.5}(nd,d,s,w) \equiv ND_{15}^{H97.5} - \left(D_{15}^{H97.5} - S_{15}^{H2.5} - W_{15}^{H2.5}\right) + \left(D_{15}^{P97.5}(d) - S_{15}^{P2.5}(s) - W_{15}^{P2.5}(w)\right)$ $$D_{15}^{P97.5}(d) \equiv A_{15}^{D97.5}\, d^2 + B_{15}^{D97.5}\, d + C_{15}^{D97.5}$$ $$S_{15}^{P2.5}(s) \equiv A_{15}^{S2.5}\, s^2 + B_{15}^{S2.5}\, s + C_{15}^{S2.5}$$ $$W_{15}^{P2.5}(w) \equiv A_{15}^{W2.5}\, w^2 + B_{15}^{W2.5}\, w + C_{15}^{W2.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.2	RTBS
FRPDY-BRQ005	The system shall calculate the 15min FRD requirement for each 15min interval of the next Trading Hour for each BAA in the EIM	Core	RTBS

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Area and for the entire EIM Area, as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRDR_{15} = A_{15}^{M2.5}\left(M_{15}^{P2.5}\right)^2 + B_{15}^{M2.5}\, M_{15}^{P2.5} + C_{15}^{M2.5}$$ Where: $M_{15}^{P2.5}(nd,d,s,w) \equiv ND_{15}^{H2.5} - \left(D_{15}^{H2.5} - S_{15}^{H97.5} - W_{15}^{H97.5}\right) + \left(D_{15}^{P2.5}(d) - S_{15}^{P97.5}(s) - W_{15}^{P97.5}(w)\right)$ $$D_{15}^{P2.5}(d) \equiv A_{15}^{D2.5}\, d^2 + B_{15}^{D2.5}\, d + C_{15}^{D2.5}$$ $$S_{15}^{P97.5}(s) \equiv A_{15}^{S97.5}\, s^2 + B_{15}^{S97.5}\, s + C_{15}^{S97.5}$$ $$W_{15}^{P97.5}(w) \equiv A_{15}^{W97.5}\, w^2 + B_{15}^{W97.5}\, w + C_{15}^{W97.5}$$	BPM: Market Operations Section 7.1.3 Tariff §44.2.4.2	
FRPDY-BRQ006	The system shall bound the 15min FRU/FRD requirements for each 15min interval of the next Trading Hour for each BAA in the EIM Area and for the entire EIM Area as follows: $$FRUR_{15} = \max\left(\begin{matrix}\mathrm{FRU\_MIN\_THRESHOLD}, ND_{15}^{H1}, \\ \min\left(\left(\mathrm{ND}_{15}^{\mathrm{H99}}, \mathrm{FRUR}_{15}\,\mathrm{FRU\_MAX\_THRESHOLD}\right)\right)\end{matrix}\right)$$ $$FRDR_{15} = \min\left(\begin{matrix}-1 * \mathrm{FRD\_MIN\_THRESHOLD}, \mathrm{ND}_{15}^{\mathrm{H99}}, \\ \max\left(\left(\mathrm{ND}_{15}^{\mathrm{H1}}, \mathrm{FRDR}_{15} - 1 * \mathrm{FRD\_MAX\_THRESHOLD}\right)\right)\end{matrix}\right)$$ Note: FRU passing group and FRD passing group will use the corresponding threshold defined for EIM_AREA.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.2	RTBS
FRPDY-BRQ007	The system shall use the FRU/FRD requirements for each 15min interval of the next Trading Hour for each BAA in the EIM Area and for the entire EIM AREA, to perform the FRU/FRD sufficiency test for each BAA in the EIM Area. Note: The FRU/FRD requirements for the EIM Area are used to calculate the EIM diversity benefit factor.	Existing System Functionality Tariff §29.34 (m)	RTBS

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ008	The system shall broadcast for each 15min interval of the next Trading Hour the set of BAAs that have passed the FRU sufficiency test. Note: at T–75', T–55', and T–40' for the Active Hour starting T.	Core Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTBS
FRPDY-BRQ009	The system shall broadcast for each 15min interval of the next Trading Hour the set of BAAs that have passed the FRD sufficiency test. Note: at T–75', T–55', and T–40' for the Active Hour starting T.	Core Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTBS
FRPDY-BRQ010	For each 15min interval of the Active Hour, the system shall receive the following 5min data for the group of BAAs that have passed the FRU sufficiency test in that 15min interval: • the 5min High Percentile net demand forecast uncertainty histogram ($ND_5^{H97.5}$) • the 5min High Percentile demand forecast uncertainty histogram ($D_5^{H97.5}$) • the 5min Low Percentile adjusted solar forecast uncertainty histogram ($S_5^{H2.5}$) • the 5min Low Percentile adjusted wind forecast uncertainty histogram ($W_5^{H2.5}$) • the second-order polynomial coefficients ($A_5^{D97.5}, B_5^{D97.5}, C_5^{D97.5}$) of the High Percentile quadratic quantile regression of 5min demand forecast uncertainty • the second-order polynomial coefficients ($A_5^{S2.5}, B_5^{S2.5}, C_5^{S2.5}$) of the Low Percentile quadratic quantile regression of 5min adjusted solar forecast uncertainty	Core Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	• the second-order polynomial coefficients ($A_5^{W2.5}, B_5^{W2.5}, C_5^{W2.5}$) of the Low Percentile quadratic quantile regression of 5min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_5^{M97.5}, B_5^{M97.5}, C_5^{M97.5}$) of the High Percentile quadratic quantile regression of 5min MOSAIC forecast uncertainty • the 5min High Percentile Threshold net demand forecast uncertainty histogram (ND_5^{H99}) • the 5min Low Percentile Threshold net demand forecast uncertainty histogram (ND_5^{H1})		
FRPDY-BRQ011	For each 15min interval of the Active Hour, the system shall receive the following 5min data for the group of BAAs that have passed the FRD sufficiency test in that 15min interval: • the 5min Low Percentile net demand forecast uncertainty histogram ($ND_5^{H2.5}$) • the 5min Low Percentile demand forecast uncertainty histogram ($D_5^{H2.5}$) • the 5min High Percentile adjusted solar forecast uncertainty histogram ($S_5^{H97.5}$) • the 5min High Percentile adjusted wind forecast uncertainty histogram ($W_5^{H97.5}$) • the second-order polynomial coefficients ($A_5^{D2.5}, B_5^{D2.5}, C_5^{D2.5}$) of the Low Percentile quadratic quantile regression of 5min demand forecast uncertainty • the second-order polynomial coefficients ($A_5^{S97.5}, B_5^{S97.5}, C_5^{S97.5}$) of the High Percentile quadratic quantile regression of 5min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_5^{W97.5}, B_5^{W97.5}, C_5^{W97.5}$) of the High Percentile quadratic quantile regression of 5min adjusted wind forecast uncertainty	Core Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	• the second-order polynomial coefficients ($A_5^{M2.5}, B_5^{M2.5}, C_5^{M2.5}$) of the Low Percentile quadratic quantile regression of 5min MOSAIC forecast uncertainty • the 5min High Percentile Threshold net demand forecast uncertainty histogram (ND_5^{H99}) • the 5min Low Percentile Threshold net demand forecast uncertainty histogram (ND_5^{H1})		
FRPDY-BRQ012	For each 15min interval of the Active Hour, the system shall receive the following 15min data for the group of BAAs that have passed the FRU sufficiency test in that 15min interval: • the 15min High Percentile net demand forecast uncertainty histogram ($ND_{15}^{H97.5}$) • the 15min High Percentile demand forecast uncertainty histogram ($D_{15}^{H97.5}$) • the 15min Low Percentile adjusted solar forecast uncertainty histogram ($S_{15}^{H2.5}$) • the 15min Low Percentile adjusted wind forecast uncertainty histogram ($W_{15}^{H2.5}$) • the second-order polynomial coefficients ($A_{15}^{D97.5}, B_{15}^{D97.5}, C_{15}^{D97.5}$) of the High Percentile quadratic quantile regression of 15min demand forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{S2.5}, B_{15}^{S2.5}, C_{15}^{S2.5}$) of the Low Percentile quadratic quantile regression of 15min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{W2.5}, B_{15}^{W2.5}, C_{15}^{W2.5}$) of the Low Percentile quadratic quantile regression of 15min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{M97.5}, B_{15}^{M97.5}, C_{15}^{M97.5}$) of the High Percentile quadratic quantile regression of 15min MOSAIC forecast uncertainty	Core Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTPD STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	• the 15min High Percentile Threshold net demand forecast uncertainty histogram (ND_{15}^{H99}) • the 15min Low Percentile Threshold net demand forecast uncertainty histogram (ND_{15}^{H1})		
FRPDY-BRQ013	For each 15min interval of the Active Hour, the system shall receive the following 15min data for the group of BAAs that have passed the FRD sufficiency test in that 15min interval: • the 15min Low Percentile net demand forecast uncertainty histogram ($ND_{15}^{H2.5}$) • the 15min Low Percentile demand forecast uncertainty histogram ($D_{15}^{H2.5}$) • the 15min High Percentile adjusted solar forecast uncertainty histogram ($S_{15}^{H97.5}$) • the 15min High Percentile adjusted wind forecast uncertainty histogram ($W_{15}^{H97.5}$) • the second-order polynomial coefficients ($A_{15}^{D2.5}, B_{15}^{D2.5}, C_{15}^{D2.5}$) of the Low Percentile quadratic quantile regression of 15min demand forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{S97.5}, B_{15}^{S97.5}, C_{15}^{S97.5}$) of the High Percentile quadratic quantile regression of 15min adjusted solar forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{W97.5}, B_{15}^{W97.5}, C_{15}^{W97.5}$) of the High Percentile quadratic quantile regression of 15min adjusted wind forecast uncertainty • the second-order polynomial coefficients ($A_{15}^{M2.5}, B_{15}^{M2.5}, C_{15}^{M2.5}$) of the Low Percentile quadratic quantile regression of 15min MOSAIC forecast uncertainty • the 15min High Percentile Threshold net demand forecast uncertainty histogram (ND_{15}^{H99}) • the 15min Low Percentile Threshold net demand forecast uncertainty histogram (ND_{15}^{H1})	Core Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTPD STUC

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FRPDY-BRQ014	The system shall calculate the 5min FRU requirement for each 5min interval of the market horizon for each BAA in the EIM Area that has failed the FRU sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_5 = A_5^{M97.5}\left(M_5^{P97.5}\right)^2 + B_5^{M97.5}\,M_5^{P97.5} + C_5^{M97.5}$$ Where: $M_5^{P97.5}(nd,d,s,w) \equiv ND_5^{H97.5} - \left(D_5^{H97.5} - S_5^{H2.5} - W_5^{H2.5}\right) + \left(D_5^{P97.5}(d) - S_5^{P2.5}(s) - W_5^{P2.5}(w)\right)$ $$D_5^{P97.5}(d) \equiv A_{D5}^{P97.5}\,d^2 + B_{D5}^{P97.5}\,d + C_{D5}^{P97.5}$$ $$S_5^{P2.5}(s) \equiv A_5^{S2.5}\,s^2 + B_5^{S2.5}\,s + C_5^{S2.5}$$ $$W_5^{P2.5}(w) \equiv A_5^{W2.5}\,w^2 + B_5^{W2.5}\,w + C_5^{W2.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTD
FRPDY-BRQ015	The system shall calculate the 5min FRU requirement for each 5min interval in the market horizon for the group of BAAs that have passed the FRU sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_5 = A_5^{M97.5}\left(M_5^{P97.5}\right)^2 + B_5^{M97.5}\,M_5^{P97.5} + C_5^{M97.5}$$ Where: $M_5^{P97.5}(nd,d,s,w) \equiv ND_5^{H97.5} - \left(D_5^{H97.5} - S_5^{H2.5} - W_5^{H2.5}\right) + \left(D_5^{P97.5}(d) - S_5^{P2.5}(s) - W_5^{P2.5}(w)\right)$ $$D_5^{P97.5}(d) \equiv A_{D5}^{P97.5}\,d^2 + B_{D5}^{P97.5}\,d + C_{D5}^{P97.5}$$ $$S_5^{P2.5}(s) \equiv A_5^{S2.5}\,s^2 + B_5^{S2.5}\,s + C_5^{S2.5}$$ $$W_5^{P2.5}(w) \equiv A_5^{W2.5}\,w^2 + B_5^{W2.5}\,w + C_5^{W2.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTD
FRPDY-BRQ016	The system shall calculate the 5min FRD requirement for each 5min interval in the market horizon for each BAA in the EIM Area that has failed the FRD sufficiency test in the corresponding 15min interval as	Core	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRDR_5 = A_5^{M2.5}\left(M_5^{P2.5}\right)^2 + B_5^{M2.5}\,M_5^{P2.5} + C_5^{M2.5}$$ Where: $$M_5^{P2.5}(nd,d,s,w) \equiv ND_5^{H2.5} - \left(D_5^{H2.5} - S_5^{H97.5} - W_5^{H97.5}\right) + \left(D_5^{P2.5}(d) - S_5^{P97.5}(s) - W_5^{P97.5}(w)\right)$$ $$D_5^{P2.5}(d) \equiv A_5^{D2.5}\,d^2 + B_5^{D2.5}\,d + C_5^{D2.5}$$ $$S_5^{P97.5}(s) \equiv A_5^{S97.5}\,s^2 + B_5^{S97.5}\,s + C_5^{S97.5}$$ $$W_5^{P97.5}(w) \equiv A_5^{W97.5}\,w^2 + B_5^{W97.5}\,w + C_5^{W97.5}$$	BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	
FRPDY-BRQ117	The system shall calculate the 5min FRD requirement for each 5min interval in the market horizon for the group of BAAs that have passed the FRD sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRDR_5 = A_5^{M2.5}\left(M_5^{P2.5}\right)^2 + B_5^{M2.5}\,M_5^{P2.5} + C_5^{M2.5}$$ Where: $$M_5^{P2.5}(nd,d,s,w) \equiv ND_5^{H2.5} - \left(D_5^{H2.5} - S_5^{H97.5} - W_5^{H97.5}\right) + \left(D_5^{P2.5}(d) - S_5^{P97.5}(s) - W_5^{P97.5}(w)\right)$$ $$D_5^{P2.5}(d) \equiv A_5^{D2.5}\,d^2 + B_5^{D2.5}\,d + C_5^{D2.5}$$ $$S_5^{P97.5}(s) \equiv A_5^{S97.5}\,s^2 + B_5^{S97.5}\,s + C_5^{S97.5}$$ $$W_5^{P97.5}(w) \equiv A_5^{W97.5}\,w^2 + B_5^{W97.5}\,w + C_5^{W97.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTD
FRPDY-BRQ018	The system shall bound the 5min FRU/FRD requirements for each 5min interval in the market horizon as follows: $$FRUR_5 = \max\begin{pmatrix} \text{FRU\_MIN\_THRESHOLD}, ND_5^{H1}, \\ \min\left((ND_5^{H99}, FRUR_5\ \text{FRU\_MAX\_THRESHOLD})\right)\end{pmatrix}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.2	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$FRDR_5 = -\min\left(\begin{array}{c}-1 * \text{FRD\_MIN\_THRESHOLD}, ND_5^{H99}, \\ \max\left((ND_5^{H1}, FRDR_5 \ -1 * \text{FRD\_MAX\_THRESHOLD})\right)\end{array}\right)$ Note: The FRD requirement is negated to make it positive. **Note:** FRU passing group and FRD passing group will use the threshold defined for EIM_AREA.		
FRPDY-BRQ019	The system shall calculate the 15min FRU requirement for each 15min interval of the market horizon for each BAA in the EIM Area that has failed the FRU sufficiency test as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_{15} = A_{15}^{M97.5}\left(M_{15}^{P97.5}\right)^2 + B_{15}^{M97.5}\, M_{15}^{P97.5} + C_{15}^{M97.5}$$ Where: $M_{15}^{P97.5}(nd, d, s, w) \equiv ND_{15}^{H97.5} - \left(D_{15}^{H97.5} - S_{15}^{H2.5} - W_{15}^{H2.5}\right) + \left(D_{15}^{P97.5}(d) - S_{15}^{P2.5}(s) - W_{15}^{P2.5}(w)\right)$ $$D_{15}^{P97.5}(d) \equiv A_{15}^{D97.5}\, d^2 + B_{15}^{D97.5}\, d + C_{15}^{D97.5}$$ $$S_{15}^{P2.5}(s) \equiv A_{15}^{S2.5}\, s^2 + B_{15}^{S2.5}\, s + C_{15}^{S2.5}$$ $$W_{15}^{P2.5}(w) \equiv A_{15}^{W2.5}\, w^2 + B_{15}^{W2.5}\, w + C_{15}^{W2.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTPD
FRPDY-BRQ020	The system shall calculate the 15min FRU requirement for each 15min interval of the market horizon for the group of BAAs that have passed the FRU sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_{15} = A_{15}^{M97.5}\left(M_{15}^{P97.5}\right)^2 + B_{15}^{M97.5}\, M_{15}^{P97.5} + C_{15}^{M97.5}$$ Where: $M_{15}^{P97.5}(nd, d, s, w) \equiv ND_{15}^{H97.5} - \left(D_{15}^{H97.5} - S_{15}^{H2.5} - W_{15}^{H2.5}\right) + \left(D_{15}^{P97.5}(d) - S_{15}^{P2.5}(s) - W_{15}^{P2.5}(w)\right)$ $$D_{15}^{P97.5}(d) \equiv A_{15}^{D97.5}\, d^2 + B_{15}^{D97.5}\, d + C_{15}^{D97.5}$$ $$S_{15}^{P2.5}(s) \equiv A_{15}^{S2.5}\, s^2 + B_{15}^{S2.5}\, s + C_{15}^{S2.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTPD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$W_{15}^{P2.5}(w) \equiv A_{15}^{W2.5}\ w^2 + B_{15}^{W2.5}\ w + C_{15}^{W2.5}$$		
FRPDY-BRQ021	The system shall calculate the 15min FRD requirement for each 15min interval of the market horizon for each BAA in the EIM Area that has failed the FRD sufficiency test as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRDR_{15} = A_{15}^{M2.5}\left(M_{15}^{P2.5}\right)^2 + B_{15}^{M2.5}\ M_{15}^{P2.5} + C_{15}^{M2.5}$$ Where: $M_{15}^{P2.5}(nd,d,s,w) \equiv ND_{15}^{H2.5} - \left(D_{15}^{H2.5} - S_{15}^{H97.5} - W_{15}^{H97.5}\right) + \left(D_{15}^{P2.5}(d) - S_{15}^{P97.5}(s) - +W_{15}^{P97.5}(w)\right)$ $$D_{15}^{P2.5}(d) \equiv A_{15}^{D2.5}\ d^2 + B_{15}^{D2.5}\ d + C_{15}^{D2.5}$$ $$S_{15}^{P97.5}(s) \equiv A_{15}^{S97.5}\ s^2 + B_{15}^{S97.5}\ s + C_{15}^{S97.5}$$ $$W_{15}^{P97.5}(w) \equiv A_{15}^{W97.5}\ w^2 + B_{15}^{W97.5}\ w + C_{15}^{W97.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTPD
FRPDY-BRQ022	The system shall calculate the 15min FRD requirement for each 15min interval of the market horizon for the group of BAAs that have passed the FRD sufficiency test in the corresponding 15min interval as follows: $$FRDR_{15} = A_{15}^{M2.5}\left(M_{15}^{P2.5}\right)^2 + B_{15}^{M2.5}\ M_{15}^{P2.5} + C_{15}^{M2.5}$$ Where: $M_{15}^{P2.5}(nd,d,s,w) \equiv ND_{15}^{H2.5} - \left(D_{15}^{H2.5} - S_{15}^{H97.5} - W_{15}^{H97.5}\right) + \left(D_{15}^{P2.5}(d) - S_{15}^{P97.5}(s) - W_{15}^{P97.5}(w)\right)$ $$D_{15}^{P2.5}(d) \equiv A_{15}^{D2.5}\ d^2 + B_{15}^{D2.5}\ d + C_{15}^{D2.5}$$ $$S_{15}^{P97.5}(s) \equiv A_{15}^{S97.5}\ s^2 + B_{15}^{S97.5}\ s + C_{15}^{S97.5}$$ $$W_{15}^{P97.5}(w) \equiv A_{15}^{W97.5}\ w^2 + B_{15}^{W97.5}\ w + C_{15}^{W97.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	RTPD
FRPDY-BRQ023	The system shall bound the 15min FRU/FRD requirements for each 15min interval in the market horizon as follows:	Core	RTPD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$FRUR_{15} = \max\left(\begin{array}{c}\text{FRU\_MIN\_THRESHOLD}, ND_{15}^{H1}, \\ \min\left(\left(\mathrm{ND}_{15}^{\mathrm{H99}}, \mathrm{FRUR}_{15}\,\text{FRU\_MAX\_THRESHOLD}\right)\right)\end{array}\right)$$ $$FRDR_{15} = \min\left(\begin{array}{c}-1 * \text{FRD\_MIN\_THRESHOLD}, \mathrm{ND}_{15}^{\mathrm{H99}}, \\ \max\left(\left(\mathrm{ND}_{15}^{\mathrm{H1}}, \mathrm{FRDR}_{15} - 1 * \text{FRD\_MAX\_THRESHOLD}\right)\right)\end{array}\right)$$ **Note:** FRU passing group and FRD passing group will use the corresponding threshold defined for EIM_AREA.	BPM: Market Operations Section 7.1.3 Tariff §44.2.4.2	
FRPDY-BRQ024	The system shall calculate the 15min FRU requirement for each 15min interval in the first two hours of the market horizon for each BAA in the EIM Area that has failed the FRU sufficiency test as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_{15} = A_{15}^{M97.5}\left(M_{15}^{P97.5}\right)^2 + B_{15}^{M97.5}\,M_{15}^{P97.5} + C_{15}^{M97.5}$$ Where: $M_{15}^{P97.5}(nd, d, s, w) \equiv ND_{15}^{H97.5} - \left(D_{15}^{H97.5} - S_{15}^{H2.5} - W_{15}^{H2.5}\right) + \left(D_{15}^{P97.5}(d) - S_{15}^{P2.5}(s) - W_{15}^{P2.5}(w)\right)$ $$D_{15}^{P97.5}(d) \equiv A_{15}^{D97.5}\,d^2 + B_{15}^{D97.5}\,d + C_{15}^{D97.5}$$ $$S_{15}^{P2.5}(s) \equiv A_{15}^{S2.5}\,s^2 + B_{15}^{S2.5}\,s + C_{15}^{S2.5}$$ $$W_{15}^{P2.5}(w) \equiv A_{15}^{W2.5}\,w^2 + B_{15}^{W2.5}\,w + C_{15}^{W2.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	STUC
FRPDY-BRQ025	The system shall calculate the 15min FRU requirement for each 15min interval in the first two hours of the market horizon for the group of BAAs that have passed the FRU sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRUR_{15} = A_{15}^{M97.5}\left(M_{15}^{P97.5}\right)^2 + B_{15}^{M97.5}\,M_{15}^{P97.5} + C_{15}^{M97.5}$$ Where: $M_{15}^{P97.5}(nd, d, s, w) \equiv ND_{15}^{H97.5} - \left(D_{15}^{H97.5} - S_{15}^{H2.5} - W_{15}^{H2.5}\right) + \left(D_{15}^{P97.5}(d) - S_{15}^{P2.5}(s) - W_{15}^{P2.5}(w)\right)$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$D_{15}^{P97.5}(d) \equiv A_{15}^{D97.5}\, d^2 + B_{15}^{D97.5}\, d + C_{15}^{D97.5}$ $S_{15}^{P2.5}(s) \equiv A_{15}^{S2.5}\, s^2 + B_{15}^{S2.5}\, s + C_{15}^{S2.5}$ $W_{15}^{P2.5}(w) \equiv A_{15}^{W2.5}\, w^2 + B_{15}^{W2.5}\, w + C_{15}^{W2.5}$		
FRPDY-BRQ026	The system shall calculate the 15min FRU requirement for each 15min interval in the last three hours of the market horizon for the EIM_Area as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $FRUR_{15} = A_{15}^{M97.5}\left(M_{15}^{P97.5}\right)^2 + B_{15}^{M97.5}\, M_{15}^{P97.5} + C_{15}^{M97.5}$ Where: $M_{15}^{P97.5}(nd,d,s,w) \equiv ND_{15}^{H97.5} - \left(D_{15}^{H97.5} - S_{15}^{H2.5} - W_{15}^{H2.5}\right) + \left(D_{15}^{P97.5}(d) - S_{15}^{P2.5}(s) - W_{15}^{P2.5}(w)\right)$ $D_{15}^{P97.5}(d) \equiv A_{15}^{D97.5}\, d^2 + B_{15}^{D97.5}\, d + C_{15}^{D97.5}$ $S_{15}^{P2.5}(s) \equiv A_{15}^{S2.5}\, s^2 + B_{15}^{S2.5}\, s + C_{15}^{S2.5}$ $W_{15}^{P2.5}(w) \equiv A_{15}^{W2.5}\, w^2 + B_{15}^{W2.5}\, w + C_{15}^{W2.5}$ Assumption: This is aligned with current PRODUCTION treatment because of the time horizon in STUC.	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n), §44.2.4.2	STUC
FRPDY-BRQ027	The system shall calculate the 15min FRD requirement for each 15min interval in the first two hours of the market horizon for each BAA in the EIM Area that has failed the FRD sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $FRDR_{15} = A_{15}^{M2.5}\left(M_{15}^{P2.5}\right)^2 + B_{15}^{M2.5}\, M_{15}^{P2.5} + C_{15}^{M2.5}$ Where: $M_{15}^{P2.5}(nd,d,s,w) \equiv ND_{15}^{H2.5} - \left(D_{15}^{H2.5} - S_{15}^{H97.5} - W_{15}^{H97.5}\right) + \left(D_{15}^{P2.5}(d) - S_{15}^{P97.5}(s) - W_{15}^{P97.5}(w)\right)$ $D_{15}^{P2.5}(d) \equiv A_{15}^{D2.5}\, d^2 + B_{15}^{D2.5}\, d + C_{15}^{D2.5}$ $S_{15}^{P97.5}(s) \equiv A_{15}^{S97.5}\, s^2 + B_{15}^{S97.5}\, s + C_{15}^{S97.5}$	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n), §44.2.4.2	STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$W_{15}^{P97.5}(w) \equiv A_{15}^{W97.5}\, w^2 + B_{15}^{W97.5}\, w + C_{15}^{W97.5}$$ Assumption: Calculate for each BAA not passing the sufficiency test because of the time horizon in STUC.		
FRPDY-BRQ028	The system shall calculate the 15min FRD requirement for each 15min interval in the first two hours of the market horizon for the group of BAAs that have passed the FRD sufficiency test in the corresponding 15min interval as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRDR_{15} = A_{15}^{M2.5}\left(M_{15}^{P2.5}\right)^2 + B_{15}^{M2.5}\, M_{15}^{P2.5} + C_{15}^{M2.5}$$ Where: $M_{15}^{P2.5}(nd,d,s,w) \equiv ND_{15}^{H2.5} - \left(D_{15}^{H2.5} - S_{15}^{H97.5} - W_{15}^{H97.5}\right) + \left(D_{15}^{P2.5}(d) - S_{15}^{P97.5}(s) - W_{15}^{P97.5}(w)\right)$ $$D_{15}^{P2.5}(d) \equiv A_{15}^{D2.5}\, d^2 + B_{15}^{D2.5}\, d + C_{15}^{D2.5}$$ $$S_{15}^{P97.5}(s) \equiv A_{15}^{S97.5}\, s^2 + B_{15}^{S97.5}\, s + C_{15}^{S97.5}$$ $$W_{15}^{P97.5}(w) \equiv A_{15}^{W97.5}\, w^2 + B_{15}^{W97.5}\, w + C_{15}^{W97.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §11. 25.1.1, §11.25.2.2.1, §29.34 (n), §44.2.4.2	STUC
FRPDY-BRQ029	The system shall calculate the 15min FRD requirement for each 15min interval in the last three hours of the market horizon for the EIM_Area as a function of net demand (nd), demand (d), solar (s), and wind (w) forecast as follows: $$FRDR_{15} = A_{15}^{M2.5}\left(M_{15}^{P2.5}\right)^2 + B_{15}^{M2.5}\, M_{15}^{P2.5} + C_{15}^{M2.5}$$ Where: $M_{15}^{P2.5}(nd,d,s,w) \equiv ND_{15}^{H2.5} - \left(D_{15}^{H2.5} - S_{15}^{H97.5} - W_{15}^{H97.5}\right) + \left(D_{15}^{P2.5}(d) - S_{15}^{P97.5}(s) - W_{15}^{P97.5}(w)\right)$ $$D_{15}^{P2.5}(d) \equiv A_{15}^{D2.5}\, d^2 + B_{15}^{D2.5}\, d + C_{15}^{D2.5}$$ $$S_{15}^{P97.5}(s) \equiv A_{15}^{S97.5}\, s^2 + B_{15}^{S97.5}\, s + C_{15}^{S97.5}$$ $$W_{15}^{P97.5}(w) \equiv A_{15}^{W97.5}\, w^2 + B_{15}^{W97.5}\, w + C_{15}^{W97.5}$$	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n), §44.2.4.2	STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Assumption: This is aligned with current PROD treatment because of the time horizon in STUC.		
FRPDY-BRQ030	The system shall bound the 15min FRU/FRD requirements for each 15min interval in the market horizon as follows: $$FRUR_{15} = \max\begin{pmatrix} \mathrm{FRU\_MIN\_THRESHOLD}, ND_{15}^{H1}, \\ \min\left(\left(\mathrm{ND}_{15}^{\mathrm{H99}}, \mathrm{FRUR}_{15}\,\mathrm{FRU\_MAX\_THRESHOLD}\right)\right)\end{pmatrix}$$ $$FRDR_{15} = \min\begin{pmatrix} -1 * \mathrm{FRD\_MIN\_THRESHOLD}, \mathrm{ND}_{15}^{\mathrm{H99}}, \\ \max\left(\left(\mathrm{ND}_{15}^{\mathrm{H1}}, \mathrm{FRDR}_{15} - 1 * \mathrm{FRD\_MAX\_THRESHOLD}\right)\right)\end{pmatrix}$$ **Note:** FRU passing group and FRD passing group will use the corresponding threshold defined for EIM_AREA.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.2	STUC
FRPDY-BRQ031	The system shall calculate FRU awards for each interval in the market horizon for each BAA that has failed the FRU sufficiency test in that interval to meet the FRU requirement for that interval and BAA, reduced by the total FRU surplus for that interval and BAA. The FRU surplus effectively relaxes the FRU requirement at a price curve. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n)	RTPD STUC RTD
FRPDY-BRQ032	The system shall calculate FRU awards for each interval in the market horizon for the group of BAAs that have passed the FRU sufficiency test in that interval to meet the FRU requirement for that interval BAA group, reduced by the total FRU surplus for that interval and BAA group. The FRU surplus effectively relaxes the FRU requirement at a price curve. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n)	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ033	The system shall calculate FRD awards for each interval in the market horizon for each BAA that has failed the FRD sufficiency test in that interval to meet the FRD requirement for that interval and BAA, reduced by the total FRD surplus for that interval and BAA. The FRD surplus effectively relaxes the FRD requirement at a price curve. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n)	RTPD STUC RTD
FRPDY-BRQ034	The system shall calculate FRD awards for each interval in the market horizon for the group of BAAs that have passed the FRD sufficiency test in that interval to meet the FRD requirement for that interval and BAA group, reduced by the total FRD surplus for that interval and BAA group. The FRD surplus effectively relaxes the FRD requirement at a price curve. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §29.34 (n)	RTPD STUC RTD
FRPDY-BRQ035	The system shall implement a FRU deployment scenario for each interval in the market horizon where: • All FRU awards are deployed. • The demand forecast for each BAA that has failed the FRU sufficiency test is increased by the FRU requirement for that BAA. • The demand forecast for the group of BAAs that have passed the FRU sufficiency test is increased by the FRU requirement for that BAA group. • The FRU surplus in each BAA that has failed the FRU sufficiency test is fully deployed. • The FRU surplus in the group of BAAs that have passed the FRU sufficiency test is fully deployed.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.1.2	RTPD STUC RTD
FRPDY-BRQ036	The system shall implement a FRD deployment scenario for each interval in the market horizon where:	Core	RTPD STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	• All FRD awards are deployed. • The demand forecast for each BAA that has failed the FRD sufficiency test is decreased by the FRD requirement for that BAA. • The demand forecast for the group of BAAs that have passed the FRD sufficiency test is decreased by the FRD requirement for that BAA group. • The FRD surplus in each BAA that has failed the FRD sufficiency test is fully deployed. • The FRD surplus in the group of BAAs that have passed the FRD sufficiency test is fully deployed.	BPM: Market Operations Section 7.1.3 Tariff §44.2.1.2	RTD
FRPDY-BRQ037	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 5min interval in the market horizon for each BAA that has failed the FRU sufficiency test in the corresponding 15min interval as follows: $$FRUDF_5(d,s,w) \equiv \frac{\left\|D_5^{P97.5}(d)\right\|}{\left\|D_5^{P97.5}(d)\right\| + \left\|S_5^{P2.5}(s)\right\| + \left\|W_5^{P2.5}(w)\right\|}$$ $$FRUSF_5(d,s,w) \equiv \frac{\left\|S_5^{P2.5}(s)\right\|}{\left\|D_5^{P97.5}(d)\right\| + \left\|S_5^{P2.5}(s)\right\| + \left\|W_5^{P2.5}(w)\right\|}$$ $$FRUWF_5(d,s,w) \equiv \frac{\left\|W_5^{P2.5}(w)\right\|}{\left\|D_5^{P97.5}(d)\right\| + \left\|S_5^{P2.5}(s)\right\| + \left\|W_5^{P2.5}(w)\right\|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ038	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 5min interval in the market horizon for the group of BAAs that have passed the FRU sufficiency test in the corresponding 15min interval as follows: $$FRUDF_5(d,s,w) \equiv \frac{\left\|D_5^{P97.5}(d)\right\|}{\left\|D_5^{P97.5}(d)\right\| + \left\|S_5^{P2.5}(s)\right\| + \left\|W_5^{P2.5}(w)\right\|}$$ $$FRUSF_5(d,s,w) \equiv \frac{\left\|S_5^{P2.5}(s)\right\|}{\left\|D_5^{P97.5}(d)\right\| + \left\|S_5^{P2.5}(s)\right\| + \left\|W_5^{P2.5}(w)\right\|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$FRUWF_5(d,s,w) \equiv \frac{\lvert W_5^{P2.5}(w)\rvert}{\lvert D_5^{P97.5}(d)\rvert + \lvert S_5^{P2.5}(s)\rvert + \lvert W_5^{P2.5}(w)\rvert}$$		
FRPDY-BRQ039	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 5min interval in the market horizon for each BAA that has failed the FRD sufficiency test in the corresponding 15min interval as follows: $$FRDDF_5(d,s,w) \equiv \frac{D_5^{P2.5}(d)}{\lvert D_5^{P2.5}(d)\rvert + \lvert S_5^{P97.5}(s)\rvert + \lvert W_5^{P97.5}(w)\rvert}$$ $$FRDSF_5(d,s,w) \equiv \frac{\lvert S_5^{P97.5}(s)\rvert}{\lvert D_5^{P2.5}(d)\rvert + \lvert S_5^{P97.5}(s)\rvert + \lvert W_5^{P97.5}(w)\rvert}$$ $$FRDWF_5(d,s,w) \equiv \frac{\lvert W_5^{P97.5}(w)\rvert}{\lvert D_5^{P2.5}(d)\rvert + \lvert S_5^{P97.5}(s)\rvert + \lvert W_5^{P97.5}(w)\rvert}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ040	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 5min interval in the market horizon for the group of BAAs that have passed the FRD sufficiency test in the corresponding 15min interval as follows: $$FRDDF_5(d,s,w) \equiv \frac{D_5^{P2.5}(d)}{\lvert D_5^{P2.5}(d)\rvert + \lvert S_5^{P97.5}(s)\rvert + \lvert W_5^{P97.5}(w)\rvert}$$ $$FRDSF_5(d,s,w) \equiv \frac{\lvert S_5^{P97.5}(s)\rvert}{\lvert D_5^{P2.5}(d)\rvert + \lvert S_5^{P97.5}(s)\rvert + \lvert W_5^{P97.5}(w)\rvert}$$ $$FRDWF_5(d,s,w) \equiv \frac{\lvert W_5^{P97.5}(w)\rvert}{\lvert D_5^{P2.5}(d)\rvert + \lvert S_5^{P97.5}(s)\rvert + \lvert W_5^{P97.5}(w)\rvert}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ041	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 15min interval in the market horizon and for each BAA that has failed the FRU sufficiency test as follows: $$FRUDF_{15}(d,s,w) \equiv \frac{\lvert D_{15}^{P97.5}(d)\rvert}{\lvert D_{15}^{P97.5}(d)\rvert + \lvert S_{15}^{P2.5}(s)\rvert + \lvert W_{15}^{P2.5}(w)\rvert}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$FRUSF_{15}(d,s,w) \equiv \frac{\left|S_{15}^{P2.5}(s)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUWF_{15}(d,s,w) \equiv \frac{\left|W_{15}^{P2.5}(w)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$		
FRPDY-BRQ042	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 15min interval in the market horizon and for the group of BAAs that have passed the FRU sufficiency test as follows: $$FRUDF_{15}(d,s,w) \equiv \frac{\left|D_{15}^{P97.5}(d)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUSF_{15}(d,s,w) \equiv \frac{\left|S_{15}^{P2.5}(s)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUWF_{15}(d,s,w) \equiv \frac{\left|W_{15}^{P2.5}(w)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTUC
FRPDY-BRQ043	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 15min interval in the market horizon for each BAA that has failed the FRD sufficiency test as follows: $$FRDDF_{15}(d,s,w) \equiv \frac{\left|D_{15}^{P2.5}(d)\right|}{\left|D_{15}^{P2.5}(d)\right| + \left|S_{15}^{P97.5}(s)\right| + \left|W_{15}^{P97.5}(w)\right|}$$ $$FRDSF_{15}(d,s,w) \equiv \frac{\left|S_{15}^{P97.5}(s)\right|}{\left|D_{15}^{P2.5}(d)\right| + \left|S_{15}^{P97.5}(s)\right| + \left|W_{15}^{P97.5}(w)\right|}$$ $$FRDWF_{15}(d,s,w) \equiv \frac{\left|W_{15}^{P97.5}(w)\right|}{\left|D_{15}^{P2.5}(d)\right| + \left|S_{15}^{P97.5}(s)\right| + \left|W_{15}^{P97.5}(w)\right|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTUC
FRPDY-BRQ044	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 15min interval in the market horizon for the group of BAAs that have passed the FRD sufficiency test as follows:	Core BPM: Market Operations Section 7.1.3	RTUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$FRDDF_{15}(d,s,w) \equiv \frac{\left|D_{15}^{P2.5}(d)\right|}{\left|D_{15}^{P2.5}(d)\right| + \left|S_{15}^{P97.5}(s)\right| + \left|W_{15}^{P97.5}(w)\right|}$$ $$FRDSF_{15}(d,s,w) \equiv \frac{\left|S_{15}^{P97.5}(s)\right|}{\left|D_{15}^{P2.5}(d)\right| + \left|S_{15}^{P97.5}(s)\right| + \left|W_{15}^{P97.5}(w)\right|}$$ $$FRDWF_{15}(d,s,w) \equiv \frac{\left|W_{15}^{P97.5}(w)\right|}{\left|D_{15}^{P2.5}(d)\right| + \left|S_{15}^{P97.5}(s)\right| + \left|W_{15}^{P97.5}(w)\right|}$$	Tariff §44.2.4.3	
FRPDY-BRQ045	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 15min interval in the first two hours of the market horizon for each BAA that has failed the FRU sufficiency test as follows: $$FRUDF_{15}(d,s,w) \equiv \frac{\left|D_{15}^{P97.5}(d)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUSF_{15}(d,s,w) \equiv \frac{\left|S_{15}^{P2.5}(s)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUWF_{15}(d,s,w) \equiv \frac{\left|W_{15}^{P2.5}(w)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	STUC
FRPDY-BRQ046	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 15min interval in the first two hours of the market horizon for the group of BAAs that have passed the FRU sufficiency test as follows: $$FRUDF_{15}(d,s,w) \equiv \frac{\left|D_{15}^{P97.5}(d)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUSF_{15}(d,s,w) \equiv \frac{\left|S_{15}^{P2.5}(s)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$ $$FRUWF_{15}(d,s,w) \equiv \frac{\left|W_{15}^{P2.5}(w)\right|}{\left|D_{15}^{P97.5}(d)\right| + \left|S_{15}^{P2.5}(s)\right| + \left|W_{15}^{P2.5}(w)\right|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	STUC

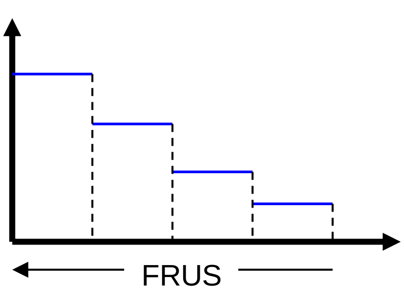
ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ047	The system shall calculate the FRU requirement allocation factors to demand, solar, and wind for each 15min interval in the last three hours of the market horizon for each BAA in the EIM Area as follows: $$FRUDF_{15}(d,s,w) \equiv \frac{\left\|D_{15}^{P97.5}(d)\right\|}{\left\|D_{15}^{P97.5}(d)\right\| + \left\|S_{15}^{P2.5}(s)\right\| + \left\|W_{15}^{P2.5}(w)\right\|}$$ $$FRUSF_{15}(d,s,w) \equiv \frac{\left\|S_{15}^{P2.5}(s)\right\|}{\left\|D_{15}^{P97.5}(d)\right\| + \left\|S_{15}^{P2.5}(s)\right\| + \left\|W_{15}^{P2.5}(w)\right\|}$$ $$FRUWF_{15}(d,s,w) \equiv \frac{\left\|W_{15}^{P2.5}(w)\right\|}{\left\|D_{15}^{P97.5}(d)\right\| + \left\|S_{15}^{P2.5}(s)\right\| + \left\|W_{15}^{P2.5}(w)\right\|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	STUC
FRPDY-BRQ048	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 15min interval in the first two hours of the market horizon for each BAA that has failed the FRD sufficiency test as follows: $$FRDDF_{15}(d,s,w) \equiv \frac{\left\|D_{15}^{P2.5}(d)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$ $$FRDSF_{15}(d,s,w) \equiv \frac{\left\|S_{15}^{P97.5}(s)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$ $$FRDWF_{15}(d,s,w) \equiv \frac{\left\|W_{15}^{P97.5}(w)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	STUC
FRPDY-BRQ049	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 15min interval in the first two hours of the market horizon for the group of BAAs that have passed the FRD sufficiency test as follows: $$FRDDF_{15}(d,s,w) \equiv \frac{\left\|D_{15}^{P2.5}(d)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$ $$FRDSF_{15}(d,s,w) \equiv \frac{\left\|S_{15}^{P97.5}(s)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	STUC

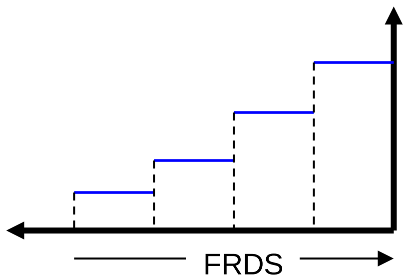
ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	$$FRDWF_{15}(d,s,w) \equiv \frac{\left\|W_{15}^{P97.5}(w)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$		
FRPDY-BRQ050	The system shall calculate the FRD requirement allocation factors to demand, solar, and wind for each 15min interval in the last three hours of the market horizon for each BAA in the EIM Area as follows: $$FRDDF_{15}(d,s,w) \equiv \frac{\left\|D_{15}^{P2.5}(d)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$ $$FRDSF_{15}(d,s,w) \equiv \frac{\left\|S_{15}^{P97.5}(s)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$ $$FRDWF_{15}(d,s,w) \equiv \frac{\left\|W_{15}^{P97.5}(w)\right\|}{\left\|D_{15}^{P2.5}(d)\right\| + \left\|S_{15}^{P97.5}(s)\right\| + \left\|W_{15}^{P97.5}(w)\right\|}$$	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	STUC
FRPDY-BRQ051	The system shall distribute the FRU requirement allocated to demand ($FRUR_5\ FRUDF_5(d,s,w)$) in each interval of the market horizon in the FRU deployment scenario as positive load to the load nodes in the respective BAA or BAA group with the same distribution factors used for distributing the demand forecast. Implementation detail: The load distribution factors for each BAA and the BAA group shall be derived from the load distribution factors of the demand forecast zones in each BAA, weighted by the demand forecast of each zone, and then re-normalized for the BAA or the BAA group.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ052	The system shall distribute the FRU requirement allocated to solar ($FRUR_5\ FRUSF_5(d,s,w)$) in each interval of the market horizon in the FRU deployment scenario as positive load to the solar VER nodes in the respective BAA or BAA group pro rata on the respective solar VER forecast.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ053	The system shall distribute the FRU requirement allocated to wind ($FRUR_5\ FRUWF_5(d,s,w)$) in each interval of the market horizon in the FRU deployment scenario as positive load to the wind VER	Core	RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	nodes in the respective BAA or BAA group pro rata on the respective wind VER forecast.	BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	
FRPDY-BRQ054	The system shall distribute the FRD requirement allocated to demand ($FRDR_5\ FRDDF_5(d,s,w)$) in each interval of the market horizon in the FRD deployment scenario as negative load to the load nodes in the respective BAA or BAA group with the same distribution factors used for distributing the demand forecast. Implementation detail: The load distribution factors for each BAA and the BAA group shall be derived from the load distribution factors of the demand forecast zones in each BAA, weighted by the demand forecast of each zone, and then re-normalized for the BAA or the BAA group.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ055	The system shall distribute the FRD requirement allocated to solar ($FRDR_5\ FRDSF_5(d,s,w)$) in each interval of the market horizon in the FRD deployment scenario as negative load to the solar VER nodes in the respective BAA or BAA group pro rata on the respective solar VER forecast.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ056	The system shall distribute the FRD requirement allocated to wind ($FRDR_5\ FRDWF_5(d,s,w)$) in each interval of the market horizon in the FRD deployment scenario as negative load to the wind VER nodes in the respective BAA or BAA group pro rata on the respective wind VER forecast.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTD
FRPDY-BRQ057	The system shall distribute the FRU requirement allocated to demand ($FRUR_{15}\ FRUDF_{15}(d,s,w)$) in each interval of the market horizon in the FRU deployment scenario as positive load to the load nodes in the respective BAA or BAA group with the same distribution factors used for distributing the demand forecast. Implementation detail: The load distribution factors for each BAA and the BAA group shall be derived from the load distribution factors of the demand forecast zones in each BAA, weighted by the demand	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	forecast of each zone, and then re-normalized for the BAA or the BAA group.		
FRPDY-BRQ058	The system shall distribute the FRU requirement allocated to solar ($FRUR_{15}\ FRUSF_{15}(d,s,w)$) in each interval of the market horizon in the FRU deployment scenario as positive load to the solar VER nodes in the respective BAA or BAA group pro rata on the respective solar VER forecast.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC
FRPDY-BRQ059	The system shall distribute the FRU requirement allocated to wind ($FRUR_{15}\ FRUWF_{15}(d,s,w)$) in each interval of the market horizon in the FRU deployment scenario as positive load to the wind VER nodes in the respective BAA or BAA group pro rata on the respective wind VER forecast.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC
FRPDY-BRQ060	The system shall distribute the FRD requirement allocated to demand ($FRDR_{15}\ FRDDF_{15}(d,s,w)$) in each interval of the market horizon in the FRD deployment scenario as negative load to the load nodes in the respective BAA or BAA group with the same distribution factors used for distributing the demand forecast. Implementation detail: The load distribution factors for each BAA and the BAA group shall be derived from the load distribution factors of the demand forecast zones in each BAA, weighted by the demand forecast of each zone, and then re-normalized for the BAA or the BAA group.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC
FRPDY-BRQ061	The system shall distribute the FRD requirement allocated to solar ($FRDR_{15}\ FRDSF_{15}(d,s,w)$) in each interval of the market horizon in the FRD deployment scenario as negative load to the solar VER nodes in the respective BAA or BAA group pro rata on the respective solar VER forecast.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC
FRPDY-BRQ062	The system shall distribute the FRD requirement allocated to wind ($FRDR_{15}\ FRDWF_{15}(d,s,w)$) in each interval of the market horizon in the FRD deployment scenario as negative load to the wind VER	Core	RTPD STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	nodes in the respective BAA or BAA group pro rata on the respective wind VER forecast.	BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	
FRPDY-BRQ063	The system shall define and maintain FRP Surplus Zones in each BAA in the EIM Area. The FRP Surplus Zones shall include generation and load nodes, and in the case of CISO, CISO Scheduling Points, so that every generation and load in a BAA shall belong to one, and only one, FRP Surplus Zone. The FRP Surplus Zones shall be used in the market to distribute FRP Surplus variables. Implementation Note: Four FRP Surplus Zones for CISO aligned with the four TAC Areas. For EIM BAAs, one FRP Surplus Zone for the entire BAA, except for BAAs with CLAPs (e.g., BANC, PSCO) where the FRP Surplus Zones shall align with the CLAPs.	Core Tariff §44.2.4.3	Master File
FRPDY-BRQ064	The system shall retrieve all defined FRP Surplus Zones and their BAA association.	Core Tariff §44.2.4.3	STUC RTPD RTD
FRPDY-BRQ065	The system shall distribute the FRU surplus in each interval of the market horizon in the FRU deployment scenario as negative load to the load and VER nodes in the respective FRP Surplus Zone with the same distribution factors used for distributing the FRU requirement in that zone.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ066	The total FRU surplus in each BAA in the EIM Area shall be limited to the distributed FRU requirement in that BAA.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3, §29.3.4(m)	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ067	The system shall distribute the FRD surplus in each interval of the market horizon in the FRD deployment scenario as positive load to the load and VER nodes in the respective FRP Surplus Zone with the same distribution factors used for distributing the FRD requirement in that zone.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ068	The total FRD surplus in each BAA in the EIM Area shall be limited to the distributed FRD requirement in that BAA.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3, §29.3.4(m)	RTPD STUC RTD
FRPDY-BRQ070	The system shall receive the FRU demand price curve $\{Q_k, P_k, k = 1,2,\ldots,n\}$ for each interval of the market horizon for each BAA in the EIM Area. Note: The FRU demand price curve has increasing positive quantities (an ascending ordering shall be performed on the quantities to ensure the MW quantities monotonically increasing) and decreasing positive prices:  	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ071	The system shall receive the FRD demand price curve $\{Q_k, P_k, k = 1,2,\ldots,n\}$ for each interval of the market horizon for each BAA in the EIM Area.	Core	RTPD STUC

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Note: The FRD demand price curve has decreasing negative quantities (a <u>descending </u>ordering shall be performed on the quantities to ensure the MW quantities monotonically decreasing) and decreasing positive prices:  	BPM: Market Operations Section 7.1.3	RTD
FRPDY-BRQ072	The system shall extend or prune the end of the FRU demand price curve for each BAA in the EIM Area to match the corresponding FRU requirement distributed to that BAA: $$Q_n = FRUR$$ Then, the system shall flip the monotonically decreasing FRU demand price curve for each interval of the market horizon for each BAA in the EIM Area horizontally to form the monotonically increasing price curve for the FRU surplus that varies from zero to $FRUR$. All Q_i shall be capped by Q_n. The system shall verify and enforce that the price curve is monotonically increasing. Finally, the system shall limit from above all segments of the FRU price curve by the FRU penalty price. If there is no FRU demand curve available, System shall extend the last available FRU demand price curve data for future use.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ073	The system shall extend or prune the end of the FRD demand price curve for each BAA in the EIM Area to match the corresponding FRD requirement distributed to that BAA: $$Q_n = -FRDR$$ Then, the system shall offset the FRD demand price curve for each interval of the market horizon for each BAA in the EIM Area by $+FRDR$ to form the monotonically increasing price curve for the FRD surplus that varies from zero to $FRDR$. All Q_i shall be capped by Q_n. The system shall verify and enforce that the price curve is monotonically increasing. Finally, the system shall limit from above all segments of the FRD price curve by the FRD penalty price. If there is no FRD demand curve available, System shall extend the last available FRD demand price curve data for future use.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ073A	• The system shall use the FRU and FRD demand price curves in the optimization to procure FRP. • In case of the energy price bid cap is greater than $1,000, System shall scale the demand price curves by 2, but capped them by the FRU/FRD penalty prices.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ074	The system shall allocate the FRU surplus price curve for each interval of the market horizon for each BAA in the EIM Area to the FRP Surplus Zones of that BAA in proportion to the distributed FRU requirement in that zone. Implementation detail: Each segment of the FRU surplus price curve for a FRP Surplus Zone in each BAA in the EIM Area shall be scaled in proportion to distributed FRU requirement in that zone to yield the corresponding segment of the FRU surplus price curve for that zone.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ075	The system shall allocate the FRD surplus price curve for each interval of the market horizon for each BAA in the EIM Area to the FRP Surplus Zones of that BAA in proportion to the distributed FRD requirement in that zone.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Implementation detail: Each segment of the FRD surplus price curve for a FRP Surplus Zone in each BAA in the EIM Area shall be scaled in proportion to distributed FRD requirement in that zone to yield the corresponding segment of the FRD surplus price curve for that zone.		
FRPDY-BRQ076	The system shall enforce transmission constraints for the base case and critical contingencies for the FRU deployment scenario. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §Appendix C (d)	RTPD STUC RTD
FRPDY-BRQ077	The system shall enforce transmission constraints for the base case and critical contingencies for the FRD deployment scenario. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §Appendix C (d)	RTPD STUC RTD
FRPDY-BRQ078	The system shall extend the current DCPA and LMPM method to binding transmission constraints in the FRU deployment scenario. In DCPA, the supply counter flow shall be the energy schedules plus the FRU awards.	Core BPM: Market Operations Section 7.1.3	RTPD RTD
FRPDY-BRQ079	The system shall extend the current DCPA and LMPM method to binding transmission constraints in the FRD deployment scenario. In DCPA, the supply counter flow shall be the energy schedules minus the FRD awards.	Core BPM: Market Operations Section 7.1.3	RTPD RTD

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FRPDY-BRQ080	The system shall limit from below (in the import direction) the algebraic net transfer (positive for export and negative for import) of each BAA that has failed the FRU sufficiency test in each interval of the market horizon to the less restrictive of the base net transfer for that BAA and interval or the net transfer of the interval prior to the failed interval. Implementation detail: This limit application is the same as Market has currently in PRODCTION. Implementation detail: Appendix A.	Existing System Functionality BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ081	The system shall limit from above (in the export direction) the algebraic net transfer (positive for export and negative for import) of each BAA that has failed the FRD sufficiency test in each interval of the market horizon to the less restrictive of the base net transfer for that BAA and interval or the net transfer of the interval prior to the failed interval. Implementation detail: This limit application is the same as Market has currently in PRODCTION. Implementation detail: Appendix A.	Existing System Functionality BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ082	The system shall constrain the net transfer in the FRU deployment scenario of each BAA that has failed the FRU sufficiency test in each interval of the market horizon to the net transfer in the base scenario of meeting the demand forecast for that BAA and interval. However, the individual dynamic (and static in RTUC/STUC) transfers (ETSRs) shall be allowed to move in the FRU deployment scenario between zero and their respective scheduling limit. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ083	The system shall constrain the net transfer in the FRU deployment scenario of each BAA that has passed the FRU sufficiency test in each interval of the market horizon to the net transfer in the base scenario of meeting the demand forecast for that BAA and interval, plus the sum of all FRU awards in that BAA and interval, plus the total FRU surplus in that BAA and interval, minus the distributed FRU requirement in that BAA and interval. However, the individual	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	dynamic (and static in RTUC/STUC) transfers (ETSRs) shall be allowed to move in the FRU deployment scenario between zero and their respective scheduling limit. Implementation detail: Appendix A.		
FRPDY-BRQ084	The system shall constrain the net transfer in the FRD deployment scenario of each BAA that has failed the FRD sufficiency test in each interval of the market horizon to the net transfer in the base scenario of meeting the demand forecast for that BAA and interval. However, the individual dynamic (and static in RTUC/STUC) transfers (ETSRs) shall be allowed to move in the FRD deployment scenario between zero and their respective scheduling limit. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ085	The system shall constrain the net transfer in the FRD deployment scenario of each BAA that has passed the FRD sufficiency test in each interval of the market horizon to the net transfer in the base scenario of meeting the demand forecast for that BAA and interval, minus the sum of all FRD awards in that BAA and interval, minus the total FRD surplus in that BAA and interval plus the distributed FRD requirement in that BAA and interval. However, the individual dynamic (and static in RTUC/STUC) transfers (ETSRs) shall be allowed to move in the FRD deployment scenario between zero and their respective scheduling limit. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3	RTPD STUC RTD
FRPDY-BRQ086	The system shall enforce upward and downward ramp capability constraints for energy dispatch, ancillary services awards, and FRU/FRD awards for each resource in each interval of the market horizon. Implementation detail: Appendix A.	Existing System Functionality	RTPD STUC RTD
FRPDY-BRQ087	The system shall enforce upward and downward capacity constraints for energy dispatch, ancillary services awards, and FRU/FRD awards for each resource in each interval of the market horizon.	Existing System Functionality	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Implementation detail: Appendix A.		
FRPDY-BRQ088	The system shall calculate the Locational Marginal Price (LMP) at each Location (PNode and APNode) of each BAA in the EIM Area in each interval of the market horizon as the sum of the shadow price of the Power Balance Constraint (PBC) for that BAA and interval and the Marginal Greenhouse Gas (GHG) Price for that Location and interval, divided by the Loss Penalty Factor (LPF) for that Location and interval, minus the congestion contributions from all binding constraints in the base and FRU/FRD deployment scenarios; the latter are the product of the shadow price of the respective binding constraint times the shift factor of the respective Location to that binding constraint in the relevant interval. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ089	The system shall decompose the LMP at each Location of each BAA in the EIM Area in each interval of the market horizon to: • The Marginal Energy Component (MEC); • The Marginal Loss Component (MCL); • The Marginal Congestion Component (MCC); and • The Marginal GHG Component. Furthermore, the system shall decompose the MCC at each Location of each BAA in the EIM Area in each interval of the market horizon to components for each BAA in the EIM Area based on the corresponding Congestion Distribution Factors (CDFs) for each binding constraint contribution.	Existing System Functionality	RTPD STUC RTD
FRPDY-BRQ090	The system shall calculate the Locational FRU Marginal Price (FRUMP) at each Location of each BAA that has failed the FRU sufficiency test in each interval of the market horizon as the shadow price of the FRU procurement constraint for that BAA and interval, minus the congestion contributions from all binding constraints in the FRU deployment scenarios; the latter are the product of the shadow price of the respective binding constraint times the shift factor of the respective Location to that binding constraint in the relevant interval.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Implementation detail: Appendix A.		
FRPDY-BRQ091	The system shall calculate the Locational FRU Marginal Price (FRUMP) at each Location of each BAA that has passed the FRU sufficiency test in each interval of the market horizon as the shadow price of the net transfer constraint in the FRU deployment scenario for that BAA and interval, plus the shadow price of the FRU procurement constraint for the group of BAAs that have passed the FRU sufficiency test in that interval, minus the congestion contributions from all binding constraints in the FRU deployment scenarios; the latter are the product of the shadow price of the respective binding constraint times the shift factor of the respective Location to that binding constraint in the relevant interval. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ092	The system shall calculate the Locational FRD Marginal Price (FRDMP) at each Location of each BAA that has failed the FRD sufficiency test in each interval of the market horizon as the shadow price of the FRD procurement constraint for that BAA and interval, plus the congestion contributions from all binding constraints in the FRD deployment scenarios; the latter are the product of the shadow price of the respective binding constraint times the shift factor of the respective Location to that binding constraint in the relevant interval. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ093	The system shall calculate the Locational FRD Marginal Price (FRDMP) at each Location of each BAA that has passed the FRD sufficiency test in each interval of the market horizon as the shadow price of the net transfer constraint in the FRD deployment scenario for that BAA and interval, plus the shadow price of the FRD procurement constraint for the group of BAAs that have passed the FRD sufficiency test in that interval, plus the congestion contributions from all binding constraints in the FRD deployment scenarios; the latter are the product of the shadow price of the respective binding constraint times the shift factor of the respective Location to that binding constraint in the relevant interval. Implementation detail: Appendix A.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD

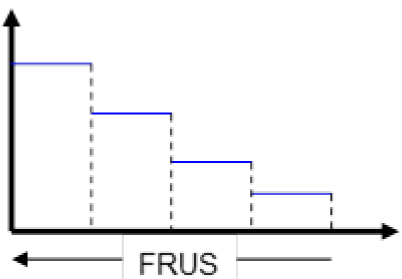
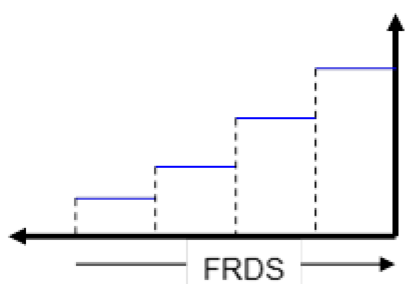
ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ094	The system shall calculate the Scheduling Point-Intertie (SP-Tie) Locational Marginal Price (SP-Tie LMP) at each SP-Tie Location of each BAA in the EIM Area in each interval of the market horizon as the sum of the shadow price of the Power Balance Constraint (PBC) for that BAA and interval and the Marginal Greenhouse Gas (GHG) Price for that Location and interval, divided by the Loss Penalty Factor (LPF) for that Location and interval, plus the shadow prices of all binding Intertie Scheduling Limits (ISLs) and Inter-Tie Constraints (ITCs) associated with that SP-Tie Location, minus the congestion contributions from all binding constraints in the base and FRU/FRD deployment scenarios; the latter are the product of the shadow price of the respective binding constraint times the shift factor of the respective Location to that binding constraint in the relevant interval.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ095	The system shall decompose the SP-Tie LMP at each SP-Tie Location of each BAA in the EIM Area in each interval of the market horizon to: • The Marginal Energy Component (MEC); • The Marginal Loss Component (MCL); • The Marginal Congestion Component (MCC); and • The Marginal GHG Component. Furthermore, the system shall decompose the MCC at each SP-Tie Location of each BAA in the EIM Area in each interval of the market horizon to components for each BAA in the EIM Area based on the corresponding Congestion Distribution Factors (CDFs) for each binding constraint contribution.	Existing System Functionality	RTPD STUC RTD
FRPDY-BRQ096	The system shall calculate the Locational FRU Marginal Price (FRUMP) at each SP-Tie Location of each BAA in the EIM Area in each interval of the market horizon as if the SP-Tie Location is a Location in that BAA, plus the shadow prices of all binding Intertie Scheduling Limits (ISLs) and Inter-Tie Constraints (ITCs) associated with that SP-Tie Location. This is required for the settlement of FRU awards from TGs.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ097	The system shall calculate the Locational FRD Marginal Price (FRDMP) at each SP-Tie Location of each BAA in the EIM Area in each interval of the market horizon as if the SP-Tie Location is a Location in that BAA, plus the shadow prices of all binding Intertie Scheduling Limits (ISLs) and Inter-Tie Constraints (ITCs) associated with that SP-Tie Location. This is required for the settlement of FRD awards from TGs.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD STUC RTD
FRPDY-BRQ098	The system shall broadcast Locational Marginal Prices and Locational FRU/FRD Marginal Prices for Pnode/Apnode/SP-Tie Locations. Implementation Note: This data is published in OASIS as public data.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD RTD
FRPDY-BRQ099	The system shall broadcast resource specific Locational FRU/FRD Marginal Prices for Pnode/Apnode/SP-Tie Locations. Implementation Note: This data is published in CMRI.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD RTD
FRPDY-BRQ100	The system shall broadcast the shadow prices of binding transmission and transfer constraints in the FRU deployment scenarios. Implementation Note: This data is published in OASIS as public data.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD RTD
FRPDY-BRQ101	The system shall broadcast the shadow prices of binding transmission and transfer constraints in the FRD deployment scenarios. Implementation Note: This data is published in OASIS as public data.	Core BPM: Market Operations Section 7.1.3 Tariff §44.2.4.3	RTPD RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ101 A	The system shall broadcast the FRU and FRD group capacity requirement for the pass group and the individual BA requirement	Core BPM: Market Operations Section 7.1.*3* Tariff §44.2.4.3	RTPD RTD
FRPDY-BRQ101 B	The system shall broadcast the FRU and FRD group shadow price for the pass group and the individual BA requirement to downstream systems.	Core BPM: Market Operations Section 7.1.*3* Tariff §44.2.4.3	RTPD RTD
FRPDY-BRQ103	System shall calculate the LMP for each Base ETSR Financial Location as the sum of the following: • SMEC • Shadow price of the PBC of the FROM BAA, if the FROM BAA is not CISO • Shadow price of each ITC/ISL associated with the FROM BAA and the INTERTIE of Base ETSR (or the Scheduling Point at that INTERTIE, if the FROM BAA is CISO). • Marginal GHG price, if the FROM BAA is not in the CA GHG regulation area. Note: The CA GHG regulation area is the union of BAAs in CA; currently CISO, BANC, and TID, and from 4/1/2021 for LADWP. Refer to Appendix B – Symmetrical Settlement for Wheeling through EIM BAAs (MF Definition) for example of MF Table definition.	Core Tariff §44.2.4.3	RTM (STUC, HASP, RTPD, RTD)
FRPDY-104	The system shall broadcast the Shadow price of the FRU/FRD procurement constraint.	Core	RTM

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	Note: For the BAAs which are passing the flex test, market will publish them as FRU_PASS_GRP/FRD_PASS_GRP with group definition.		
FRPDY-BRQ105	When a EIM BAA is in contingency, the BAA should be removed from FLEX UP and FLEX DOWN passing group definition. There will be no FRU/FRD procurement for that BAA.	Core	RTD
FRPDY-BRQ106	For each 5 minute while an EIM BAA is in contingency, the system shall receive the updated histograms and polynomial coefficients information for the updated FRU/FRD passing group, which does not include that BAA. **Note:** Refer to FRPDY-BRQ 010 and FRPDY-BRQ011 for the types of histograms and polynomial coefficients needed for flex requirement calculation.	Core	RTD
FRPDY-BRQ107	When an EIM BAA is in contingency, the FRU/FRD requirement for that BAA shall be set to zero.	Existing System Functionality	RTD
FRPDY-BRQ108	When an EIM BAA is in contingency, the system shall constrain the net transfer of the BAA to the net transfer in the base scenario from previous advisory intervals.	Existing System Functionality	RTD
FRPDY-BRQ109	System shall broadcast the updated FRU/FRD pass group information to downstream systems.	Core	RTD
FRPDY-BRQ110	When CISO is under contingency (RTCD/RTDD), the FRU/FRD requirement for shall be set to zero for CISO.	Existing System Functionality	RTCD/RTDD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ111	When CISO is under contingency, Market shall continue to send out payload for EIM BAAs using the advisory values of the pre-contingency RTD.	Existing System Functionality	RTCD/RTDD
FRPDY-BRQ111A	System shall broadcast the 1st advisory interval (binding interval for FRP) FRU/FRD surplus price curve by FRP surplus zone. Note: For FRD surplus price curve, the MW and Price need to be multiplied by -1 for external posting.	Core	RTPD/RTD
FRPDY-BRQ111B	System shall receive the min and max threshold value for the FRU/FRD requirement from Internal System.	Core	RTM
FRPDY-BRQ111C	System shall broadcast the FRP resource awards to downstream	Core	RTM
FRPDY-BRQ111D	The system shall use the EIM_AREA regression coefficients for calculating FRU/FRD uncertainty requirement for the FRU/FRD passing group when Market does not get the dynamic coefficients from Internal System in real time.	Core	RTPD STUC RTD
FRPDY-BRQ111E	The system shall receive the 5-minute/15-minute FRU price curve $\{Q_k, P_k, k = 1,2, \ldots, n\}$ for each BAA in the EIM Area. Note: The FRU demand price curve has increasing positive quantities (an ascending ordering shall be performed on the quantities to ensure the MW quantities monotonically increasing) and decreasing positive prices:	Core	RTPD STUC RTD

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
			
FRPDY-BRQ111F	The system shall receive the 5-minute/15-minute FRD demand price curve $\{Q_k, P_k, k = 1,2, \ldots, n\}$ for each BAA in the EIM Area as default price curve. Note: The FRD demand price curve has decreasing negative quantities (a descending ordering shall be performed on the quantities to ensure the MW quantities monotonically decreasing) and decreasing positive prices: 	Core	RTPD STUC RTD

5.2 Business Process: Manage Billing and Settlements

5.2.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ112	Settlements shall receive the Forecasted Movement Awards from the payload Resource Awards.	Existing System Functionality	Settlements
FRPDY-BRQ112A	Settlements shall receive FRU and FRD Uncertainty Awards from payload Flex Resource Awards	Core	Settlements
FRPDY-BRQ112B	Settlements shall receive Uncertainty Movement from payload Resource Awards	Existing System Functionality	Settlements
FRPDY-BRQ112D	Settlements shall receive the resource level FRUMP and FRDMP from payload Flex Resource Awards **Note:** The resource level/nodal FRUMP and FRDMP will not include indications for host control area ID.	Core	Settlements
FRPDY-BRQ113	Settlements shall consume FRUMP and FRDMP from Pnode clearing payload. **Note:** The resource level/nodal FRUMP and FRDMP will not include indications for host control area ID.	Core Tariff §11.25.2	Settlements
FRPDY-BRQ114	Settlements shall receive the awards for forecasted movement and uncertainty movement.	Existing System Functionality	Settlements
FRPDY-BRQ115	Settlements shall settle forecasted movement by FRUMP and FRDMP host control area ID. **Note:**	Core Tariff §11.25.1.1	Settlements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
	For each BAA, the host control area ID shall either be EIM Area or BAA specific depending upon the passing of the sufficiency test. Settlements shall use the FRU and FRD passing group information derived from the payloads below to identify the host control area ID		
FRPDY-BRQ116	Settlements shall allocate forecasted movement to the BAA based upon the host control area ID. Note: For the EIM_area host control area ID, Settlements shall allocate the costs to the BAAs that pass the sufficiency test. For the forecasted movement cost associated with the BAA that did not pass the sufficiency test, those costs will allocated to the metered demand of that BAA.	Core Tariff §11.25.1.1, § 11.25.1.4, § 11.25.2.2	Settlements
FRPDY-BRQ117	Settlements shall settle uncertainty awards by FRUMP and FRDMP For each BAA, the host control area ID shall either be EIM Area or BAA specific depending upon the passing of the sufficiency test. Settlements shall use the FRU and FRD passing group information derived from the payloads below to identify the host control area ID	Core	Settlements
FRPDY-BRQ117A	Settlements shall calculate the categories (Supply/Intertie/Load) for the EIM Area Pass Group. Note: For all EIM entities that pass either FRU or FRD settlements will derive the total quantity of each category.	Core Tariff §11.25.2.2	Settlements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ118	Settlements shall allocate uncertainty awards to the BAA based upon the pass group. **Notes** • For the EIM_area host control area ID, Settlements shall allocate the costs to the BAAs that pass the sufficiency test based on their categories. • For the uncertainty award cost associated with the BAA that did not pass the sufficiency test, those costs will be allocated to the BAA based on its categories and any residual unallocated balance to the metered demand of that BAA.	Core Tariff §11.25.2.2	Settlements
FRPDY-BRQ119	Settlements shall consume the FRU passing group information for every fifteen minutes of the trade date from FMM.	Core Tariff §11.25.2.2	Settlements
FRPDY-BRQ120	Settlements shall consume the FRD passing group information for every fifteen minutes of the trade date from FMM.	Core Tariff §11.25.2.2	Settlements
FRPDY-BRQ121	Settlements shall consume FRU/FRD constraint shadow prices associated with the FRU/FRD deployment scenarios.	Core Tariff §11.25.2.2, §44.2.4.3	Settlements
FRPDY-BRQ122	Settlements shall not assess grid management charges or Flexible ramp forecasted movements and uncertainty awards.	Existing System Functionality	Settlements
FRPDY-BRQ122A	System shall receive the FRP Resource awards from RTM	Core	Settlements

5.3 Business Process: Manage Open Access Same Time Information System (OASIS)

5.3.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ124	OASIS shall publish the RTPD passing group ID /failing entities to which EIM entity determine who are part of the EIM area requirement. This report is titled as: Flexible Ramp Test Result Groups	Core BPM: Market Instruments Section 10	OASIS
FRPDY-BRQ124A	OASIS shall publish the every RTD run passing group ID /failing entities to which EIM entity determine who are part of the EIM area requirement.	Core BPM: Market Instruments Section 10	OASIS
FRPDY-BRQ125	OASIS must report the FRU/FRD Nodal prices at the Pnode level for all P-nodes, SP-ties and AP-nodes calculated by the FMM and RTD binding market run. This report is titled “Flexible Ramping Nodal Prices”	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ126	OASIS must report the shadow price for binding constraints in FRU and FRD deployment scenarios for RTPD & RTD.	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ127	The system shall publicly report on the total RTD Binding resource forecast grouped by EIM Entity by technology type for solar and wind. This report is titled “Flexible Ramping Forecasts”	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ128	The system shall publicly report on the total RTD and RTPD 1st interval advisory resource forecast grouped by EIM Entity by technology type for solar and wind. This report is titled “Flexible Ramping Forecasts	Core BPM: Market Instruments Section 12	OASIS

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ129	The system shall publicly report on the total RTD Binding resource forecast grouped by EIM Entity for demand. This report is titled “Flexible Ramping Forecasts.	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ130	The system shall publicly report on the total RTPD and RTD 1st interval advisory resource forecast grouped by EIM Entity by technology type for demand. This report is titled “”Flexible Ramping Forecasts”	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ131	The system shall continue to publicly report on FRU/FRD shadow price and EIM Area Requirement of each BAA calculated by market run for RTPD & RTD. Existing Report: “Flexible Ramping Constraint Result”.	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ137	OASIS must report the Flex ramp up surplus price curve by BAA from the 2nd Binding interval for RTD and 3rd Binding interval for RTPD This information will now be calculated and sent out by the market. This is an existing report is titled “Flexible Ramp Surplus Price Demand Curve”	Core BPM: Market Instruments Section 12	OASIS
FRPDY-BRQ138	OASIS must report the Flex ramp down surplus price curve by BAA from the 2nd Binding interval for RTD and 3rd Binding interval for RTPD. This information will now be calculated and sent out by the market. This is an existing report is titled “Flexible Ramp Surplus Price Demand Curve”	Core BPM: Market Instruments Section 12	OASIS

5.4 Business Process: Manage CAISO Markets Results Interface

5.4.1 Business Requirements

ID#	Business Feature	Requirement Type	Potential Application(s) Impacted
FRPDY-BRQ138B	System shall receive and display the FRP Resource Awards from RTM.	Core	CMRI

5.5 Business Process: Business Process: Market/Business Simulation

5.3.1 Business Requirements

This section shall provide a basis for the development of the Market/Business Simulation Scenarios. These requirements will provide guidance on the market participant impacts, inputs into the Scenarios, endpoints to the Scenarios and reasons for potential Scenarios. The guidance on market participant impacts shall be gathered from the requirements that impact rules, interfaces, applications/reports, new system processes, new/modified data models and new user roles. The source and sink systems shall be determined through the development of the system context diagram and the web service requirements. The Reason for the Potential Scenario column will be to offer guidance regarding what potential Scenarios, and their context, may be needed for this project. This section applies to all policy development projects, market enhancements, technology enhancements, operation enhancements, Energy Imbalance Market (EIM) implementations and Reliability Coordination (RC) service implementations.

In the Reason for Potential Scenario column, the Business Analyst must select one or more of the following reasons:

1. **Rule Impacts**: Generalized changes in market rules, bidding rules, settlements rules, market design changes, or other business rules.
2. **Interface changes**: Changes that impact templates (e.g. the Resource Adequacy {RA} supply plan), user interface (UI), and application programming interface (API) (e.g. retrievals of new shadow settlement data).
3. **New application/report**: Changes that cause addition/modification of market software or reports, especially when market data input is required by the market participant.
4. **New system process**: Modification of data flow in systems, especially if the new process requires the market participant to demonstrate proficiency prior to production.
5. **New/Modified model data**: Addition or substantial modification of model data as a market solution provided by the ISO.
6. **New user role**: The addition or modification of access permissions for a user role applied to specific business units within an EIM entity or market participant organization (e.g. Load Serving Entity (LSE) as a Local Regulatory Authority (LRA) role). Scenarios are beneficial for market participants taking on a new function or process within their organization.

5.5.1 Business Requirements

Note: The market simulation scenarios will be covered extensively in the Market Sim Scenario document.

POC: The Project team

ID#	Guidance on Market Participant Impacts	Source System	Sink System	Reason for Potential Scenario
FRPDY-MKT001	Demonstrate the variability of locational pricing for FRU.	RTM	OASIS, CMRI, Settlements	1. Rule Impacts 2. Interface changes
FRPDY-MKT002	Demonstrate the variability of locational pricing for FRD.	RTM	OASIS, CMRI, Settlements	1. Rule Impacts 2. Interface changes

6 Appendix A: Flexible Ramping Product Refinements: Procurement and Deployment Scenarios Draft Technical Description

6.1 Introduction

This technical paper describes an enhancement to the Flexible Ramping Product (FRP) procurement in the Real-Time Market (RTM) to address situations where FRP awards are awarded behind binding transmission constraints that would prevent their deployment when uncertainty materializes. FRP awards are awarded based on the opportunity cost of reserved capacity versus the revenue from dispatching this capacity as energy. For resources constrained by binding transmission constraints, there is no opportunity cost for reserving capacity above their constrained energy dispatch; therefore, the RTM awards FRP to that capacity to minimize the overall operating cost. This is because the current FRP procurement in the RTM, with its extension to the Energy Imbalance Market (EIM), is at the Balancing Authority Area (BAA) level without any regard to binding transmission constraints.

The existing method seriously undermines the quality and objective of the FRP initiative, and it also raises a reliability concern because the system may be ill prepared to respond to large amounts of uncertainty when they materialize in real time. The proposed method in this technical paper, as part of the FRP Refinements initiative, procures locational FRP awards that their full deployment does not violate transmission constraints or scheduling limits in the entire EIM Area. This is achieved by augmenting the RTM mathematical optimization problem with FRP deployment scenarios subject to the same transmission constraints that are enforced in the original problem of serving the demand forecast. Although there are potentially many FRP deployment scenarios depending on how much and where uncertainty may materialize in the system, only the two following deployment scenarios are selected for simplicity:

1) Flexible Ramp Up (FRU) deployment of all FRU awards to meet the maximum upward uncertainty requirement (97.5 uncertainty percentile) that may materialize in each BAA in the EIM Area, net of any FRU elastic demand relaxation.
2) Flexible Ramp Down (FRD) deployment of all FRD awards to meet the maximum downward uncertainty requirement (2.5 uncertainty percentile) that may materialize in each BAA in the EIM Area, net of any FRD elastic demand relaxation.

The distribution of the upward and downward uncertainty in the deployment scenarios in each BAA is divided among load, solar, and wind resources. The allocation factors are derived from historical data that reflect the relative contributions of these resource classes to the overall uncertainty.

The enhancement provides also an opportunity to redesign the FRP procurement in EIM, which is currently overly complex and not entirely accurate in modeling EIM diversity.

6.1.1 Current FRP Procurement Implementation

In the current implementation, FRU/FRD is procured with different constraints for each BAA and a constraint for the entire EIM Area. If a BAA has passed the FRU/FRD sufficiency test, the FRU/FRD requirement for that BAA is not only reduced by the FRU/FRD demand elasticity, but also by the available net import/export transfer capacity from/to other BAAs in the EIM Area to maximize the benefits of BAA diversity and economic displacement by participating in the EIM. On the contrary, if a BAA has failed the FRU/FRD sufficiency test, the FRU/FRD requirement for that BAA is only reduced by the FRU/FRD demand elasticity and a FRU/FRD credit equal to the net transfer that is optimally scheduled above/below the net base transfer. The justification for the credit is that it can be recalled in the next market run if needed to meet materialized uncertainty. An additional constraint is enforced for each BAA that has failed the FRU/FRD sufficiency test to limit its net transfer import/export below/above its net base transfer to prevent leaning on other BAAs in the EIM Area.

Besides ignoring transmission constraints, the current implementation has the following drawbacks:

- For a BAA that has passed the FRU/FRD sufficiency test, the calculation of the net import/export transfer capacity from/to other BAAs in the EIM Area considers only the available transfer capacity on the transfers of that BAA alone. Subtracting that net import/export transfer capacity from the FRU/FRD requirement of that BAA assumes that it can be fully used to satisfy the FRU/FRD requirement in that BAA from other BAAs in the EIM Area. However, that may not be possible due to transfer constraints beyond the BAA boundary and resource ramp capability constraints, which are not considered in this evaluation.
- Similarly, when the uncertainty materializes in a BAA that has failed the FRU/FRD sufficiency test, it is assumed that the FRU/FRD credit for that BAA can be fully cashed out by recalling net export/import transfer above/below the net base transfer. However, that may not be possible due to transfer constraints beyond the BAA boundary and resource ramp capability constraints, which are not considered in this evaluation.
- The FRU/FRD awards in a BAA satisfy the FRU/FRD requirements not only in that BAA, but also in the EIM Area. Similarly, the FRU/FRD demand elasticity in a BAA reduces the FRU/FRD requirements not only in that BAA, but also in the EIM Area, because otherwise, the demand elasticity in that BAA may be substituted by additional FRU/FRD awards outside that BAA, or by FRU/FRD demand elasticity at the EIM Area level. Nevertheless, additional constraints must be enforced to prevent FRU/FRD demand elasticity in excess of the minimum required to result in no FRU/FRD awards in that BAA when the cost of the former is less than the cost of the latter. These constraints compound on the complexity of the FRP procurement method resulting in an overly complex and non-transparent model.

6.1.2 Proposed Enhancement

In the proposed enhancement, the FRU/FRD procurement is significantly simplified for BAAs that have passed the FRU/FRD sufficiency test by formulating a single constraint for the extreme uncertainty in the entire BAA group, reduced by the FRU/FRD demand elasticity in that BAA group. For each BAA that has failed the FRU/FRD sufficiency test, FRU/FRD is still procured separately for the respective FRU/FRD requirement, but the latter is only reduced by the FRU/FRD demand elasticity in that BAA, without any FRU/FRD credit. An additional constraint is enforced for each BAA that has failed the FRU/FRD sufficiency test to limit its net transfer import/export below/above its net base transfer to prevent leaning on other BAAs in the EIM Area. Furthermore, in both cases, all transmission and transfer constraints are enforced in the FRU/FRD deployment scenarios. The result is locational FRU/FRD awards that their full deployment does not violate any transmission or transfer constraints in the entire EIM Area.

FRU/FRD credit is not supported in this proposal because the FRU/FRD procurement for BAAs that have failed the FRU/FRD sufficiency test is strictly separate from the FRU/FRD procurement for BAAs that have passed the FRU/FRD sufficiency test. Allowing a FRU/FRD credit for BAAs that have failed the FRU/FRD sufficiency test must appear as an additional FRU/FRD requirement for the group of BAAs that have passed the FRU/FRD sufficiency test. This would overly complicate the FRU/FRD procurement and cost allocation. Without FRU/FRD credit, the FRU/FRD cost allocation is greatly simplified because the FRU/FRD cost is contained within each BAA that has failed the FRU/FRD sufficiency test, and separately in the group of BAAs that have passed the FRU/FRD sufficiency test.

6.2 Assumptions

The following assumptions are made in this technical paper:

- There are no capacity bids for FRU/FRD; they are priced at opportunity costs.
- Only 5min dispatchable resources are eligible for FRU/FRD awards.
- Variable Energy Resources (VERs) are scheduled up to their forecast and they may be awarded FRU/FRD; VER FRU/FRD awards are deployed in the FRU/FRD deployment scenarios.
- All physical transmission constraints that are enforced in the original problem including base case and contingency constraints are also enforced in the FRU/FRD deployment scenarios.
- All transfer constraints that are enforced in the original problem are also enforced in the FRU/FRD deployment scenarios.
- The distribution of the FRU/FRD requirements in the FRU/FRD deployment scenarios in each BAA is divided among load, solar, and wind resources; the allocation factors are derived from historical data that reflect the relative contributions of these resource classes to the overall uncertainty.
- The FRU/FRD demand elasticity is achieved with FRU/FRD surplus variables with cost curves that reflect the expected cost of foregoing FRU/FRD procurement so that FRU/FRD is not

procured at a higher cost than the benefit it provides. The FRU/FRD surplus variables are modeled as independent controls in each FRP Surplus Zone, effectively relaxing the distributed FRU/FRD requirements in the respective zone.

6.3 Notation

The following notation is used in this technical paper:

i	Resource/node index.
j, k	BAA indices (0 for CISO).
l	Energy transfer schedule (ETSR) index for a given BAA pair (for different interties and/or ETSR classes like base, static, or dynamic).
m	Transmission or ITC/ISL constraint index.
r	Ancillary Services Region index.
z	FRP Surplus Zone index.
$^{(u)}$	Superscript denoting FRU deployment scenario values.
$^{(d)}$	Superscript denoting FRD deployment scenario values.
T	The unit of time for energy calculations (60min).
T_5	Flexible Ramp time domain (5min).
T_{10}	Ancillary services time domain (10min).
T_{15}	Ancillary services awards duration (15min).
T_{30}	Sustained energy time period for contingency reserve dispatch (30min).
ΔT	Time period duration (15min in FMM and 5min in RTD).
N	Number of time periods in the FMM or RTD time horizon.
GAF	Granularity adjustment factor (3 in FMM and 1 in RTD).
ASF	Ancillary services adjustment factor (1 in FMM and ½ in RTD).
$\forall$	For all…
$\in$	Member of…
$\notin$	Not member of…
$\wedge$	Logical and…
$\cup$	Union…
$\cap$	Intersection…
$\rightarrow$	Leads to…
Δ	Denotes incremental values from the previous iteration or incremental load adjustments in the FRU/FRD deployment scenarios.
BAA_j	Set of resources in BAA j.
EIM	Set of BAAs in the EIM Area.
Z_j	Set of FRP Surplus Zones in BAA j.
PU_t	Set of BAAs that pass the Flexible Ramp Up sufficiency test in time period t.
PD_t	Set of BAAs that pass the Flexible Ramp Down sufficiency test in time period t.
S_5	Set of 5min-start units ($SUT \leq$ 5min) that can provide FRU from offline status ($u = 0$).

S_{10}	Set of Fast-Start Units ($SUT \leq 10$min) that can be certified to provide Non-Spinning Reserve from offline status ($u = 0$).
S_r	Set of resources in Ancillary Services Region r.
S_z	Set of resources in FRP Surplus Zone z.
I_m	Set of import resources, including ETSRs, associated with ITC/ISL m.
E_m	Set of export resources, including ETSRs, associated with ITC/ISL m.
S_m	Set of intertie resources, including ETSRs, associated with ITC/ISL m; $S_m = I_m \cup E_m$.
S_{PSH}	Set of Pumped-Storage Hydro Resources.
S_{LESR}	Set of Limited Energy Storage Resources.
S_{SVER}	Set of Solar Variable Energy Resources.
S_{WVER}	Set of Wind Variable Energy Resources.
$u_{i,t}$	Binary (0/1) variable indicating commitment status (offline/online) for Resource i in time period t. For Pumped-Storage Hydro Resources, 1 indicates generating mode operation. For Limited Energy Storage Resources, 1 indicates discharging mode operation.
$v_{i,t}$	Binary (0/1) variable for Pumped-Storage Hydro Resources indicating pumping mode operation in time period t.
$y_{i,t}$	Binary (0/1) variable indicating that Resource i has a start-up in time period t.
η_i	Pumping efficiency of Pumped-Storage Hydro Resource i, or charging efficiency of Limited Energy Storage Resource i.
C	Objective function.
$LOL_{i,t}$	Lower Operating Limit of Resource i in time period t.
$UOL_{i,t}$	Upper Operating Limit of Resource i in time period t.
$LRL_{i,t}$	Lower Regulating Limit of Resource i in time period t.
$URL_{i,t}$	Upper Regulating Limit of Resource i in time period t.
$LEL_{i,t}$	Lower Economic Limit of Resource i in time period t.
$UEL_{i,t}$	Upper Economic Limit of Resource i in time period t.
$CL_{i,t}$	Capacity Limit for Resource i in time period t; $UEL_{i,t} \leq CL_{i,t} \leq UOL_{i,t}$; it defaults to $UOL_{i,t}$; it is used to limit regulation awards.
$LCL_{i,t}$	Lower Capacity Limit of Resource i in time period t.
$UCL_{i,t}$	Upper Capacity Limit of Resource i in time period t.
$SUC_{i,t}$	Start-Up Cost for Resource i in time period t.
$SUT_{i,t}$	Start-Up Time for Resource i in time period t.
$MLC_{i,t}$	Minimum Load Cost for Resource i in time period t.
$PC_{i,t}$	Pumping cost for Pumped Storage Hydro Resource i in time period t.
$PL_{i,t}$	Pumping level for Pumped Storage Hydro Resource i in time period t.
$EN_{i,t}$	Energy schedule of Resource i in time period t; positive for supply (generation and imports) and negative for demand (demand response and exports).

$D_{j,t}$	Demand forecast for BAA j in time period t.
$L_{i,t}$	Load at load node i in time period t.
$T_{j,t}$	Net transfer of EIM BAA j in time period t; positive for export and negative for import.
$\tilde{T}_{j,t}$	Net base transfer of EIM BAA j in time period t.
$\overline{T}_{j,t}$	Upper scheduling limit on net transfer of BAA j in time period t.
$\underline{T}_{j,t}$	Lower scheduling limit on net transfer of BAA j in time period t.
$IT_{j,k,l,t}$	Import energy transfer schedule (ETSR) l to BAA j from BAA k in time period t.
$ET_{j,k,l,t}$	Export energy transfer schedule (ETSR) l from BAA j to BAA k in time period t.
$\widetilde{IT}_{j,k,l,t}$	Base import energy transfer schedule (ETSR) l to BAA j from BAA k in time period t.
$\widetilde{ET}_{j,k,l,t}$	Base export energy transfer schedule (ETSR) l from BAA j to BAA k in time period t.
$\overline{IT}_{j,k,l,t}$	Scheduling limit of the import energy transfer schedule (ETSR) l to BAA j from BAA k in time period t.
$\overline{ET}_{j,k,l,t}$	Scheduling limit of the export energy transfer schedule (ETSR) l from BAA j to BAA k in time period t.
$FRU_{i,t}$	Flexible Ramp Up award of Resource i for potential delivery in time period t.
$FRD_{i,t}$	Flexible Ramp Down award of Resource i for potential delivery in time period t.
$FRUS_{z,j,t}$	Flexible Ramp Up surplus (elastic demand) in FRP Surplus Zone z in BAA j in time period t.
$FRDS_{z,j,t}$	Flexible Ramp Down surplus (elastic demand) in FRP Surplus Zone z in BAA j in time period t.
$FRUS_{i,z,j,t}$	Flexible Ramp Up surplus (elastic demand) distributed to node i in FRP Surplus Zone z in BAA j in time period t.
$FRDS_{i,z,j,t}$	Flexible Ramp Down surplus (elastic demand) distributed to node i in FRP Surplus Zone z in BAA j in time period t.
$RU_{i,t}$	Regulation Up award of Resource i in time period t.
$RD_{i,t}$	Regulation Down award of Resource i in time period t.
$SR_{i,t}$	Spinning Reserve award of Resource i in time period t.
$NR_{i,t}$	Non-Spinning Reserve award of Resource i in time period t.
$RUBC_{i,t}$	Regulation Up bid capacity of Resource i in time period t.
$RDBC_{i,t}$	Regulation Down bid capacity of Resource i in time period t.
$SRBC_{i,t}$	Spinning Reserve bid capacity of Resource i in time period t.
$NRBC_{i,t}$	Non-Spinning Reserve bid capacity of Resource i in time period t.
$ENBP_{i,t}$	Energy bid price of Resource i in time period t.
$FRUSP_{j,t}$	Flexible Ramp Up surplus (elastic demand) price in BAA j in time period t.
$FRDSP_{j,t}$	Flexible Ramp Down surplus (elastic demand) price in BAA j in time period t.
$RUBP_{i,t}$	Regulation Up bid price of Resource i in time period t.
$RDBP_{i,t}$	Regulation Down bid price of Resource i in time period t.

$SRBP_{i,t}$ Spinning Reserve bid price of Resource i in time period t.
$NRBP_{i,t}$ Non-Spinning Reserve bid price of Resource i in time period t.
$FRUR_{j,t}$ Flexible Ramp Up requirement in BAA j in time period t.
$FRDR_{j,t}$ Flexible Ramp Down requirement in BAA j in time period t.
$FRUR_t$ Flexible Ramp Up requirement in the group of BAAs that have passed the Flexible Ramp Up sufficiency test in time period t.
$FRDR_t$ Flexible Ramp Down requirement in the group of BAAs that have passed the Flexible Ramp Down sufficiency test in time period t.
$FRUDF_{j,t}$ Flexible Ramp Up demand allocation factor in BAA j in time period t.
$FRUSF_{j,t}$ Flexible Ramp Up solar allocation factor in BAA j in time period t.
$FRUWF_{j,t}$ Flexible Ramp Up wind allocation factor in BAA j in time period t.
$FRDDF_{j,t}$ Flexible Ramp Down demand allocation factor in BAA j in time period t.
$FRDSF_{j,t}$ Flexible Ramp Down solar allocation factor in BAA j in time period t.
$FRDWF_{j,t}$ Flexible Ramp Down wind allocation factor in BAA j in time period t.
$FRUDF_t$ Flexible Ramp Up demand allocation factor in the group of BAAs that have passed the Flexible Ramp Up sufficiency test in time period t.
$FRUSF_t$ Flexible Ramp Up solar allocation factor in the group of BAAs that have passed the Flexible Ramp Up sufficiency test in time period t.
$FRUWF_t$ Flexible Ramp Up demand wind factor in the group of BAAs that have passed the Flexible Ramp Up sufficiency test in time period t.
$FRDDF_t$ Flexible Ramp Down demand allocation factor in the group of BAAs that have passed the Flexible Ramp Down sufficiency test in time period t.
$FRDSF_t$ Flexible Ramp Down solar allocation factor in the group of BAAs that have passed the Flexible Ramp Down sufficiency test in time period t.
$FRDWF_t$ Flexible Ramp Down demand wind factor in the group of BAAs that have passed the Flexible Ramp Down sufficiency test in time period t.
$\widehat{FRUR}_{j,t}$ Flexible Ramp Up requirement distributed to BAA j in the group of BAAs that have passed the Flexible Ramp Up sufficiency test in time period t.
$\widehat{FRDR}_{j,t}$ Flexible Ramp Down requirement distributed to BAA j in the group of BAAs that have passed the Flexible Ramp Down sufficiency test in time period t.
$RUR_{r,t}$ Regulation Up requirement in Ancillary Services Region r and time period t.
$RDR_{r,t}$ Regulation Down requirement in Ancillary Services Region r and time period t.
$SRR_{r,t}$ Spinning Reserve requirement in Ancillary Services Region r and time period t.
$NRR_{r,t}$ Non-Spinning Reserve requirement in Ancillary Services Region r and time period t.
$RRU_i(p,\tau)$ Piecewise linear ramp up capability function of Resource i from energy schedule p for time domain τ.
$RRD_i(p,\tau)$ Piecewise linear ramp down capability function of Resource i from energy schedule p for time domain τ.

$\underline{RRU}_{i,t}(\tau)$	Lowest ramp up capability within the applicable operating range of Resource *i* in time period *t* for time domain τ.
$\underline{RRD}_{i,t}(\tau)$	Lowest ramp down capability within the applicable operating range of Resource *i* in time period *t* for time domain τ.
$LPF_{i,t}$	Loss Penalty Factor for node *i* in time period *t*.
$LDF_{i,j,t}$	Load distribution factor for node *i* in BAA *j* in time period *t*.
$SDF_{i,j,t}$	Solar distribution factor for node *i* in BAA *j* in time period *t*.
$WDF_{i,j,t}$	Wind distribution factor for node *i* in BAA *j* in time period *t*.
$FS_{i,j,t}$	Solar forecast at node *i* in BAA *j* in time period *t*.
$FW_{i,j,t}$	Wind forecast at node *i* in BAA *j* in time period *t*.
$SF_{i,m,t}$	Shift Factor for energy injection at node *i* on network constraint *m* in time period *t*.
$SF_{z,j,m,t}^{(u)}$	Aggregate Shift Factor for the Flexible Ramp Up surplus (elastic demand) injection in FRP Surplus Zone *z* in BAA *j* on network constraint *m* in the FRU deployment scenario in time period *t*.
$SF_{z,j,m,t}^{(d)}$	Aggregate Shift Factor for the Flexible Ramp Down surplus (elastic demand) injection in FRP Surplus Zone *z* in BAA *j* on network constraint *m* in the FRD deployment scenario in time period *t*.
$F_{m,t}$	Active power flow on network constraint *m* in time period *t*.
$\tilde{F}_{m,t}$	Initial active power flow or scheduled flow from the ACPF solution on network constraint *m* in time period *t*.
$LFL_{m,t}$	Lower active power flow or scheduling limit on network constraint *m* in time period *t*.
$UFL_{m,t}$	Upper active power flow or scheduling limit on network constraint *m* in time period *t*.
$\widetilde{LFL}_{m,t}$	Lower active power flow limit adjusted for reactive power flow on network constraint *m* in time period *t*.
$\widetilde{UFL}_{m,t}$	Upper active power flow limit adjusted for reactive power flow on network constraint *m* in time period *t*.
α	Shared ramping coefficient for Regulation.
β	Shared ramping coefficient for Spinning Reserve.
γ	Shared ramping coefficient for Non-Spinning Reserve.
δ	Shared ramping coefficient for Flexible Ramp.
$\overline{EN}_i$	Maximum Energy Limit for Resource *i* in a given RTM run.
$\underline{EN}_i$	Minimum Energy Limit for Resource *i* in a given RTM run.
$SOC_{i,t}$	State of Charge for Limited Energy Storage Resource *i* in time period *t*.
$\overline{SOC}_{i,t}$	Maximum State of Charge for Limited Energy Storage Resource *i* in time period *t*.
$\underline{SOC}_{i,t}$	Minimum State of Charge for Limited Energy Storage Resource *i* in time period *t*.
$\lambda_{j,t}$	Shadow price of energy balance constraint for BAA *j* in time period *t*.

$\lambda_{j,t}^{(u)}$	Shadow price of energy balance constraint in the FRU deployment scenario for BAA j in the group of BAAs that pass the FRU sufficiency test in time period t.
$\lambda_{j,t}^{(d)}$	Shadow price of energy balance constraint in the FRD deployment scenario for BAA j in the group of BAAs that pass the FRD sufficiency test in time period t.
$\rho_{j,t}$	Shadow price of FRU procurement constraint for BAA j in time period t.
$\sigma_{j,t}$	Shadow price of FRD procurement constraint for BAA j in time period t.
ρ_t	Shadow price of FRU procurement constraint for the group of BAAs that pass the FRU sufficiency test in time period t.
σ_t	Shadow price of FRD procurement constraint for the group of BAAs that pass the FRD sufficiency test in time period t.
$\mu_{m,t}$	Shadow price of network constraint m in time period t.
$LMP_{i,t}$	Locational Marginal Price for Energy at node i in time period t.
$FRUMP_{i,t}$	Marginal Price for the Flexible Ramp Up award of Resource i in time period t.
$FRDMP_{i,t}$	Marginal Price for the Flexible Ramp Down award of Resource i in time period t.

6.4 Mathematical Formulation

The focus of the mathematical formulation in this technical paper is on the revised FRU/FRD procurement method and the extension of the EIM problem with the network constraints in the FRU/FRD deployment scenarios. Emphasis is given on the particular elements that are required for this task. Known existing features that apply in general to the Security Constrained Unit Commitment (SCUC) engine, such as unit commitment, inter-temporal constraints, multi-state generator (MSG) modeling, nomograms, and soft constraint penalty relaxation or scarcity treatment, are not included for simplicity. These features do not materially affect the extension of the EIM problem with the FRU/FRD deployment scenarios.

6.4.1 General Problem Formulation

The SCUC problem is a Mixed Integer Linear Programming (MILP) formulation of minimizing the objective function subject to equality and inequality constraints:

$$\begin{array}{cc} \min & C(\mathbf{x}) \\ \text{s.t.} & \begin{array}{c} \mathbf{A}_{eq}\,\mathbf{x} = \mathbf{b}_{eq} \\ \mathbf{A}\,\mathbf{x} \leq \mathbf{b} \end{array} \end{array}$$

6.4.2 Flexible Ramp Capacity Model

This section gives a brief overview of the Flexible Ramp Capacity model without any ancillary services and EIM transfers for simplicity. *Figure 1* below shows the Energy schedule and the FRU/FRD deployment scenario targets in a given time interval.

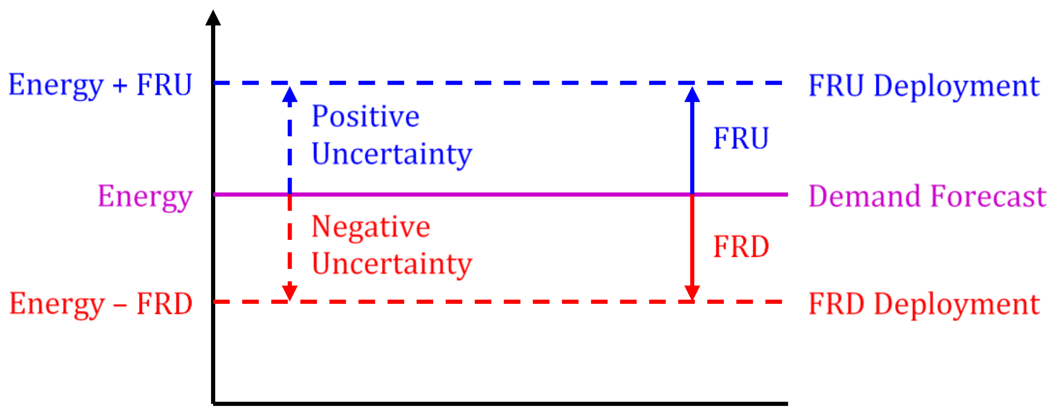


Figure 1. RTM targets for Energy and FRU/FRD

The constraints to meet these targets in the RTM problem are as follows:

$$\left.\begin{array}{l} \sum_i EN_{i,t} = D_t \\ \sum_i FRU_{i,t} \geq FRUR_t \\ \sum_i FRD_{i,t} \geq FRDR_t \end{array}\right\}, t = 1,2, \dots, N$$

FRU/FRD is ramping capacity between intervals reserved to meet uncertainty in the net demand forecast that may materialize in the next market run. *Figure 2* shows the potential FRU/FRD awards for a physical resource in a given time interval that can be reserved for the next market run based on its energy schedule in the previous time interval and its ramp capability.

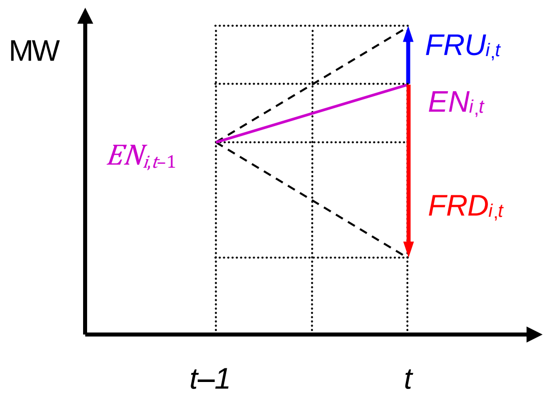


Figure 2. Energy schedules and FRU/FRD awards

The dashed lines represent the upward and downward ramp capability of the resource from its energy schedule in the previous time interval. The FRU/FRD awards are limited by that ramp capability; they represent ramping capacity that is reserved from the scheduled ramp from the previous time interval to the next time interval to meet any uncertainty that may materialize in next market run.

The energy schedules and FRU/FRD awards are calculated simultaneously by co-optimizing all commodities. They are constrained by the following set of capacity and ramp capability constraints:

$$\left.\begin{array}{l} LEL_{i,t} + FRD_{i,t} \leq EN_{i,t} \leq UEL_{i,t} - FRU_{i,t} \\ EN_{i,t} - EN_{i,t-1} \leq RRU_i\left(EN_{i,t-1}, \Delta T\right) - GAF\ \delta\ FRU_{i,t} \\ EN_{i,t} - EN_{i,t-1} \geq -RRD_i\left(EN_{i,t-1}, \Delta T\right) + GAF\ \delta\ FRD_{i,t} \end{array}\right\}, \forall i \wedge t = 1,2, \dots, N$$

The granularity adjustment factor (GAF) converts the 5min FRU/FRD awards to the market time domain; it is 3 in FMM and 1 in RTD. These constraints are more complicated when considering ancillary services awards, as shown in §6.4.12 and §6.4.13.

6.4.3 Objective Function

The objective function, ignoring MSG state transitions and regulation mileage, but including the FRU/FRD demand elasticity, and assuming flat (single segment) energy and demand elasticity bids for simplicity, is as follows:

$$C=\sum_{t=1}^{N}\sum_{i}y_{i,t}\,SUC_{i,t}+\sum_{t=1}^{N}\sum_{i}u_{i,t}\,MLC_{i,t}-\sum_{t=1}^{N}\sum_{i\in S_{PSH}}v_{i,t}\,PC_{i,t}+\sum_{t=1}^{N}\sum_{i}u_{i,t}\left(EN_{i,t}-LOL_{i,t}\right)ENBP_{i,t}$$
$$+\sum_{t=1}^{N}\sum_{i\in BAA_0}RU_{i,t}\,RUBP_{i,t}+\sum_{t=1}^{N}\sum_{i\in BAA_0}RD_{i,t}\,RDBP_{i,t}+\sum_{t=1}^{N}\sum_{i\in BAA_0}SR_{i,t}\,SRBP_{i,t}$$
$$+\sum_{t=1}^{N}\sum_{i\in BAA_0}NR_{i,t}\,NRBP_{i,t}+\sum_{t=1}^{N}\sum_{j\in EIM}FRUSP_{j,t}\sum_{z\in Z_j}FRUS_{z,j,t}$$
$$+\sum_{t=1}^{N}\sum_{j\in EIM}FRDSP_{j,t}\sum_{z\in Z_j}FRDS_{z,j,t}$$

The unit commitment binary variables are fixed in RTD, thus the startup and minimum load costs are not included in the objective function. All online services are zero when the resource is offline, whereas Non-Spinning Reserve can be provided by offline Fast-Start Units ($SUT \leq 10$min) and FRU can be provided by offline 5min-start units ($SUT \leq 5$min),:

$$u_{i,t}=0\rightarrow\left\{\begin{matrix}EN_{i,t}=RU_{i,t}=RD_{i,t}=SR_{i,t}=FRD_{i,t}=0\\ NR_{i,t}=0,\forall i\notin S_{10}\\ FRU_{i,t}=0,\forall i\notin S_5\end{matrix}\right\},\forall i\wedge t=1,2,\ldots,N$$

System Resources (SRs), Intertie Transactions (TIDs), and Non-Generator Resources (NGRs) have no discontinuities or inter-temporal constraints, thus they are always online ($u = 1$). Ancillary services and FRU/FRD can only be awarded to resources certified to provide them. Any 5min dispatchable physical resource can be certified to provide FRU/FRD. Any resource certified for FRU/FRD with energy bids can be awarded FRU/FRD.

The FRU/FRD surplus (demand elasticity) price for each BAA in the EIM Area is derived as the expected cost of uncertainty, i.e., the product of the probability of uncertainty materializing and the energy bid ceiling/floor.

6.4.4 Power Balance Constraints

A power balance constraint is enforced for each BAA in the EIM Area, as follows:

$$\sum_{i\in BAA_j}EN_{i,t}-D_{j,t}=T_{j,t},\forall j\in EIM\wedge t=1,2,\ldots,N$$

The net transfer for each BAA is the mismatch of the respective power balance constraint. The demand forecast is distributed to the load nodes in each BAA using load distribution factors that are adopted from the State Estimator solution for the relevant season, type of day, and time of day. The distributed load, accounting for transmission losses, is adjusted by the distributed load slack in the

AC power flow (ACPF) solution while maintaining the Net Scheduled Interchange (NSI) for each BAA, but it is not a variable in the RTM, hence the linearized power balance constraints are as follows:

$$\sum_{i \in BAA_j} \frac{\Delta EN_{i,t}}{LPF_{i,t}} = \Delta T_{j,t}, \forall j \in EIM \wedge t = 1,2, \dots, N$$

The incremental energy injections are divided by the corresponding Loss Penalty Factors to account for changes in transmission losses from the previous ACPF solution. The Loss Penalty Factors are derived from the Jacobian (matrix of first partial derivatives) of the ACPF equations.

6.4.5 Transfers

The net transfer may be constrained by scheduling limits, e.g., when the BAA has failed the flexible ramping sufficiency test or when it is under contingency, as follows:

$$\underline{T}_{j,t} \le T_{j,t} \le \overline{T}_{j,t}, \forall j \in EIM \wedge t = 1,2, \dots, N$$

The net transfer is distributed optimally to the energy transfer schedules (ETSRs) defined on various interties between BAAs, as follows:

$$T_{j,t} = \sum_{\substack{k \in EIM \\ k \ne j}} \sum_{l} \left(ET_{j,k,l,t} - IT_{j,k,l,t} \right), \forall j \in EIM \wedge t = 1,2, \dots, N$$

For any given intertie, the power flow will be in one direction; hence, only the export or the import ETSR may have a positive schedule.

The energy transfer schedules are symmetric:

$$ET_{j,k,l,t} = IT_{k,j,l,t}, \forall j, k \in EIM \wedge j \ne k \wedge t = 1,2, \dots, N$$

Due to the symmetry, the sum of all net transfers nets to zero:

$$\sum_{j \in EIM} T_{j,t} = 0, t = 1,2, \dots, N$$

This is expected because the sum of all power balance constraints yields the system power balance for the entire EIM Area.

The distribution of the net transfer observes the applicable ETSR scheduling limits:

$$\left. \begin{array}{l} 0 \le ET_{j,k,l,t} \le \overline{ET}_{j,k,l,t} \\ 0 \le IT_{j,k,l,t} \le \overline{IT}_{j,k,l,t} \end{array} \right\}, \forall j, k \in EIM \wedge j \ne k \wedge \forall l \wedge t = 1,2, \dots, N$$

It is assumed that the ETSR scheduling limits are also symmetric:

$$\overline{ET}_{j,k,l,t} = \overline{IT}_{k,j,l,t}, \forall j, k \in EIM \wedge j \ne k \wedge \forall l \wedge t = 1,2, \dots, N$$

There are three different transfer types:

a) Base transfers are fixed in both FMM and RTD at their base schedules. Currently, there are no base transfers with the CISO; they are defined only between EIM BAAs.

b) Static transfers are variable in FMM, but fixed in RTD.

c) Dynamic transfers are variables in both FMM and RTD. However, at interties where static transfers are defined, dynamic transfers are scheduled only in RTD.

The net base transfer is derived as the net of all base transfers, as follows:

$$\tilde{T}_{j,t} = \sum_{\substack{k \in EIM \\ k \neq j}} \sum_{l} \left(\widetilde{ET}_{j,k,l,t} - \widetilde{IT}_{j,k,l,t} \right), \forall j \in EIM \wedge t = 1,2, \dots, N$$

Since, base transfers are not defined with the CISO:

$$\tilde{T}_{0,t} = 0, t = 1,2, \dots, N$$

Transfer constraints are also enforced under the FRU/FRD deployment scenarios as described in §6.4.11.3

6.4.6 Ancillary Services Procurement Constraints

With regional ancillary services procurement, the constraints are as follows:

$$\left.\begin{array}{r} \sum_{i \in S_r} RD_{i,t} \geq RDR_{r,t} \\ \sum_{i \in S_r} RU_{i,t} \geq RUR_{r,t} \\ \sum_{i \in S_r} RU_{i,t} + \sum_{i \in S_r} SR_{i,t} \geq RUR_{r,t} + SRR_{r,t} \\ \sum_{i \in S_r} RU_{i,t} + \sum_{i \in S_r} SR_{i,t} + \sum_{i \in S_r} NR_{i,t} \geq RUR_{r,t} + SRR_{r,t} + NRR_{r,t} \end{array}\right\}, \forall r \wedge t = 1,2, \dots, N$$

Ancillary services are procured in FMM and they are fixed in RTD. FRU/FRD awards are procured in FMM and then re-procured in RTD. Currently in the EIM, ancillary services are procured only in the CISO. Ancillary services base schedules can be submitted for resources in EIM BAAs, but they are not optimized. The ancillary services regions are nested under the CISO region and the regional requirements are the minimum requirements for the region. Cascaded procurement is employed where higher quality services can meet the requirements for lower quality services. FRU/FRD do not overlap or cascade with ancillary services because they are reserved capacity that can be dispatched or re-procured in real time irrespective of regulation or contingency response needs.

6.4.7 Upper/Lower Capacity Bounds

The ancillary services and FRU/FRD upper/lower bound constraints are as follows:

$$\left.\begin{array}{c} 0 \le RD_{i,t} \le RDBC_{i,t} \\ 0 \le RU_{i,t} \le RUBC_{i,t} \\ 0 \le SR_{i,t} \le SRBC_{i,t} \\ 0 \le NR_{i,t} \le NRBC_{i,t} \\ 0 \le FRU_{i,t} \\ 0 \le FRD_{i,t} \end{array}\right\}, \forall i \wedge t = 1,2,\dots,N$$

The ancillary services capacity bids are limited by the corresponding certified quantities. There are no capacity bids for FRU/FRD.

The ancillary services and FRU/FRD awards are further constrained by capacity and ramp capability constraints, described in §6.4.12 and §6.4.13 respectively.

6.4.8 Flexible Ramp Procurement Constraints

FRU/FRD is procured separately for each BAA that has failed the FRU/FRD sufficiency test:

$$\left.\begin{array}{l} \left.\begin{array}{c} \sum_{i \in BAA_j} FRU_{i,t} + \sum_{z \in Z_j} FRUS_{z,j,t} = FRUR_{j,t} \\ 0 \le FRUS_{z,j,t}, \forall z \in Z_j \end{array}\right\}, \forall j \in EIM - PU_t \\ \left.\begin{array}{c} \sum_{i \in BAA_j} FRD_{i,t} + \sum_{z \in Z_j} FRDS_{z,j,t} = FRDR_{j,t} \\ 0 \le FRDS_{z,j,t}, \forall z \in Z_j \end{array}\right\}, \forall j \in EIM - PD_t \end{array}\right\}, t = 1,2,\dots,N$$

Additionally, the net transfer for these BAAs is constrained from below/above by the net base transfer as follows:

$$\left.\begin{array}{c} T_{j,t} \ge \tilde{T}_{j,t}, \forall j \in EIM - PU_t \\ T_{j,t} \le \tilde{T}_{j,t}, \forall j \in EIM - PD_t \end{array}\right\}, t = 1,2,\dots,N$$

For the BAAs that have passed the FRU/FRD sufficiency test, FRU/FRD is procured for the entire group to maximize the benefits of BAA diversity and economic displacement by participating in the EIM:

$$\left.\begin{array}{l}\sum_{j\in PU_t}\sum_{i\in BAA_j} FRU_{i,t} + \sum_{j\in PU_t}\sum_{z\in Z_j} FRUS_{z,j,t} = FRUR_t \\ \left.\begin{array}{l} 0 \leq FRUS_{z,j,t}, \forall z \in Z_j \\ \sum_{z\in Z_j} FRUS_{z,j,t} \leq \widehat{FRUR}_{j,t} \end{array}\right\}, \forall j \in PU_t \\ \sum_{j\in PD_t}\sum_{i\in BAA_j} FRD_{i,t} + \sum_{j\in PD_t}\sum_{z\in Z_j} FRDS_{z,j,t} = FRDR_t \\ \left.\begin{array}{l} 0 \leq FRDS_{z,j,t}, \forall z \in BAA_j \\ \sum_{z\in Z_j} FRDS_{z,j,t} \leq \widehat{FRDR}_{j,t} \end{array}\right\}, \forall j \in PD_t \end{array}\right\}, t = 1,2,\dots,N$$

The FRU/FRD requirements are calculated as the extreme historical net demand forecast error within a specified confidence interval (95%), adjusted to reflect forecasted real-time conditions. The net demand forecast is the demand forecast reduced by the Variable Energy Resource (VER) forecast. The net demand forecast error in FMM is measured as the difference between the extreme net demand forecast among the underlying 5min binding intervals in RTD for the first advisory 15min FMM interval and the net demand forecast in that advisory FMM interval. The net demand forecast error in RTD is measured as the difference between the net demand forecast in the binding 5min interval in the next RTD run and the net demand forecast in the first advisory 5min interval in the current RTD run.

The FRU/FRD surplus variables effectively relax the FRU/FRD requirements independently at FRP Surplus Zones in each BAA in the EIM Area if the cost of procuring FRU/FRD is higher than the benefit it provides. For each BAA in the group of BAAs that have passed the FRU/FRD sufficiency test, the total FRU/FRD surplus over all FRP Surplus Zones in that BAA is limited by the distributed FRU/FRD requirement in that BAA to prevent FRU/FRD demand elasticity from relaxing FRU/FRD requirements in other BAAs in the group. These limits are derived in §6.4.11.2.

6.4.9 Transmission Constraints

In this technical paper, only base-case transmission constraints are considered for simplicity. Transmission constraints are enforced for active power flows on transmission elements as follows:

$$LFL_{m,t} \leq F_{m,t} \leq UFL_{m,t}, \forall m \wedge \ t = 1,2,\dots,N$$

These constraints are two-sided algebraic thermal limits (the lower limit is negative) on either single transmission lines and transformers, or a group of transmission lines (branch groups, flowgates, or transmission corridors). In the latter case, the limit may be a simultaneous power transfer capability limit.

These constraints are nonlinear, but they are linearized at an ACPF solution as follows:

$$\widetilde{LFL}_{m,t} \leq \tilde{F}_{m,t} + \sum_{i} \Delta EN_{i,t}\, SF_{i,m,t} \leq \widetilde{UFL}_{m,t}, \forall m \wedge t = 1,2,\ldots,N$$

The incremental energy injection changes from the previous iteration are multiplied by the corresponding shift factor for the relevant transmission constraint to account for changes in the active power flow from the ACPF solution. The transmission constraint upper/lower active power flow limits are adjusted in each iteration to convert the respective MVA limits to MW limits accounting for reactive power flows at the previous ACPF solution. Linear lossless shift factors are used in this linearization; they are derived from the imaginary part of the nodal admittance matrix of the transmission network; therefore, they solely depend on the transmission network configuration. The linear lossless shift factors are calculated with reference the distributed load in the EIM Area.

Transmission constraints are also enforced under the FRU/FRD deployment scenarios as described in §6.4.11.4

6.4.10 Scheduling Limits

Besides the scheduling limits on net transfers and ETSRs, described in §6.4.5, Intertie Transmission Corridor (ITC) or Intertie Scheduling Limit (ISL) constraints limit energy schedules and ancillary services awards from intertie or pseudo-tied resources at a single intertie or a group of interties. ITC/ISL constraints may also limit ETSRs at the corresponding intertie(s). The ITC/ISL constraint formulation allows netting of import and export energy schedules, but it prevents netting between energy schedules and ancillary services awards because they are not simultaneously dispatched. Their generic formulation is as follows:

$$\left.\begin{array}{l} \max\left(0, \sum_{i \in S_m} EN_{i,t}\right) + \sum_{i \in I_m}\left(RU_{i,t} + SR_{i,t} + NR_{i,t}\right) + \sum_{i \in S_m} FRU_{i,t} \leq UFL_{m,t} \\ LFL_{m,t} \leq \min\left(0, \sum_{i \in S_m} EN_{i,t}\right) - \sum_{i \in I_m} RD_{i,t} - \sum_{i \in S_m} FRD_{i,t} \end{array}\right\}, \forall m \wedge t = 1,\ldots,N$$

The ITC/ISL constraints are linearized as follows:

$$\left.\begin{array}{l}\sum_{i\in S_m} EN_{i,t} + \sum_{i\in I_m}\left(RU_{i,t} + SR_{i,t} + NR_{i,t}\right) + \sum_{i\in S_m} FRU_{i,t} \le UFL_{m,t} \\ \sum_{i\in I_m}\left(RU_{i,t} + SR_{i,t} + NR_{i,t}\right) + \sum_{i\in S_m} FRU_{i,t} \le UFL_{m,t} \\ LFL_{m,t} \le \sum_{i\in S_m} EN_{i,t} - \sum_{i\in I_m} RD_{i,t} - \sum_{i\in S_m} FRD_{i,t} \\ LFL_{m,t} \le -\sum_{i\in I_m} RD_{i,t} - \sum_{i\in S_m} FRD_{i,t}\end{array}\right\}, \forall m \wedge t = 1, \dots, N$$

In the case of ITC constraints, the set S_m includes all intertie resources bound by the ITC m, and in the case of ISL constraints, the set S_m includes all intertie resources associated with (tagged at) the corresponding intertie of the ISL m. For ITC/ISL constraints, the upper limit is an import limit, whereas the lower limit is an algebraic export limit. By convention, the import direction in ITC constraints is to the associated BAA, and the import direction in ISL constraints is to the "from" BAA definition of the associated intertie.

Intertie bids are only allowed at CISO interties. Ancillary services can only be provided by certified import resources at CISO interties. Intertie resources may not be certified for FRU/FRD awards because they cannot be dispatched in RTD with the exception of Dynamic Schedules (TGs and TNGRs) and pseudo-tied resources at CISO interties. For an export or a demand response resource, FRU dispatch is a decrease in the energy schedule, whereas FRD dispatch is an increase in the energy schedule.

Since FRU/FRD awards are reserved from intertie transmission capacity via ITC/ISL constraints, there is no reason to enforce these constraints in the FRU/FRD deployment scenarios when these FRU/FRD awards are deployed.

6.4.11 Flexible Ramp Deployment Scenarios

6.4.11.1 Flexible Ramp Requirement Distribution

In the FRU/FRD deployment scenarios, the FRU/FRD awards are fully deployed while the net demand forecast is increased/decreased by the FRU/FRD requirements. The distribution of the FRU/FRD requirements in the ACPF solution is divided among load, solar, and wind resources using allocation factors derived from historical data that reflect the relative contributions of these resource classes to the net demand forecast uncertainty.

The FRU requirement component for load is distributed in the FRU deployment scenario as a positive demand change, whereas the FRD requirement component for load is distributed in the FRD deployment scenario as a negative demand change. The distribution of this requirement component is to the load nodes in the respective BAA or BAA group with the same Load Distribution Factors that are used to distribute the demand forecast:

$$\left.\begin{array}{l}\Delta L_{i,t}^{(u)} = LDF_{i,j,t}\, FRUDF_{j,t}\, FRUR_{j,t}, \forall i \in BAA_j, \forall j \in EIM - PU_t \\ \Delta L_{i,t}^{(d)} = -LDF_{i,j,t}\, FRDDF_{j,t}\, FRDR_{j,t}, \forall i \in BAA_j, \forall j \in EIM - PU_t \\ \Delta L_{i,t}^{(u)} = LDF_{i,j,t}^{(u)}\, FRUDF_t\, FRUR_t, \forall i \in BAA_j, \forall j \in PU_t \\ \Delta L_{i,t}^{(d)} = -LDF_{i,j,t}^{(d)}\, FRDDF_t\, FRDR_t, \forall i \in BAA_j, \forall j \in PD_t\end{array}\right\}, t = 1,2, \ldots, N$$

The Load Distribution Factors for the load nodes in the group of BAAs that have passed the FRU/FRD sufficiency test must be renormalized for the BAA group, as follows:

$$\left.\begin{array}{l}LDF_{i,j,t}^{(u)} = LDF_{i,j,t}\, \dfrac{D_{j,t}}{\sum_{j \in PU_t} D_{j,t}}, \forall i \in BAA_j, \forall j \in PU_t \\ LDF_{i,j,t}^{(d)} = LDF_{i,j,t}\, \dfrac{D_{j,t}}{\sum_{j \in PD_t} D_{j,t}}, \forall i \in BAA_j, \forall j \in PD_t\end{array}\right\}, t = 1,2, \ldots, N$$

The FRU requirement components for solar and wind are distributed in the FRU deployment scenario as a positive demand change, whereas the FRD requirement components for solar and wind are distributed in the FRD deployment scenario as a negative demand change. The distributions of these requirement components are to the solar and wind VERs in the respective BAA or BAA group in proportion to the respective VER forecast:

$$\left.\begin{array}{l}\Delta L_{i,t}^{(u)} = SDF_{i,j,t}\, FRUSF_{j,t}\, FRUR_{j,t}, \forall i \in S_{SVER} \cap BAA_j, \forall j \in EIM - PU_t \\ \Delta L_{i,t}^{(u)} = WDF_{i,j,t}\, FRUWF_{j,t}\, FRUR_{j,t}, \forall i \in S_{WVER} \cap BAA_j, \forall j \in EIM - PU_t \\ \Delta L_{i,t}^{(d)} = -SDF_{i,j,t}\, FRDSF_{j,t}\, FRDR_{j,t}, \forall i \in S_{SVER} \cap BAA_j, \forall j \in EIM - PD_t \\ \Delta L_{i,t}^{(d)} = -WDF_{i,j,t}\, FRDWF_{j,t}\, FRDR_{j,t}, \forall i \in S_{WVER} \cap BAA_j, \forall j \in EIM - PD_t \\ \Delta L_{i,t}^{(u)} = SDF_{i,j,t}^{(u)}\, FRUSF_t\, FRUR_t, \forall i \in S_{SVER} \cap BAA_j, \forall j \in PU_t \\ \Delta L_{i,t}^{(u)} = WDF_{i,j,t}^{(u)}\, FRUWF_t\, FRUR_t, \forall i \in S_{WVER} \cap BAA_j, \forall j \in PU_t \\ \Delta L_{i,t}^{(d)} = -SDF_{i,j,t}^{(d)}\, FRDSF_t\, FRDR_t, \forall i \in S_{SVER} \cap BAA_j, \forall j \in PD_t \\ \Delta L_{i,t}^{(d)} = -WDF_{i,j,t}^{(d)}\, FRDWF_t\, FRDR_t, \forall i \in S_{WVER} \cap BAA_j, \forall j \in PD_t\end{array}\right\}, t = 1,2, \ldots, N$$

Where the Solar/Wind Distribution Factors are derived as follows:

$$\left.\begin{array}{l}
SDF_{i,j,t} = \frac{FS_{i,j,t}}{\sum_{i \in BAA_j} FS_{i,j,t}}, \forall i \in S_{SVER} \cap BAA_j, \forall j \in EIM - PU_t \cup EIM - PD_t \\
WDF_{i,j,t} = \frac{FW_{i,j,t}}{\sum_{i \in BAA_j} FW_{i,j,t}}, \forall i \in S_{WVER} \cap BAA_j, \forall j \in EIM - PU_t \cup EIM - PD_t \\
SDF_{i,j,t}^{(u)} = \frac{FS_{i,j,t}}{\sum_{j \in PU_t} \sum_{i \in BAA_j} FS_{i,j,t}}, \forall i \in S_{SVER} \cap BAA_j, \forall j \in PU_t \\
WDF_{i,j,t}^{(u)} = \frac{FW_{i,j,t}}{\sum_{j \in PU_t} \sum_{i \in BAA_j} FW_{i,j,t}}, \forall i \in S_{WVER} \cap BAA_j, \forall j \in PU_t \\
SDF_{i,j,t}^{(d)} = \frac{FS_{i,j,t}}{\sum_{j \in PD_t} \sum_{i \in BAA_j} FS_{i,j,t}}, \forall i \in S_{SVER} \cap BAA_j, \forall j \in PD_t \\
WDF_{i,j,t}^{(d)} = \frac{FW_{i,j,t}}{\sum_{j \in PD_t} \sum_{i \in BAA_j} FW_{i,j,t}}, \forall i \in S_{WVER} \cap BAA_j, \forall j \in PD_t
\end{array}\right\},$$

$$t = 1,2, \dots, N$$

6.4.11.2 Flexible Ramp Surplus Distribution

The FRU/FRD surplus in each FRP Surplus Zone in each BAA in the EIM Area is distributed in the ACPF solution with the same distribution factors that are used to distribute the FRU/FRD requirement, but renormalized for that FRP Surplus Zone:

$$\left.\begin{array}{l}
FRUS_{i,z,j,t} = \frac{\Delta L_{i,t}^{(u)}}{\sum_{i \in S_z} \Delta L_{i,t}^{(u)}} FRUS_{z,j,t}, \forall i \in S_z, \forall z \in Z_j, \forall j \in EIM - PU_t \\
FRDS_{i,z,j,t} = \frac{\Delta L_{i,t}^{(d)}}{\sum_{i \in S_z} \Delta L_{i,t}^{(d)}} FRDS_{z,j,t}, \forall i \in S_z, \forall z \in Z_j, \forall j \in EIM - PU_t \\
FRUS_{i,z,j,t} = \frac{\Delta L_{i,t}^{(u)}}{\sum_{i \in S_z} \Delta L_{i,t}^{(u)}} FRUS_{z,j,t}, \forall i \in S_z, \forall z \in Z_j, \forall j \in PU_t \\
FRDS_{i,z,j,t} = \frac{\Delta L_{i,t}^{(d)}}{\sum_{i \in S_z} \Delta L_{i,t}^{(d)}} FRDS_{z,j,t}, \forall i \in S_z, \forall z \in Z_j, \forall j \in PD_t
\end{array}\right\}, t = 1,2, \dots, N$$

The total FRU/FRD surplus over all FRP Surplus Zones in each BAA in the group of BAAs that have passed the FRU/FRD sufficiency test is limited by the distributed FRU/FRD requirement in that BAA to prevent FRU/FRD demand elasticity from relaxing FRU/FRD requirements in other BAAs in the group. These upper bounds on the FRU/FRD surplus variables are derived as follows:

$$\left.\begin{array}{l}\sum_{z\in Z_j} FRUS_{z,j,t} \le \widehat{FRUR}_{j,t} \equiv \sum_{z\in Z_j}\sum_{i\in S_z} \Delta L_{i,t}^{(u)}, \forall j \in PU_t \\ \sum_{z\in Z_j} FRDS_{z,j,t} \le \widehat{FRDR}_{j,t} \equiv -\sum_{z\in Z_j}\sum_{i\in S_z} \Delta L_{i,t}^{(d)}, \forall j \in PD_t\end{array}\right\}, t = 1,2,\ldots,N$$

6.4.11.3 Transfer Constraints

The transfers are optimally calculated in the FRU/FRD deployment scenarios and they may be different from the transfers in the base scenario of serving the demand forecast. For the BAAs that have failed the FRU/FRD sufficiency test, the net transfer in the FRU/FRD deployment scenarios is kept fixed to the net transfer in the base scenario of serving the demand forecast, but the ETSRs on individual interties may vary to allow loop flow:

$$\left.\begin{array}{l}T_{j,t}^{(u)} = T_{j,t} = \sum_{\substack{k\in EIM\\k\neq j}}\sum_{l}\left(ET_{j,k,l,t}^{(u)} - IT_{j,k,l,t}^{(u)}\right), \forall j \in EIM - PU_t \\ T_{j,t}^{(d)} = T_{j,t} = \sum_{\substack{k\in EIM\\k\neq j}}\sum_{l}\left(ET_{j,k,l,t}^{(d)} - IT_{j,k,l,t}^{(d)}\right), \forall j \in EIM - PD_t\end{array}\right\}, t = 1,2,\ldots,N$$

For each BAA in the group of BAAs that have passed the FRU/FRD sufficiency test, the net transfer is optimally calculated in the FRU/FRD deployment scenarios and distributed to ETSRs as follows:

$$\left.\begin{array}{l}\left.\begin{array}{l}T_{j,t}^{(u)} = T_{j,t} + \sum_{i\in BAA_j} FRU_{i,t} + \sum_{z\in Z_j} FRUS_{z,j,t} - \widehat{FRUR}_{j,t} \\ T_{j,t}^{(u)} = \sum_{\substack{k\in EIM\\k\neq j}}\sum_{l}\left(ET_{j,k,l,t}^{(u)} - IT_{j,k,l,t}^{(u)}\right)\end{array}\right\}, \forall j \in PU_t \\ \left.\begin{array}{l}T_{j,t}^{(d)} = T_{j,t} - \sum_{j\in BAA_j} FRD_{j,t} - \sum_{z\in Z_j} FRDS_{r,j,t} + \widehat{FRDR}_{j,t} \\ T_{j,t}^{(d)} = \sum_{\substack{k\in EIM\\k\neq j}}\sum_{l}\left(ET_{j,k,l,t}^{(d)} - IT_{j,k,l,t}^{(d)}\right)\end{array}\right\}, \forall j \in PD_t\end{array}\right\}, t = 1,2,\ldots,N$$

The ETSRs in the FRU/FRD deployment scenarios are constrained by the same transfer limits that apply in the base scenario of serving the demand forecast:

$$\left.\begin{array}{l} 0 \le ET_{j,k,l,t}^{(u)} \le \overline{ET}_{j,k,l,t} \\ 0 \le IT_{j,k,l,t}^{(u)} \le \overline{IT}_{j,k,l,t} \\ 0 \le ET_{j,k,l,t}^{(d)} \le \overline{ET}_{j,k,l,t} \\ 0 \le IT_{j,k,l,t}^{(d)} \le \overline{IT}_{j,k,l,t} \end{array}\right\}, \forall j,k \in EIM \wedge j \ne k \wedge \forall l \wedge t = 1,2,\dots,N$$

6.4.11.4 Transmission Constraints

The linearized transmission constraints enforced in the FRU/FRD deployment scenarios are as follows:

$$\left.\begin{array}{l} \widetilde{LFL}_{m,t}^{(u)} \le \tilde{F}_{m,t}^{(u)} + \sum_i \left(\Delta EN_{i,t} + \Delta FRU_{i,t}\right) SF_{i,m,t} + \sum_{j \in EIM} \sum_{z \in Z_j} \Delta FRUS_{z,j,t}\, SF_{z,j,m,t}^{(u)} \le \widetilde{UFL}_{m,t}^{(u)} \\ \widetilde{LFL}_{m,t}^{(d)} \le \tilde{F}_{m,t}^{(d)} + \sum_i \left(\Delta EN_{i,t} - \Delta FRD_{i,t}\right) SF_{i,m,t} - \sum_{j \in EIM} \sum_{z \in Z_j} \Delta FRDS_{z,j,t}\, SF_{z,j,m,t}^{(d)} \le \widetilde{UFL}_{m,t}^{(d)} \end{array}\right\},$$
$$\forall m \wedge t = 1,2,\dots,N$$

Two additional AC power flows per interval are needed, one for each of the FRU/FRD deployment scenarios. The incremental energy, FRU/FRD, and FRUS/FRDS injection changes from the previous iteration are multiplied by the corresponding shift factors for the relevant transmission constraint to account for changes in the active power flow from the ACPF solution. The transmission constraint upper/lower active power flow limits are adjusted in each iteration to convert the respective MVA limits to MW limits accounting for reactive power flows at the previous ACPF solution. The effect of transmission losses due to the deployment of FRU/FRD awards and the distribution of the FRU/FRD requirements and surplus variables are included in the ACPF solution. The shift factors in the FRU/FRD deployment scenarios are the same as the ones in the base scenario of serving the demand forecast because the transmission network is the same. The aggregate shift factors for the FRU/FRD surplus at each FRP Surplus Zone are derived as follows:

$$\left.\begin{array}{l} SF_{z,j,m,t}^{(u)} = \dfrac{\sum_{i \in S_z} \Delta L_{i,t}^{(u)}\, SF_{i,m,t}}{\sum_{i \in S_z} \Delta L_{i,t}^{(u)}} \\ SF_{z,j,m,t}^{(d)} = \dfrac{\sum_{i \in S_z} \Delta L_{i,t}^{(d)}\, SF_{i,m,t}}{\sum_{i \in S_z} \Delta L_{i,t}^{(d)}} \end{array}\right\}, \forall z \in Z_j, \forall j \in EIM, t = 1,2,\dots,N$$

6.4.12 Capacity Constraints

This section describes the resource capacity constraints. In the RTM, an energy bid is required for energy schedules, Spinning and Non-Spinning Reserve awards, and FRU/FRD awards, but not for Regulation awards. Therefore, energy schedules, Spinning and Non-Spinning Reserve awards, and

FRU/FRD awards are limited by the LEL/UEL, whereas Regulation awards are limited by the CL and the LRL/URL. To formulate the resource capacity constraints generally for all cases, it is convenient to define upper and lower capacity limits as follows:

$$\left.\begin{array}{l} RU_{i,t} + RD_{i,t} > 0 \Longrightarrow \begin{cases} UCL_{i,t} = \min\left(UOL_{i,t}, URL_{i,t}, CL_{i,t}\right) \\ LCL_{i,t} = \max\left(LOL_{i,t}, LRL_{i,t}\right) \end{cases} \\ RU_{i,t} + RD_{i,t} = 0 \Longrightarrow \begin{cases} UCL_{i,t} = UOL_{i,t} \\ LCL_{i,t} = LOL_{i,t} \end{cases} \end{array}\right\}, \forall i \wedge t = 1,2,\dots,N$$

$$\left.\begin{array}{l} UEL'_{i,t} = \min\left(UCL_{i,t}, UEL_{i,t}\right) \\ LEL'_{i,t} = \max\left(LCL_{i,t}, LEL_{i,t}\right) \end{array}\right\}, \forall i \wedge t = 1,2,\dots,N$$

Then, the capacity constraints for online resources are as follows:

$$\left.\begin{array}{l} EN_{i,t} \le UCL_{i,t} - RU_{i,t} - SR_{i,t} - NR_{i,t} - FRU_{i,t} \\ LCL_{i,t} + RD_{i,t} + FRD_{i,t} \le EN_{i,t} \\ LEL'_{i,t} + FRD_{i,t} \le EN_{i,t} \le UEL'_{i,t} - SR_{i,t} - NR_{i,t} - FRU_{i,t} \end{array}\right\}, \forall i \wedge u_{i,t} = 1 \wedge t = 1,2,\dots,N$$

Similarly, the capacity constraints for offline resources are as follows:

$$NR_{i,t} \le UEL'_{i,t}, \forall i \in S_{10} \wedge u_{i,t} = 0 \wedge t = 1,2,\dots,N$$

$$NR_{i,t} + FRU_{i,t} \le UEL'_{i,t}, \forall i \in S_5 \wedge u_{i,t} = 0 \wedge t = 1,2,\dots,N$$

6.4.13 Ramp Capability Constraints

This section describes the resource ramp capability constraints. In FMM, the ancillary services awards are simultaneously constrained by the 10min ramp capability from the energy schedules, as follows:

$$\left.\begin{array}{l} RU_{i,t} + SR_{i,t} + NR_{i,t} \le RRU_i\left(EN_{i,t}, T_{10}\right) \\ RD_{i,t} \le RRD_i\left(EN_{i,t}, T_{10}\right) \end{array}\right\}, \forall i \wedge u_{i,t} = 1 \wedge t = 1,2,\dots,N$$

Ancillary services can be dispatched at any time during the ramp between hourly schedules; hence, the performance hit for using the dynamic ramp capability from the energy schedules in the above constraints is not justified. A static approach can be used instead, formulating the constraints conservatively with the lowest ramp capability within the applicable operating range of the resource, calculated as follows:

$$\left.\begin{array}{l} \underline{RRU}_{i,t}(T_{10}) \cong \min\left(RRU(p_i, T_{10})\Big|_{p_i=LCL_{i,t}}^{p_i=UCL_{i,t}-RRD\left(UCL_{i,t}, T_{10}\right)}\right) \\ \underline{RRD}_{i,t}(T_{10}) \cong \min\left(RRD(p_i, T_{10})\Big|_{p_i=LCL_{i,t}+RRU\left(LCL_{i,t}, T_{10}\right)}^{p_i=UCL_{i,t}}\right) \end{array}\right\}, \forall i \wedge u_{i,t} = 1 \wedge t = 1,2,\dots,N$$

The ramp capability constraints for offline Non-Spinning Reserve in FMM are as follows:

$$NR_{i,t} \leq LOL_{i,t} + RRU_i(LOL_{i,t}, T_{10} - SUT_{i,t}), \forall i \in S_{10} \wedge u_{i,t} = 0 \wedge t = 1,2, \dots, N$$

Where the ramp up from LOL starts after the SUT has elapsed.

Similarly, the ramp capability constraints for offline FRU in FMM are as follows:

$$NR_{i,t}/2 + FRU_{i,t} \leq LOL_{i,t} + RRU_i(LOL_{i,t}, T_5 - SUT_{i,t}), \forall i \in S_5 \wedge u_{i,t} = 0 \wedge t = 1,2, \dots, N$$

Where the ramp up from LOL starts after the SUT has elapsed.

Ancillary services awards are not re-procured in RTD; hence, these ramp capability constraints for ancillary services awards are not enforced in RTD. However, the energy schedules, the ancillary services awards, and the FRU/FRD awards are simultaneously constrained by dynamic ramp capability constraints in both FMM and RTD. For resources that remain online across time intervals, these constraints are as follows:

$$\left.\begin{array}{l} EN_{i,t} - EN_{i,t-1} \leq RRU_i(EN_{i,t-1}, \Delta T) - ASF\ (\alpha\ RU_{i,t} + \beta\ SR_{i,t} + \gamma\ NR_{i,t}) - GAF\ \delta\ FRU_{i,t} \\ EN_{i,t} - EN_{i,t-1} \geq -RRD_i(EN_{i,t-1}, \Delta T) + ASF\ \alpha\ RD_{i,t}\ ASF + GAF\ \delta\ FRD_{i,t} \end{array}\right\},$$
$$\forall i \wedge u_{i,t-1} = u_{i,t} = 1 \wedge t = 1,2, \dots, N$$

The ancillary services adjustment factor (ASF) allocates the 10min ancillary services awards to the duration of the interval; it is 1 in FMM and ½ in RTD. The granularity adjustment factor (GAF) converts the 5min FRU/FRD awards to the market time domain; it is 3 in FMM and 1 in RTD.

For resources that start up at the beginning of an interval, the ramp capability constraints are as follows:

$$EN_{i,t} \leq LOL_{i,t} + RRU_i(LOL_{i,t}, \Delta T/2) - ASF\ (\alpha\ RU_{i,t} + \beta\ SR_{i,t} + \gamma\ NR_{i,t}) - GAF\ \delta\ FRU_{i,t}\},$$
$$\forall i \wedge u_{i,t-1} = 0 \wedge u_{i,t} = 1 \wedge t = 1,2, \dots, N$$

Where the ramp up from LOL is for half of the interval ramp.

For resources that shut down at the end of an interval, the ramp capability constraints are as follows:

$$EN_{i,t} \leq LOL_{i,t} + RRU_i(LOL_{i,t}, \Delta T/2) - ASF\ \alpha\ RD_{i,t} - GAF\ \delta\ FRD_{i,t}\},$$
$$\forall i \wedge u_{i,t} = 1 \wedge u_{i,t+1} = 0 \wedge t = 1,2, \dots, N-1$$

Where the ramp down to LOL is for half of the interval ramp. No resources are shut down at the end of the time horizon.

The shared ramping coefficients (α, β, γ, and δ) specify how the various commodities share the resource ramp capability. The ramp capability constraint reserves ramp capability for the ancillary services and FRU/FRD awards over the ramp between the interval midpoints or the half ramp after startup or before shutdown. A coefficient of one reserves all the ramp capability that is required for a service that is continuously dispatched concurrently with energy, such as Regulation and FRU/FRD, whereas smaller coefficients may be used to reserve ramp capability for contingency reserves.

6.4.14 Energy Limit Constraints

Energy limit constraints apply to resources that have energy limitations. There are two kinds of energy limit constraints in the RTM:

a) Daily energy limits as they apply in real time; and

b) State of Charge (SOC) limits.

Daily energy limits restrict the hourly energy schedules so that the total energy production over the Trading Day is limited by a maximum daily energy limit. These constraints are typically enforced in the DAM for resources with a limited fuel supply, such as hydro resources with water reservoirs and water management limitations. If these limits are enforced in the DAM, they are also enforced in RTM with an allocation of the allowed daily energy over the RTM time horizon as follows:

$$\sum_{t=1}^{N} EN_{i,t} \leq \overline{EN}_i$$

For Pumped-Storage Hydro (PSH) Resources that can operate in either generating mode (positive energy schedule) or pumping mode (negative energy schedule), the daily energy limit constraints are two-sided; they limit the total algebraic energy production over the Trading Day between a negative minimum and a positive maximum daily energy limit. If these limits are enforced in the DAM, they are also enforced in RTM with an allocation of the allowed daily energy over the RTM time horizon as follows:

$$\underline{EN}_i \leq \sum_{t=1}^{N} \left(u_{i,t} + v_{i,t}\,\eta_i\right) EN_{i,t} \leq \overline{EN}_i$$

Where the pumping energy is multiplied by the pumping efficiency and the operating modes are mutually exclusive:

$$\left.\begin{array}{l} u_{i,t} = 1 \rightarrow EN_{i,t} \geq 0 \\ v_{i,t} = 1 \rightarrow EN_{i,t} = -PL_{i,t} \\ u_{i,t} = v_{i,t} = 0 \rightarrow EN_{i,t} = 0 \\ u_{i,t} + v_{i,t} \leq 1 \end{array}\right\} , \forall i \in S_{PSH} \wedge t = 1,2,\ldots,N$$

The SOC limits constrain the energy schedules, ancillary services awards, and FRU/FRD awards for Limited Energy Storage Resources (LESR), a specific type of a Non-Generator Resource (NGR) that can operate in either discharging mode (positive energy schedule) or charging mode (negative energy schedule). The SOC for a LESR is calculated as follows:

$$\left.\begin{array}{l} SOC_{i,t} = SOC_{i,t-1} - \left(EN_{i,t}^{(+)} + \eta_i \, EN_{i,t}^{(-)}\right) \dfrac{\Delta T}{T} \\ 0 \leq EN_{i,t}^{(+)} \leq u_{i,t} \, UEL'_{i,t} \\ \left(1 - u_{i,t}\right) LEL'_{i,t} \leq EN_{i,t}^{(-)} \leq 0 \\ EN_{i,t} = EN_{i,t}^{(+)} + EN_{i,t}^{(-)} \end{array}\right\}, \forall i \in S_{LESR} \wedge t = 1,2, \dots, N$$

Where the charging energy is multiplied by the charging efficiency. Then, the SOC limit constraints in FMM and RTD are as follows:

$$\left.\begin{array}{l} \text{FMM:}\left\{\begin{array}{l} \underline{SOC}_{i,t} + RU_{i,t} \dfrac{T_{15}}{T} + \left(SR_{i,t} + NR_{i,t}\right) \dfrac{T_{30}}{T} + FRU_{i,t} \dfrac{T_{15}}{T} \leq SOC_{i,t} \\ SOC_{i,t} \leq \overline{SOC}_{i,t} - \eta_i \left(RD_{i,t} \dfrac{T_{15}}{T} + FRD_{i,t} \dfrac{T_{15}}{T}\right) \end{array}\right\} \\ \text{RTD:}\left\{\begin{array}{l} \underline{SOC}_{i,t} + RU_{i,t} \dfrac{T_{15}}{T} + \left(SR_{i,t} + NR_{i,t}\right) \dfrac{T_{30}}{T} + FRU_{i,t} \dfrac{T_{5}}{T} \leq SOC_{i,t} \\ SOC_{i,t} \leq \overline{SOC}_{i,t} - \eta_i \left(RD_{i,t} \dfrac{T_{15}}{T} + FRD_{i,t} \dfrac{T_{5}}{T}\right) \end{array}\right\} \end{array}\right\},$$

$$\forall i \in S_{LESR} \wedge t = 1,2, \dots, N$$

A sustained 15min energy requirement is used for the Regulation Down awards in FMM and RTD. For the FRU/FRD awards, a sustained 15min energy requirement is used in FMM and a sustained 5min energy requirement is used in RTD. A sustained 30min energy requirement is used in both FMM and RTD for contingency reserves, and for regulation up that can substitute for contingency reserves through the cascaded ancillary services procurement, discussed in §6.4.6.

6.4.15 Price Formation

This section presents the price formation for Energy schedules and FRU/FRD awards in the RTM. The marginal prices for these commodities for each interval in the time horizon are derived from the shadow prices of the power balance and FRU/FRD procurement constraints:

$$
\left.\begin{array}{ll}
\sum_{i\in BAA_j}\frac{\Delta EN_{i,t}}{LPF_{i,t}}-\Delta T_{j,t}=0,\forall j\in EIM & \lambda_{j,t}\\
\sum_{i\in BAA_j}FRU_{i,t}+\sum_{z\in Z_j}FRUS_{z,j,t}=FRUR_{j,t},\forall j\in EIM-PU_t & \rho_{j,t}\\
\sum_{i\in BAA_j}FRU_{i,t}+\sum_{z\in Z_j}FRUS_{z,j,t}+T_{j,t}-T_{j,t}^{(u)}=\widehat{FRUR}_{j,t},\forall j\in PU_t & \lambda_{j,t}^{(u)}\\
\sum_{j\in PU_t}\sum_{i\in BAA_j}FRU_{i,t}+\sum_{j\in PU_t}\sum_{z\in Z_j}FRUS_{z,j,t}=FRUR_t & \rho_t\\
\sum_{i\in BAA_j}FRD_{i,t}+\sum_{z\in Z_j}FRDS_{z,j,t}=FRDR_{j,t},\forall j\in EIM-PD_t & \sigma_{j,t}\\
\sum_{j\in BAA_j}FRD_{j,t}+\sum_{z\in Z_j}FRDS_{r,j,t}-T_{j,t}+T_{j,t}^{(d)}=\widehat{FRDR}_{j,t},\forall j\in PD_t & \lambda_{j,t}^{(d)}\\
\sum_{j\in PD_t}\sum_{i\in BAA_j}FRD_{i,t}+\sum_{j\in PD_t}\sum_{z\in Z_j}FRDS_{z,j,t}=FRDR_t & \sigma_t
\end{array}\right\},
$$

$$t=1,2,\ldots,N$$

There are additional price contributions from binding transmission and scheduling constraints in the base scenario and the FRU/FRD deployment scenarios, described in §6.4.9, §6.4.10, and §6.4.11.4.. Including these contributions, the marginal prices of the Energy schedules and FRU/FRD awards in the RTM are calculated as follows:

$$
\left.\begin{array}{l}
LMP_{i,t}=\frac{\lambda_{j,t}}{LPF_{i,t}}-\sum_m SF_{i,m,t}\left(\mu_{m,t}+\mu_{m,t}^{(u)}+\mu_{m,t}^{(d)}\right),\forall i\in BAA_j\wedge j\in EIM\\
FRUMP_{i,t}=\rho_{j,t}-\sum_m SF_{i,m,t}\,\mu_{m,t}^{(u)},\forall i\in BAA_j\wedge j\in EIM-PU_t\\
FRUMP_{i,t}=\lambda_{j,t}^{(u)}+\rho_t-\sum_m SF_{i,m,t}\,\mu_{m,t}^{(u)},\forall i\in BAA_j\wedge j\in PU_t\\
FRDMP_{i,t}=\sigma_{j,t}+\sum_m SF_{i,m,t}\,\mu_{m,t}^{(d)},\forall i\in BAA_j\wedge j\in EIM-PD_t\\
FRDMP_{i,t}=\lambda_{j,t}^{(d)}+\sigma_t+\sum_m SF_{i,m,t}\,\mu_{m,t}^{(d)},\forall i\in BAA_j\wedge j\in PD_t
\end{array}\right\},
$$

$$t=1,2,\ldots,N$$

The sign convention for the binding network constraint shadow prices above is based on the assumption that the constraints are formulated as "≤" constraints. The settlement of Energy schedules and FRU/FRD awards, as well as the Forecasted Movement, is based on these marginal prices. The FRU/FRD cost allocation remains the same as the current tiered approach; however, for the group of BAAs that have passed the FRU/FRD sufficiency test, the cost allocation applies to the entire group, whereas for BAAs that have failed the test, the cost allocation applies to each BAA individually.