Midwest Market Initiative

Manual No. 002

Business Practices Manual for Energy Markets

Version 4

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Revision History

Version	Date	Description
0a	04-06-2004	Initial Draft
1	07-15-2004	Revised based on Market Practices Task Force (MPTF) comments and other Midwest ISO revisions
2	12-30-2004	Revised based on MPTF comments and other Midwest ISO revisions
3	01-13-2005	Revisions were made in the following sections: ▪ Section 2.2 Day-Ahead & Real-Time Energy Markets ▪ Section 3 Reliability Assessment Commitment Activities ▪ Section 3.3 Committing Long Start-Up Resources ▪ Section 4.1.3 Responding to Sub-Region Shortage Conditions ▪ Section 4.1.5 Responding to Sub-Region Surplus Conditions ▪ Section 5.4.1 Responding to System Shortage Conditions ▪ Section 5.5 Emergency Energy Purchases Minor revisions were also incorporated in other sections
4	03-15-2005	Revisions were made to reflect the: ▪ Change in the Day-Ahead Energy Market closing/posting times to 1100/1700 hours EST ▪ Change in the re-bid period for the Day-Ahead RAC to 1700-1800 hours EST ▪ Change in RAC instructions sent time to 2000 hours EST

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1. Introduction

This introduction to Midwest ISO *Business Practices Manual (BPM) for Energy Markets* includes basic information about this BPM and the other Midwest ISO BPMs. The first section (Section 1.1) of this Introduction identifies the other BPMs that are available. The second section (Section 1.2) is an introduction to this BPM. The third section (Section 1.3) identifies other documents in addition to the BPMs, which can be used by the reader as references when reading this BPM.

1.1 Purpose of Midwest ISO Business Practices Manuals

The BPMs developed by Midwest ISO provide background information, guidelines, business rules, and processes established by Midwest ISO for the operation and administration of the Midwest ISO markets, provisions of transmission reliability services, and compliance with Midwest ISO settlements, billing, and accounting requirements. Exhibit 1-1 lists Midwest ISO BPMs.

Exhibit 1-1: Midwest ISO Business Practices Manuals

Manual Number	Title
001	BPM for Market Registration
002	BPM for Energy Markets
003	BPM for Energy Markets Instruments
004	BPM for Financial Transmission Rights
005	BPM for Market Settlements
006	BPM for Coordinated Reliability, Dispatch, & Control
007	BPM for Scheduling
008	BPM for Outage Operations
009	BPM for Market Monitoring & Mitigation
010	BPM for Network & Commercial Models
011	BPM for Resource Adequacy
100	BPM for Definitions

1.2 Purpose of this Business Practices Manual

This *BPM for Energy Markets* covers the rules, design, and operational elements of Midwest ISO's Day-Ahead Energy Market and Real-Time Energy Market.

Midwest ISO prepares and maintains the *BPM for Energy Markets* as it relates to the operation of the Energy Markets. This BPM conforms and complies with Midwest ISO's Open Access Transmission and Energy Markets Tariff, NERC operating policies, and the applicable Regional Reliability Council reliability principles, guidelines, and standards and is designed to facilitate administration of efficient Energy Markets. This and other BPMs are available for reference through Midwest ISO's Extranet.

This BPM benefits readers who want answers to the following questions:

- What are the roles of Midwest ISO and the Market Participants (MPs) in the Energy Markets?
- What are the basic concepts that one needs to know to interact with the Energy Markets?
- What MP activities must be performed to engage in the Energy Markets?

1.3 References

Other reference information related to this BPM includes:

- Other BPMs
- Open Access Transmission and Energy Markets Tariff for the Midwest Independent System Operator, Inc. (referred to as EMT)
- Additional documents are referenced in the text of this BPM
- Agreement of Transmission Facilities Owners to Organize the Midwest Independent Transmission System Operator, Inc., a Delaware Non-Stock Corporation (referred to as "T.O. Agreement" or TOA)

2. Energy Markets Overview

This section presents a high level description of the Real-Time and Day-Ahead Energy Markets. The intent is to explain the basics including the following:

- Energy Markets Instruments
- Day-Ahead and Real-Time Energy Markets and Settlements
- Roles and Responsibilities of the entities that interact with the Energy Markets
- Market models and terminology
- Day-Ahead and Real-Time computer system components
- Market operation tools

2.1 Energy Markets Instruments Overview

Energy Markets Instruments are the vehicles by which Market Participants can engage in the activities of the Day-Ahead and Real-Time Energy Markets. The Energy Markets Instruments that are available to MPs are defined and described in greater detail in the *BPM for Energy Markets Instruments* and are summarized in Exhibit 2-1.

Exhibit 2-1: Energy Markets Instruments

Energy Markets Instruments	Day-Ahead Energy Market Interface	Real-Time Energy Market Interface
Physical Bilateral Transaction (Normal / Dynamic) ▪ Fixed ▪ Up to TUC ▪ Dispatchable	Market Portal PSS / E-Tag	Market Portal PSS / E-Tag
Financial Bilateral Transaction ▪ Fixed ▪ Pseudo-Tie ▪ Grandfathered Agreement	Market Portal ▪ finSched ▪ N/A ▪ finSched	Market Portal ▪ finSched ▪ finSched ▪ N/A
Generation Resource Offer	Market Portal	Market Portal
Demand Response Resource (DRR) Offer	Market Portal	Market Portal
Demand Bid	Market Portal	N/A
Virtual Supply Offer	Market Portal	N/A
Virtual Demand Bid	Market Portal	N/A
TUC = Transmission Usage Charge N/A = Not allowed PSS = Physical Scheduling Software finSched = Financial Scheduling Software		

2.2 Day-Ahead & Real-Time Energy Markets

Midwest ISO operates two Energy Markets:

- ***Day-Ahead Energy Market*** – The Day-Ahead Energy Market is a forward market in which hourly clearing prices are calculated for each hour of the next Operating Day based on the concept of Locational Marginal Prices (LMPs). The Day-Ahead Energy Market is cleared using Security-Constrained Unit Commitment (SCUC) and Security-Constrained Economic Dispatch (SCED) computer programs to satisfy Energy demand requirements of the Day-Ahead Energy Market. The results of the Day-Ahead Energy Market clearing include hourly LMP values, hourly demand and supply quantities, and hourly Balancing Authority (BA) Net Scheduled Interchange (NSI). See Section 4 of this BPM for details of the Day-Ahead Energy Market.

- ***Real-Time Energy Market*** – The Real-Time Energy Market is a market in which the LMPs are calculated every five minutes, based on Midwest ISO Dispatch Instructions and actual system operating conditions, as described by Midwest ISO's State Estimator. The Real-Time Energy Market dispatch is supported by a Reliability Assessment Commitment (RAC) process to ensure sufficient capacity is on line to meet Real-Time operating conditions. See Section 5 of this BPM for details of the Real-Time Energy Market.

These Energy Markets operate in a coordinated sequence as summarized by the process/event overview timeline in Exhibit 2-2. See Section 3 of this BPM for details of the supporting Reliability Assessment Commitment activities.

Separate accounting Settlements are performed for each Energy Market:

- ***Day-Ahead Settlement*** – The Day-Ahead Settlement is based on scheduled hourly quantities and on Day-Ahead hourly prices. In the Settlement of the Day-Ahead Energy Market each hourly MWh injection award is paid the Day-Ahead Energy Market LMP at its Commercial Pricing Node (CPNode). Withdrawals are charged the Day-Ahead Energy Market LMP at their respective CPNode. The Day-Ahead Energy Market LMPs are also used to establish the settlement value of Financial Transmission Rights (FTRs). Bilateral Transactions are also assessed charges based on Day-Ahead Energy Market LMPs.

- ***Real-Time Settlement*** – The Real-Time Settlement is based on actual hourly quantity deviations from the Day-Ahead Scheduled quantities and on Real-Time prices integrated over the hour. Any demand that exceeds its Day-Ahead Scheduled quantity pays real-

time LMPs, and demand deviations below their Day-Ahead Scheduled quantities receive revenues based on Real-Time LMPs. Energy suppliers are paid Real-Time LMPs for any generation that exceeds the Day-Ahead Scheduled quantities and pay for generation deviations below the scheduled quantities. Deviations of Real-Time Physical Bilateral Transaction quantities from cleared Day-Ahead Physical Bilateral Transactions are charged according to the agreement between the parties and the type of Physical Bilateral Transaction. Financial Bilateral Transactions are assessed charges based on Day-Ahead and Real-Time Energy Market LMPs for congestion and losses only. All purchases and sales in the Real-Time Energy Market are settled at the Real-Time LMPs. Refer to the *BPM for Market Settlements* for a detailed description.

Both the Day-Ahead price calculations and the real-time price calculations are based on the concept of Locational Marginal Prices as described in detail in Section 4.2 and Section 6.1 of this BPM.

Exhibit 2-2: Reliability Assessment Commitment & Energy Markets – Timeline Overview

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
Real-Time Energy Market Reliability Assessment Commitment Pre Day-Ahead (See Section 3)		
OD-7 @ 0000	OD-1 @ 2400	RAC Pre Day-Ahead Time Frame
Day-Ahead Energy Market Activities (See Section 4)		
OD-7 @ 0000	OD-1 @ 1100	Prepare for Day-Ahead Energy Market
	OD-1 @ 1100	Close Day-Ahead Energy Market
	OD-1 @ 1700	Post Results for Day-Ahead Energy Market
Real-Time Energy Market Reliability Assessment Commitment Post Day-Ahead (See Section 3)		
OD-1 @ 1700	OD-1 @ 1800	Revise Offers for RAC Post Day-Ahead (with knowledge of DAEM Posting)
OD-1 @ 2000	OD @ 0000	Notify Start-up/Shut-downs for RAC Post Day-Ahead
Real-Time Energy Market Reliability Assessment Commitment Intraday (See Section 3)		
OD-1@ 2000	OD @ 2400	RAC Intraday Time Frame
Real-Time Energy Market Activities (See Section 5)		
OD-1 @ 2330	OD @ RT	Real-Time Energy Market Time Frame
	OD-1 @ OH-30min	Close Real-Time Energy Market 30 minutes Prior to Top of Each OH
	OD @ RT-5min (Every 5 minutes)	Send UDS Basepoints and NSIs to BAs and Resource Operators, and Post Results
Energy Markets Closure Activities (See Section 6)		
OD = Operating Day		UDS = Unit Dispatch System
OH = Operating Hour (00 to 23)		NSI = Net Scheduled Interchange
RT = Real-Time (target time for UDS basepoints)		BA = Balancing Authority
RAC = Reliability Assessment Commitment		

2.3 Market Modeling Terminology

This section describes the models and terminology that Midwest ISO utilizes to coordinate the electric power system (Network Model) with the Energy Markets (Commercial Model). Model coordination is crucial to the Settlement process so that credits and charges are accurately allocated to the MPs. The following subsections provide an overview of market modeling. Refer to the *BPM for Network & Commercial Models* for a detailed description.

2.3.1 Network Model

The Network Model is a representation of the actual Transmission System, including all connection points modeled for generation and load. This model has many purposes, including the need for the analysis of the anticipated impact of physical Energy flow across the transmission system.

2.3.2 Commercial Model

The Commercial Model differs from the Network Model in that it describes the financial market relationships of the MPs, Asset Owners, and the commercial relationships among the elements of the Network Model. The hierarchy of relationships is as follows:

- Market Participant Level
- Asset Owner Level
- Commercial Pricing Node Level (Asset Level)
- Elemental Pricing Node Level

2.3.3 Elemental Pricing Nodes

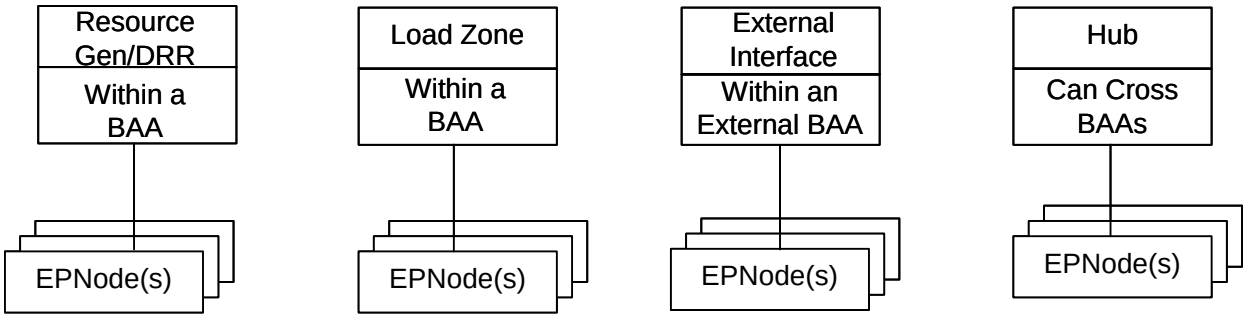
The Elemental Pricing Node (EPNode) is the finest level of granularity in the Commercial Model. There are EPNodes modeled as part of the Network Model representing the points on the Transmission System where Energy is injected or withdrawn or other commercially significant point. Midwest ISO calculates the LMP of supplying and consuming electric Energy at each EPNode.

2.3.4 Commercial Pricing Nodes

The CPNode represents the next hierarchical level in the Commercial Model and consists of one or more EPNodes. All Energy Markets Instruments are financially settled at the CPNode level at LMPs that are publicly available. Refer to the *BPM for Energy Markets Instruments* for a description of Midwest ISO Energy Markets Instruments.

There are four types of CPNodes: Resource (Generator, DRR, etc.), Load Zone, Hub, and Midwest ISO External Interface. Exhibit 2-3 illustrates the relationship between EPNodes and CPNodes.

Exhibit 2-3: Commercial Pricing Node Types



BAA = Balancing Authority Area

EPNodes may be allocated by percent of ownership to more than one CPNode, provided that the total allocation equals 100 percent. For each CPNode, the relationship of EPNodes to CPNodes determines how the LMP is aggregated for use by market Settlements. This nodal relationship is maintained in Midwest ISO's customer care system. CPNodes that represent Generation Resources, and Load are referred to as assets and all of these types of Assets must be completely assigned (i.e., 100%) to an Asset Owner.

2.3.5 Asset Owners

The Asset Owner (AO) is the next higher hierarchical level in the Commercial Model and typically, but not necessarily, represents a company. A company may choose to be registered as more than one Asset Owner. Within the Commercial Model, Asset Owners can own any combination of generation, load, and/or Financial Transmission Right (FTR) assets and/or Energy Markets Instruments across any number of BAAs. All Asset Owners must be represented by an MP.

Midwest ISO calculates charges and produces market Settlements statements for each Asset Owner. Each Settlement statement provides the billing determinants for each transaction, along with the Asset Owner's total financial obligation resulting from their transactions.

2.3.6 Market Participants

The MP is the highest hierarchical level in the Commercial Model and is the entity in the Commercial Model that is financially obligated to Midwest ISO for market Settlements. A single MP represents one or more Asset Owners. A single MP may authorize other entities such as an Asset Owner to act in Midwest ISO Energy Markets on its behalf. The MP remains financially responsible for market Settlements. MPs receive Settlement summaries and invoices from Midwest ISO for market settled Energy Markets Instruments executed by the MPs' or entities authorized by the MP. Refer to the *BPM for Market Settlements* for detailed information.

2.4 Roles & Responsibilities

Roles and responsibilities are described for the following entities:

- Midwest ISO
- Market Participants
- Transmission Owners/Operators
- Generation Owners/Operators
- Load-Serving Entities
- Market Support Services Providers
- Balancing Authorities
- Independent Market Monitor

2.4.1 Midwest ISO

Midwest ISO provides all market services for Energy and Transmission Service in accordance with the terms of the EMT, the BPMs, and related agreements. This includes the Day-Ahead Energy Market and the Real-Time Energy Market.

Midwest ISO serves as the sole point of application for all Energy Market services provided in the Market Footprint (see *BPM for Coordinated Reliability, Dispatch, & Control*). Midwest ISO administers the Energy Markets, including performing the following functions:

1) **Reliability Assessment Commitment (see Section 3):**

   - Accumulate information to assess system reliability for the next seven days, including gathering data for analyses, identifying potential problems, and determining if sufficient capacity is available to meet Energy requirements.

   - Continuously monitor the power system to ensure sufficient generation is available to meet forecasted Load and reserve obligations in the Real-Time Energy Market.

- Commit, if necessary, Long Lead Start Units for the future Operating Day.

2) **Day-Ahead Energy Market (see Section 4):**

- Acquire Day-Ahead data, including transmission outages, generation outages, and Day-Ahead Bids and Offers
- Acquire Day-Ahead Physical Bilateral Transactions
- Clear the Day-Ahead Energy Market by committing and dispatching Day-Ahead supply (including consideration of Start-Up, No-Load, and energy Offer price for Generation Resource Offers) against Day-Ahead demand
- Review Day-Ahead Energy Market results
- Publish data for Day-Ahead Energy Market results (e.g., schedule, commitment, and load)
- Communicate Day-Ahead Energy Market results to the Midwest ISO Reliability Assessment group

3) **Real-Time Energy Market Dispatch (see Section 5):**

- Review Real-Time Energy Market Offers
- Commit additional resources not previously committed during the Real-Time Energy Market RAC, if necessary, to meet forecast load, before and during the Operating Day based on Start-Up and No-Load Price Offers, and Energy Offers (MW/Price) over the full operating range of the unit. (RAC will only consider operation at Dispatch Minimum.)
- Acquire Day-Ahead data (e.g. operating plan)
- Acquire Real-Time Physical Bilateral Transactions and Real-Time Resource Offer data
- Acquire Real-Time Operating Reserve schedules
- Revalidate Resource adequacy
- Acquire current system conditions, including: Binding Transmission Constraints, limits/actuals, and actual generation

- Calculate 5-minute Load forecast
- Operate and clear the Real-Time Energy Market (ex-ante LMPs and Dispatch Instructions)
- Process Automatic Reserve Sharing requirements
- Send Dispatch Instructions to BAs and MPs
- Send Real-Time Net Scheduled Interchange (NSI) to the BAs and hourly integrated NSI (after-the-fact) to the Physical Scheduling Software (PSS)
- Calculate preliminary 5-minute ex-post LMPs
- Calculate preliminary integrated hourly ex-post LMPs
- Publish preliminary Real-Time Energy Market results (ex-post LMPs)
- Schedule and payback Inadvertent Interchange
- Initiate Emergency procedures, as needed

2.4.2 Market Participants

MPs are entities that are qualified, pursuant to procedures established by Midwest ISO, to perform the following actions: Refer to the *BPM for Energy Markets Instruments* for additional information.

1) **Day-Ahead Energy Market:**

- Submit Physical Bilateral Transactions to Midwest ISO for consideration in the Day-Ahead Energy Market
- Submit Bids to purchase and/or Offers including Self-Scheduled Resources, to sell Energy in the Day-Ahead Energy Market
- Submit Day-Ahead Financial Bilateral Transactions to Midwest ISO by 1200 hours EST the day following the Operating Day (OD+1)
- Submit Virtual Supply Offers and Virtual Demand Bids

2) **Real-Time Energy Market:**

- Submit Offers for any of the RAC (beginning at OD-7)
- Submit Physical Bilateral Transactions to Midwest ISO for consideration in the Real-Time Energy Market
- Submit new or modified Offers, including Self-Scheduled Resources, to supply Energy in the Real-Time Energy Market no later than 30 minutes prior to the Operating Hour
- Submit Real-Time Financial Bilateral Transactions by 1200 hours EST the day following the Operating Day (OD+1)

3) **Settlements:**

Only MPs may settle with Midwest ISO on Energy Markets Instruments. The MP is responsible and liable to Midwest ISO for all Energy Market activities conducted by the MP or the MP's scheduling, metering, or billing agent.

2.4.3 Transmission Owners/Operators

A Transmission Owner is a member of Midwest ISO that has (in whole or in part) transferred functional responsibilities of their transmission facilities classified as transmission and covered under the EMT and TOA. Those facilities make up Midwest ISO's Transmission System. Transmission Operators perform the following actions:

1) **Prior to the Operating Day:**

- Receive and/or develop transmission maintenance requirements and plans for Transmission Owners
- Define operating limits, develop contingency plans, and monitor operations of the transmission facilities under the Transmission Operator's control and as directed by Midwest ISO
- Provide operating information to Midwest ISO
- Determine amounts required and arrange for Ancillary Services from Generation Owners to ensure reactive supply and voltage control (e.g. from Generation Resources) in coordination with the Balancing Authorities and Midwest ISO

- Update transmission facility ratings

2) **During the Operating Day:**

- Operate or direct the operations of the Transmission System within equipment and facility ratings established by the Transmission Owners and Generation Owners, and system ratings established by Midwest ISO
- Deploy reactive Resources from Transmission Owners and Generation Owners as Ancillary Services to maintain acceptable voltage profiles and direct Distribution Providers to maintain voltages within limits
- Provide Real-Time operations information to Midwest ISO
- Notify Generation Owners and other affected entities of Transmission System problems (e.g. voltage limitations or equipment overloads that may affect generator operations)
- Request Midwest ISO actions to mitigate equipment overloads (e.g., Dispatch Instructions, Transmission Loading Relief)
- Coordinate Load Shedding with, or as directed by, Midwest ISO and direct Distribution Providers to shed Load

2.4.4 Generation Owners/Operators

A Generation Owner is an entity that owns, or leases with rights equivalent to ownership, facilities for generation of Energy that are located within or are used to supply Energy in the Midwest ISO Market Footprint. Generation Resources within the Market Footprint must be represented by an MP. Generator Operators perform the following actions:

1) **Prior to the Operating Day:**

- Submit maintenance schedules
- Submit operational parameters and facility limitations (e.g., long lead time units)

2) **During the Operating Day:**

- Respond to dispatch and control directives or signals
- Respond to reactive supply and voltage control directives
- Respond to start-up and shut-down directives

2.4.5 Load-Serving Entities

LSEs are any parties taking Transmission Service on behalf of wholesale or retail power customers that have undertaken an obligation to provide or obtain electric Energy for end-use customers by statute, franchise, regulatory requirement or contract for Load located within or attached to the Transmission System.

An LSE must either qualify as an MP, or arrange with an MP to be served through the Energy Markets. LSEs perform the following actions:

1) **Prior to the Operating Day:**

   - Submit Load forecasts (hourly for 7 days out) to the Balancing Authority
   - Provide generation commitment (applies to Demand Response Resources)

2) **During the Operating Day:**

   - Respond to dispatch instructions (applies to Demand Response Resources)
   - Respond to interruptible Load and Load shedding directives

2.4.6 Market Support Services Providers

There are three types of market support services providers:

- ***Scheduling Agent (SA)*** – an agent designated by a MP to physically exchange market information, such as submitting schedules, transactions, Bids, and Offers or receiving market data and notifications to Midwest ISO on the MP's behalf

- ***Metering Data Management Agent (MDMA)*** – an entity that is designated by an MP to manage and conduct the metering function

- ***Billing Agent*** – an entity that may be designated by a MP to receive bills and/or make payments on behalf of the MP

Market support services providers do not need to be qualified as MPs as long as the MPs they represent remain financially liable to Midwest ISO for all the activities that the market support services providers perform. The market support services providers are required to act in accordance with the provisions of the EMT. However, the MP responsibilities and liabilities to Midwest ISO are those of the MP and cannot be transferred to market support service providers.

2.4.7 Balancing Authorities

The BAs perform the following activities to support the Energy Markets:

- Balance the Energy output of the Generation Resources and Demand Response Resources (DRRs) within their respective electric power system(s) and Energy purchases and sales from entities outside their electric power system(s), with the Load within their electric power system(s)
- Maintain Net Scheduled Interchange (NSI), established by Midwest ISO, within the limits of Good Utility Practice
- Maintain the frequency of their electric power system(s) within reasonable limits in accordance with Good Utility Practice and the criteria of the applicable NERC Regional Reliability Council (RCC)
- Maintain Operating Reserves and Regulation in accordance with Good Utility Practice and the criteria of the applicable NERC RCC

For more information, please refer to the *BPM for Coordinated Reliability, Dispatch, & Control*.

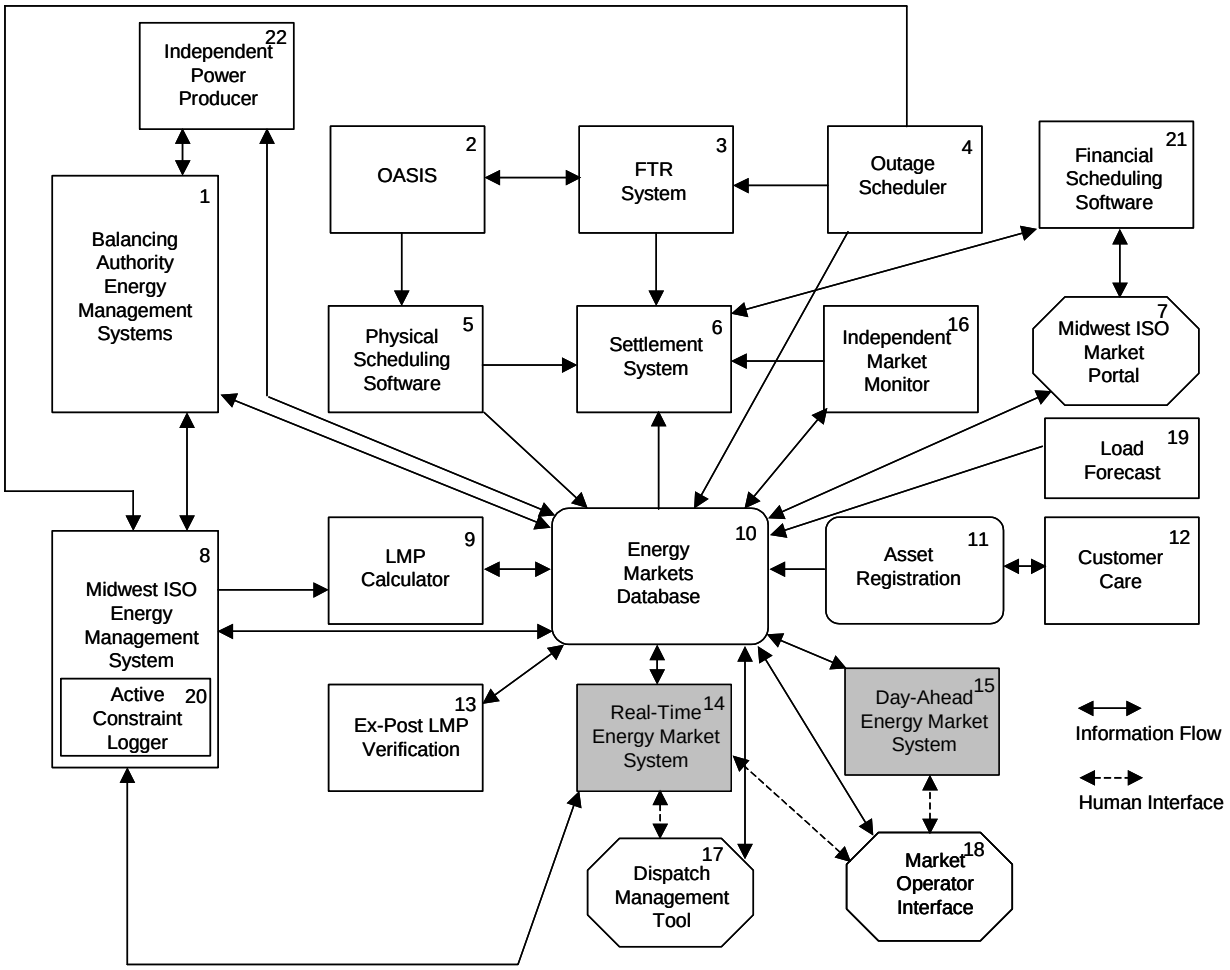
2.4.8 Independent Market Monitor

Midwest ISO uses the services of its Independent Market Monitor (IMM) to provide for the independent, impartial, and effective monitoring and reporting on the Midwest ISO Energy Markets as a whole. In addition, the IMM provides the means for Midwest ISO to mitigate the market effects of any conduct that would distort competitive outcomes in the Energy Markets. For further information on the Independent Market Monitor, please refer to the *BPM for Market Monitoring & Mitigation*.

2.5 Day-Ahead & Real-Time Energy Markets System Components

The Day-Ahead and Real-Time Energy Markets (DART) system consists of software, servers, and related applications used to support the operation of the Day-Ahead and Real-Time Energy Markets. Exhibit 2-4 depicts the major components of this system.

Exhibit 2-4: DART System Components Overview



The following components are shown in Exhibit 2-4:

1) ***Balancing Authority Energy Management Systems*** – the BA EMSs that are within the Market Footprint and include Resources that are dispatched by Midwest ISO

2) ***Open Access Same-Time Information System (OASIS)*** – used to manage Transmission Service reservations that may be used to schedule Energy interchange, e.g., Physical Bilateral Transactions. Reservations for Firm Transmission Service may also be accompanied by an FTR request via the OASIS.

3) ***Financial Transmission Rights (FTR) System*** – maintains records of FTR Holders, allocates new FTRs, and conducts auctions

4) ***Outage Scheduler*** – the system that tracks the status of transmission and generation outages and their expected return to service

5) ***Physical Scheduling Software (PSS)*** – system for entering and disseminating interchange transaction information including Physical Bilateral Transactions. Physical Bilateral Transactions are submitted to the PSS via NERC E-Tag.

6) ***Settlement System*** – calculates the MP charges and credits for the Day-Ahead Energy Market, the Real-Time Energy Market, and the FTR Market

7) ***Midwest ISO Market Portal*** – the internet portal by which MP information is entered via input/output displays and data templates

8) ***Midwest ISO Energy Management System*** – consists of the power system network analysis functions (including the State Estimator and Contingency Analysis) that are used by Midwest ISO Operators to maintain reliable power system operations

9) ***Locational Marginal Pricing (LMP) Calculator*** – performs ex-post analysis of Real-Time Energy Market operations to identify marginal resources/demands based on actual performance versus Dispatch Instructions and calculates the three components of LMP (energy, congestion, losses) for each commercially significant location in the Market Footprint

10) ***Energy Markets Database*** – the central repository of all market-related data and coordinates market component communications

11) ***Asset Registration*** – the system for the storing of authorized MP information relevant to participation in Midwest ISO markets

12) ***Customer Care*** – customer services and Midwest ISO response to market inquiries

13) ***Ex-Post LMP Verification*** – comparison and correction of LMP Calculator results against actual operating conditions and events

14) ***Real-Time Energy Market System*** – provides desired generation dispatches for a near-term forecast of operating conditions for the Real-Time Energy Market, using a least-offer price SCED algorithm. For the Real-Time Energy Market the Scheduling, Pricing, and Dispatch (SPD) application is executed on a five-minute periodic basis to produce a constrained economic dispatch and determines ex-ante LMPs based on the current system conditions, the actively managed transmission constraints, and the forecast system conditions. This does not apply to RAC.

15) ***Day-Ahead Energy Market System*** – provides Security Constrained Unit Commitment (SCUC) and Security Constrained Economic Dispatch (SCED) schedules, based on MP submitted Offers and Bids. The following applications are executed for each hour:

- ***Resource Scheduling and Commitment (RSC)*** – a Security Constrained Unit Commitment which performs generation commitment for the 24-hour period
- ***Scheduling, Pricing, and Dispatch (SPD)*** – uses the Network Model to perform dispatch for 24 hours and determines LMPs
- ***Simultaneous Feasibility Test (SFT)*** – performs contingency analysis for each hour to evaluate network security of a set of injections and withdrawals under a range of contingent scenarios

16) ***Independent Market Monitor (IMM)*** – provides the independent observation of the market activities to detect market rule violations and the influence of market power

17) ***Dispatch Management Tool (DMT)*** – allows the Operator to make changes to the planned operation of specific Generation and Demand Response Resources

18) ***Market Operator Interface (MOI)*** – allows the Operator to view the inputs and outputs of the market system and to make input parameter adjustments

19) ***Load Forecast*** – provides short-term Load forecast over the next hour for the Real-Time Energy Market dispatch and provides 24 hour Load forecast values for rolling seven days for use in the Reliability Assessment Commitment (RAC) for the Real-Time Energy Market

20) ***Active Constraint Logger*** – records and logs transmission constraints that are “actively” being controlled and impacting the dispatch solution produced by UDS in the Real-Time Energy Market

21) ***Financial Scheduling Software (finSched)*** – used by MPs to enter Financial Bilateral Transactions

22) ***Independent Power Producer (IPP)*** – a generation Resource that operates within a Balancing Authority (or is a BA) and that submits MW/Price Offers into the Energy Markets, independently of any other generation Resource(s) within the BA.

3. Reliability Assessment Commitment Activities

The Reliability Assessment Commitment (RAC) process settles as part of the Real-Time Energy Market to ensure that sufficient Resources are available and on-line to meet the demand and reserve requirements within the Market Footprint, as projected by Midwest ISO for each hour of the Operating Day. The RAC process enables Midwest ISO to reliably operate the Transmission System by committing additional Resources:

- Before the Day-Ahead Energy Market, if required
- After the posting of the Day-Ahead Energy Market, if Pre Day-Ahead RACs and Day-Ahead Energy Market commitments are not sufficient
- During Real-Time operations, if required

The RAC process employs a Security-Constrained Unit Commitment (SCUC) algorithm to minimize the cost of committing the required capacity, including Start-Up, No-Load, and cost to operate at Dispatch Minimum. The RAC analysis minimizes the cost of committing sufficient resources to meet the forecast capacity requirements, not to serve the forecast energy. Resources are guaranteed to receive their Start-Up, No-Load, and dispatch minimum costs (based on their Offers). Resource Offer rules that apply to the RAC are described in the *BPM for Energy Markets Instruments*. The RAC timeline is presented in Exhibit 3-1, covering the three RAC processes:

- *RAC Pre Day-Ahead*
- *RAC Post Day-Ahead*
- *RAC Intraday*

Exhibit 3-1: Reliability Assessment Commitment Timeline

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
Data Required for RAC Pre Day-Ahead Process		
OD-7 @ 0000	As available during RAC run	Transmission Owners/Operators submit requests for transmission facility outages
OD-7 @ 0000	As available during RAC run	Generation Owners/Operators submit planned generation facility outage Schedules
OD-7 @ 0000	As available during RAC run	BAs submit Load forecasts
RAC Pre Day-Ahead Process		
OD-7 @ 0000	OD-1 @ 1700	Perform Multi-day Reliability Assessment Commitment as necessary to evaluate need for Long Lead Start Units
OD-7 @ 0000	OD-1 @ 1700	Identify reliability violations and coordinate with BAs, as required

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
RAC Post Day-Ahead Process		
OD-1 @ 1700	OD-1 @ 1800	Resource Offer re-bidding
OD-1 @ 1800	OD-1 @ 2000	Perform RAC Next-Day Analysis
	OD-1 @ 2000+	Notify Resources of scheduled commitment: ▪ Start time and Dispatch Minimum ▪ Stop time
RAC Intraday Process		
OD-1 @ 2000	OD @ 2400	Perform RAC Intraday Analysis as required
OD = Operating Day OH = Operating Hour (00 to 23) RAC = Reliability Assessment Commitment BA = Balancing Authority		

The following are taken in account in the RAC process:

- Forecasted Load
- Pre-scheduled Physical Bilateral Transactions greater than one day out
- Committing Long Lead Start Resources
- Scheduled outages
- Maintaining facility ratings

3.1 Forecasting Load

Midwest ISO produces and publishes an initial hourly forecast of Load for the Operating Day beginning seven days prior to that day and updated daily as the Operating Day approaches.

Midwest ISO requires BAs to submit hourly Load forecasts for a rolling seven days in the future. For each day, a 24-hour Load shape is developed. The first step in developing a Load forecast is to obtain weather information for the time period. Weather information is provided at regular intervals by a contracted-for weather service. The forecast period is reviewed to determine any conditions that could affect Midwest ISO's Load, including but not limited to: day of week, holidays, special events, daylight savings time changes, and BA Load forecasts.

A Load forecast is required by the Real-Time Energy Market RAC to ensure that sufficient Resources are committed. The RAC process ensures that sufficient generation capacity is scheduled on-line (or that available 'fast start' units will contribute to reserves) to meet the Load in Midwest ISO's Market Footprint, including capacity needed for reserves. The RAC process is

performed several times throughout the timeline. This Load forecast is used in the Real-Time Energy Market RAC only; it is not used to clear the Day-Ahead Energy Market.

The BAs provide a Load forecast at an hourly granularity for the next seven days to Midwest ISO by the Day-Ahead market offer deadline at 1100 hours EST. Midwest ISO requires the MPs serving Load in a BA area to supply a forecast of these values to its BA for the Load served by the MP if the BA needs the data to develop the BA forecast. Midwest ISO also produces a seven-day hourly forecast for each BA, and will utilize the Load forecast produced for use in the RAC process.

3.2 Pre-Scheduling Physical Bilateral Transactions Greater than One Day Out

Pre-scheduled Physical Bilateral Transactions are transactions that are scheduled one or more days prior to their Operating Day for the Day-Ahead or Real-Time Energy Markets. Each MP making a Physical Bilateral Transmission E-Tag import or export covering a period greater than the Operating Day must furnish all required information to Midwest ISO via a NERC E-tag that transfers into the PSS.

Midwest ISO confirms the Physical Bilateral Transaction E-Tag with the affected External BA, as necessary, and may condition acceptance for scheduling on such confirmation. Midwest ISO provides the requesting MP with notice, as soon as is practicable, as to whether the pre-scheduled Physical Bilateral Transaction E-Tag request is accepted for scheduling and, if it is not accepted, the reason why. Midwest ISO responds to E-Tags in accordance with NERC established guidelines. MPs with pre-scheduled Physical Bilateral Transactions are subject to LMPs established for the External Interface CPNode(s) that the schedule utilizes.

Refer to the *BPM for Energy Markets Instruments* for additional information.

3.3 Committing Long Start-Up Resources

Midwest ISO supports unit commitment service for Resources with Start-Up times longer than those that can be accommodated in the post Day-Ahead RAC process. These Resources can also Self-Schedule or engage in Financial Bilateral Transactions and Physical Bilateral Transactions to utilize the Resource.

Uncommitted Resources with Start-Up and Notification times longer than those that can be committed in the post Day-Ahead RAC process can submit Start-Up, No-Load, and Dispatch Minimum Limit Real-Time Offers for consideration by Midwest ISO as part of this Pre Day-Ahead RAC process. The following time frames reflect the process employed:

- ***Seven to Four Days prior to Operating Day:***
  - Generation units with Start-Up and Notification times greater than 24 hours must submit Start-Up and Notification times and binding MW and Price Offers for Start-Up, No-Load, and Energy at Dispatch Minimum.
  - If adequacy violations are detected, they are logged and evaluated but no specific commitment action is taken until three days prior to the market day, unless three days prior does not allow sufficient time to resolve the potential violations
- ***Three to Two Days prior to Operating Day:***
  - Generation units that have not been committed by Midwest ISO may submit revised Start-Up and Notification times and binding Real-Time MW and Price Offers for Start-Up, No-Load, and Energy at Dispatch Minimum.
  - If violations of reliability criteria (as described in the *BPM for Coordinated Reliability, Dispatch, & Control*) are detected, Midwest ISO coordinates with the local Operators to verify the violation. After the violation has been verified, Midwest ISO will direct certain generation operations if the only alternative to resolve the generation-adequacy or constraint violation is to commit a generator with a Start-Up and Notification requirement of longer time than can be accommodated in (OD-2) or (OD-1) RAC processes.

3.4 Scheduling Outages

Midwest ISO is responsible for approving the scheduling of maintenance on all transmission facilities making up Midwest ISO Transmission System and coordinating with Generation Owners, as appropriate, the scheduling of maintenance on generation facilities. This information is required for determining Resource availability and the topology and capability of the transmission network. See the *BPM for Outage Operations* for a description of transmission and generation outage coordination process, which includes outage scheduling, outage analysis, and outage reporting.

3.5 Maintaining Facility Ratings

MPs, Transmission Owners, and Midwest ISO are required to fulfill requirements for facility ratings. All Transmission Owners must regularly update and verify facility ratings to Midwest ISO Operations Planning Department (or successor department). These procedures are updated as needed and are further described in the Transmission Owner Agreement (see reference in Section 1 of this BPM).

See Midwest ISO's facility rating Coordination Policy Manual for a description of the facility rating coordination process, including the responsibilities of MPs, Transmission Owners, and Midwest ISO.

4. Day-Ahead Energy Market Activities

MPs who wish to participate in the Day-Ahead Energy Market must submit approved Energy Markets Instruments for the purchase and sale of Energy no later than 1100 hours EST on the day prior to the Operating Day (OD-1) for use in clearing the Day-Ahead Energy Market. Exhibit 4-1 shows the timeline for the principle activities associated with the Day-Ahead Energy Market.

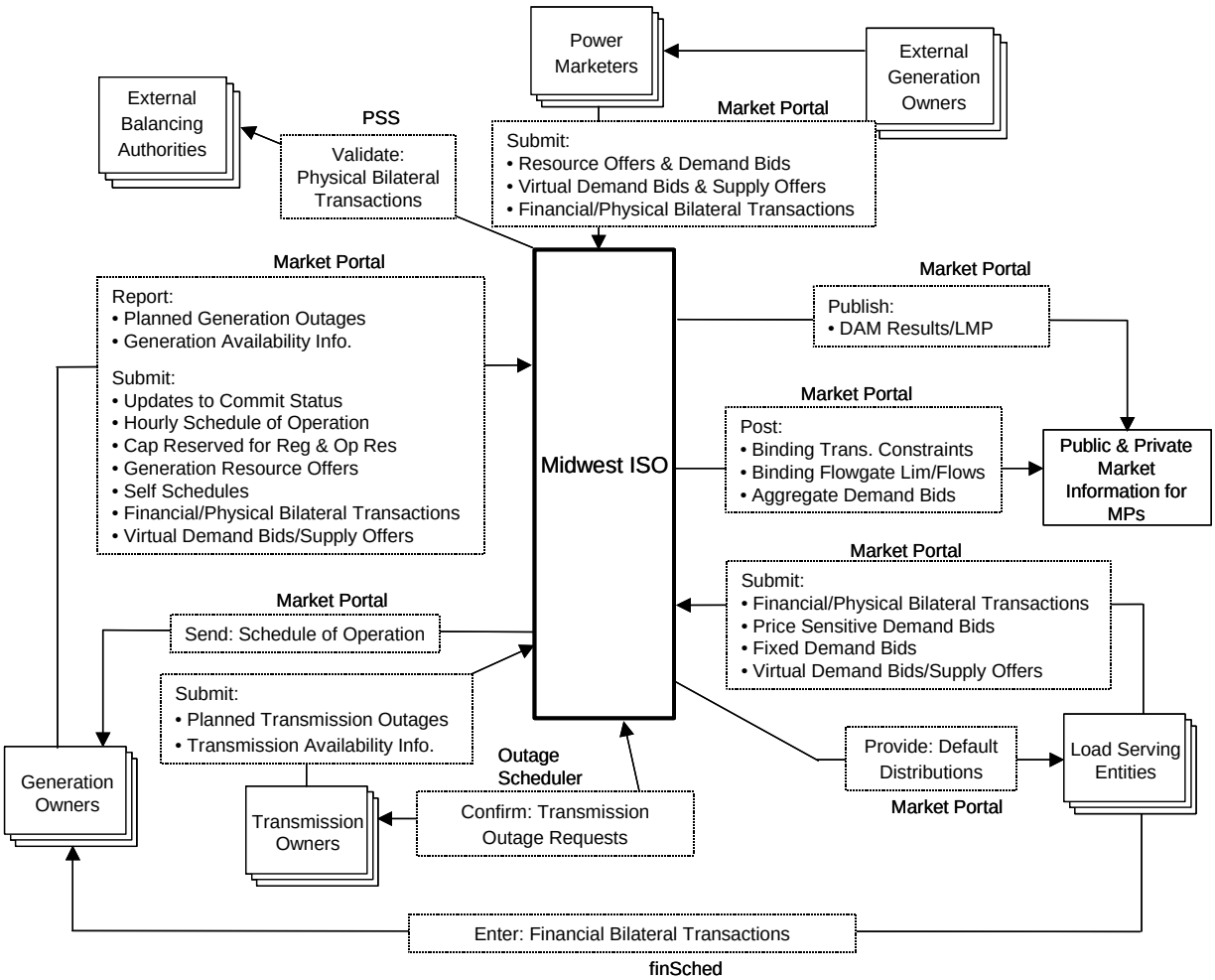
Exhibit 4-1: Day-Ahead Energy Market Activities Timeline

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
Data Required for the Day-Ahead Energy Market		
As previously scheduled	OD-1 @ 1100	Scheduled transmission facility outages
As previously scheduled	OD-1 @ 1100	Scheduled Generation Resource outages
OD-7 @ 0000 or previous submittal	OD-1 @ 1100	Generation Resource Offers and Demand Response Resource Offers into the Day-Ahead Energy Market
OD-7 @ 0000	OD-1 @ 1100	Fixed Demand Bids and Price-Sensitive Demand Bids into the Day-Ahead Energy Market only
OD-7 @ 0000	OD-1 @ 1100	Virtual Supply Offers and Virtual Demand Bids into the Day-Ahead Energy Market only
OD-7 @ 0000	OD-1 @ 1100	Day-Ahead Fixed Physical Bilateral Transactions – not considered binding until OD-1 @ 0900 – roll into Real-Time Energy Market, if cleared and not “zeroed” by MP
OD-7 @ 0000	OD-1 @ 1100	Day-Ahead Dispatchable Physical Bilateral Transactions – not considered binding until OD-1@0900 – roll into Real-Time Energy Market as Fixed Physical Bilateral Transactions, if cleared
OD-7 @ 0000	OD-1 @ 1100	Up to TUC Physical Bilateral Transactions (Day-Ahead Energy Market only) not considered binding until OD-1@0900 - roll into Real-Time Energy Market as Fixed Physical Bilateral Transactions, if cleared
OD-7 @ 0000	OD-1 @ 1100	GFA Option B Schedules
As scheduled by Operations Eng.	OD-1 @ 1000	SSRs – from determination by Operations Engineering
As scheduled by RAC	OD-1 @ 1100	Long lead time Resource schedules – from RAC
As previously entered	OD-1 @ 1100	Energy Markets Instruments parameters and network model parameters
As previously entered	OD-1 @ 1100	Updated facility ratings

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
Day-Ahead Energy Market Activities		
	OD-1 @ 1100	Close the Day-Ahead Energy Market and acquire data
OD-1 @ 1100	OD-1 @ 1700	Clear the Day-Ahead Energy Market
	OD-1 @ 1700	Post the Day-Ahead Energy Market Results
OD-7 @ 0000	OD+1 @ 1200	Enter Financial Bilateral Transactions for the Day-Ahead Energy Market
OD = Operating Day RAC = Reliability Assessment Commitment SSR = System Support Resource TUC = Transmission Usage Charge		

The interactions and data flows between the entities that participate in the Day-Ahead Energy Market are shown in Exhibit 4-2.

Exhibit 4-2: Data Flow for Day-Ahead Energy Market



4.1 Midwest ISO Activities

Midwest ISO operates the Day-Ahead Energy Market to develop a Day-Ahead Schedule of operation for each MP. The Day-Ahead Energy Market is a forward market in which hourly LMP values are calculated for each hour of the next Operating Day based on MP purchases and sales. MPs may purchase and sell Energy in the Day-Ahead Energy Market at financially binding Day-Ahead LMPs. Refer to Exhibit 2-1 of the BPM for a summary of the Energy Markets Instruments that apply to the Day-Ahead Energy Market.

The Day-Ahead Energy Market Settlement is based on hourly MW cleared and on Day-Ahead hourly LMPs.

4.1.1 Clearing Day-Ahead Energy Market

The Day-Ahead Energy Market clears for each hour of the upcoming Operating Day. A multi-hour optimization methodology, utilizing the SCUC and SCED algorithms, is employed to simultaneously perform the following tasks:

- Clear Resource Offers and Demand Bids for each hour of the upcoming Operating Day to yield Day-Ahead Schedules
- Allocate transmission capacity to Day-Ahead Schedules by respecting transmission constraints
- Commit offered Resources at least-offer price to meet the Energy and transmission constraint requirements throughout the projected upcoming Operating Day
- Respect Resource operating constraints, including minimum run-times and minimum down-times, considering any carryovers from the previous day.

The objective in clearing the Day-Ahead Energy Market is to minimize the costs of Day-Ahead energy procurement over the 24-hour dispatch horizon, subject to network constraints and Resource operating constraints. The overall costs include the Start-Up and No-Load Price Offers of Midwest ISO committed Resources and the MW/Price Offers of all Resources selected for Day-Ahead schedules.

Midwest ISO clears the Day-Ahead Energy Market, calculates the Day-Ahead LMPs, and posts the results on Midwest ISO's Market Portal at 1700 hours EST. The following Day-Ahead Energy Market cleared results are posted:

- The 24 hourly injections for each Resource of each MP whose Offers are accepted in the Day-Ahead Energy Market, including all Self-Scheduled Resources, all cleared Resource Offers, all cleared Virtual Supply Offers, and all cleared Physical Bilateral Transaction Imports

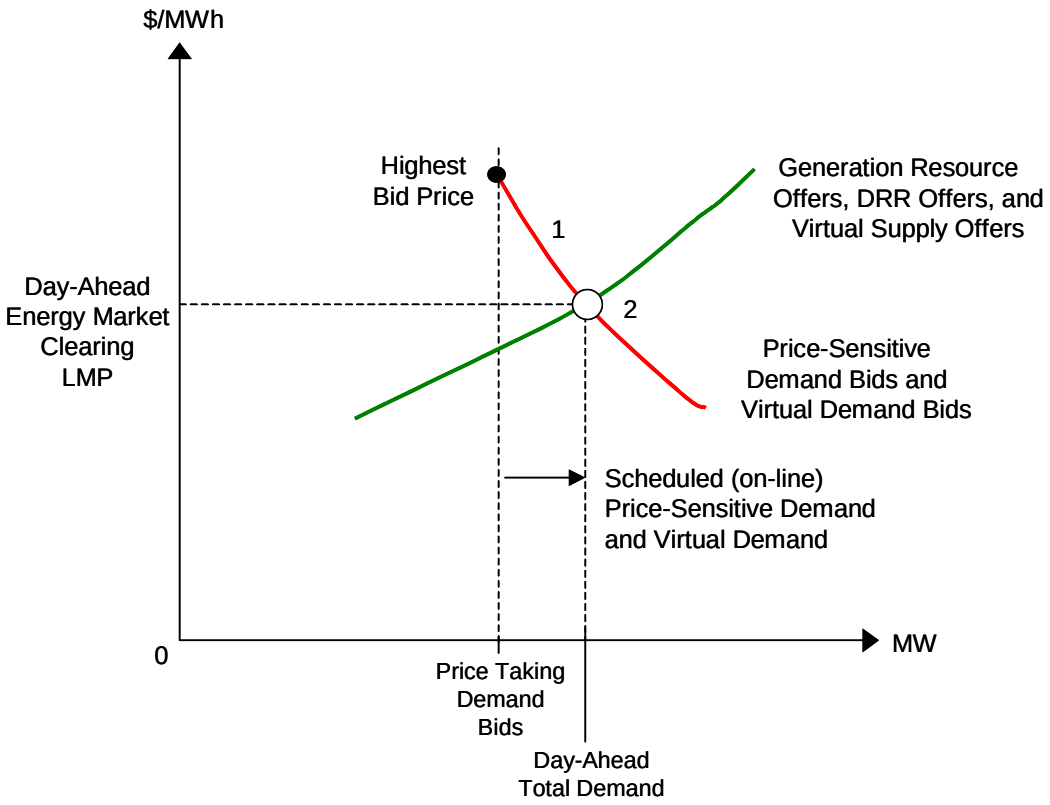
- The 24 hourly withdrawals of each MP whose Bids are accepted in the Day-Ahead Energy Market, including all Fixed Demand Bids, cleared Price-Sensitive Demand Bids, Cleared Virtual Bids, and all cleared Physical Bilateral Transaction Exports

The Day-Ahead Energy Market Clearing LMPs are determined as illustrated in Exhibit 4-3. For this illustration, we ignore the effects of transmission losses and transmission constraints, i.e., all the LMPs have the same value. The procedure is to:

1) Build the demand curve by connecting the price responsive components to the price taking components.

2) Determine the point at which the Offer and Bid curves intersect. This establishes the clearing price and the total Day-Ahead Demand

Exhibit 4-3: Day-Ahead Cleared Demand



4.1.2 Responding to System Shortage Conditions

If while clearing the Day-Ahead Energy Market, the sum of the Day-Ahead Demand Bids, Virtual Demand Bids, and Physical Bilateral Transaction Exports within the Market Footprint cannot be satisfied with all available Offers (Generation Offers, Physical Bilateral Transaction Imports, and Virtual Supply Offers), Midwest ISO implements the following steps to clear the Day-Ahead Energy Market:

- ***Step One*** – employ the Emergency Maximum Limit of all on-line Generation and Demand Response Resources (DRRs) as required to clear the Day-Ahead Energy Market. Resource Offers for the Emergency Dispatch Range are used in the calculation. The LMP is set to the highest Offer price of all on-line units that have cleared the Day-Ahead Energy Market.

- ***Step Two*** – if the balance still cannot be met, employ off-line Generation Resources and DRRs that are designated as available only for Maximum Generation Emergency (MGE) conditions based on economic Offer data and clear the Day-Ahead Energy Market. The LMP is set to the highest Offer of all on-line units that have cleared the Day-Ahead Energy Market.

- ***Step Three*** – if the balance still cannot be achieved, reduce Demand Bids (real and virtual) proportionately within the appropriate area until balance is achieved and the Day-Ahead Energy Market is cleared. Offers are set to the higher of the highest Offer of all on-line Generation Resources that have been cleared in the Day-Ahead Energy Market or $1,000/MWh.

4.1.3 Responding to Sub-Region Shortage Conditions

If while clearing the Day-Ahead Energy Market, the sum of the Day-Ahead Demand Bids, Virtual Demand Bids, and Physical Bilateral Transaction Exports within a sub-region of the Market Footprint cannot be satisfied with all available Offers (Generation Offers, Physical Bilateral Transaction Imports, and Virtual Supply Offers), Midwest ISO implements the following steps to clear the Day-Ahead Energy Market:

- ***Step One*** – employ the Emergency Maximum Limit of sub-regional, on-line Generation and Demand Response Resources (DRRs) as required to clear the Day-Ahead Energy Market. Resource Offers for the Emergency Dispatch Range are used in the calculation if applicable.

- ***Step Two*** – if the balance still cannot be met, employ off-line Generation Resources and DRRs that are designated as available only for Maximum Generation Emergency (MGE)

conditions based on economic Offer data and clear the Day-Ahead Energy Market. Resource Offers for the Emergency Dispatch Range are used in the calculation if applicable.

- ***Step Three*** – if the balance still cannot be achieved, reduce Demand Bids (real and virtual) proportionately within the appropriate area until balance is achieved and the Day-Ahead Energy Market is cleared.

4.1.4 Responding to System Surplus Conditions

If while clearing the Day-Ahead Energy Market, the sum of the Day-Ahead Self-Scheduled (non-price sensitive) Generation and Demand Response Resources, Must-Run Generation resources at their Dispatch Minimum Limit, Virtual Supply Offers, and Fixed Physical Bilateral Transaction Imports within the Market Footprint exceeds the sum of the Demand Bids, Physical Bilateral Export Transactions and Virtual Demand Bids, Midwest ISO performs the following steps to clear the Day-Ahead Energy Market:

- ***Step One*** – employ any Offers submitted in conjunction with Physical Bilateral Transaction Imports to cut the Dispatchable Physical Bilateral Transaction Imports to zero MW.

- ***Step Two*** – if the Energy balance still cannot be met, employ the Emergency Minimum Limit of all on-line Generation Resources as required to clear the Day-Ahead Energy Market. Resource Offers for the lower Emergency Dispatch Range are used in the calculation. The LMP is set to the lowest Offer of all on-line units that have cleared in the Day-Ahead Energy Market.

- ***Step Three*** – if the Energy balance still cannot be achieved, reduce the Dispatch Minimum Limit below the Emergency Minimum Limit proportional to the Emergency Minimum Limit in order to achieve balance. Offers are set to negative $30/MWh.

4.1.5 Responding to Sub-Region Surplus Conditions

If while clearing the Day-Ahead Energy Market, the sum of the Day-Ahead Self-Scheduled (non-price sensitive) Generation and Demand Response Resources, Must-Run Generation resources at their Dispatch Minimum Limit, Virtual Supply Offers, and Fixed Physical Bilateral Transaction Imports within a sub-region of the Market Footprint exceeds the sub-regional network export capability, Midwest ISO performs the following steps to clear the Day-Ahead Energy Market:

- ***Step One*** – employ any Offers submitted in conjunction with Physical Bilateral Transaction Imports to cut the Dispatchable Physical Bilateral Transaction Imports to zero MW.

- ***Step Two*** – if the Energy balance still cannot be met, employ the Emergency Minimum Limit of sub-regional, on-line Generation Resources as required to clear the Day-Ahead Energy Market. Resource Offers for the lower Emergency Dispatch Range are used in the calculation if applicable.

- ***Step Three*** – if the Energy balance still cannot be achieved, reduce the Dispatch Minimum Limit below the Emergency Minimum Limit proportional to the Emergency Minimum Limit in order to achieve balance. Resource Offers for the lower Emergency Dispatch Range are used in the calculation if applicable.

4.1.6 Monitoring & Mitigating Day-Ahead Energy Market

Any Bid, Offer, schedule, transaction, or changes in availability submitted to Midwest ISO by MPs is subject to market monitoring and mitigation measures. The complete process is described in the *BPM for Market Monitoring & Mitigation*.

4.2 Day-Ahead Locational Marginal Prices

Midwest ISO calculates the price of Energy at the Load buses and Resource buses in Midwest ISO's Market Footprint and at the External Interfaces between Midwest ISO's Market Footprint and adjacent BAs on the basis of LMPs. LMPs can be set by Offers to sell or Bids to purchase Energy, including Physical Bilateral Transactions. Midwest ISO establishes Hubs and Load Zones based on a pre-defined set of buses. The LMPs, Hub prices, External Interface prices, and Load Zone prices include separate components for the marginal costs of energy, congestion, and losses. Day-Ahead Market LMPs are calculated and posted on a Day-Ahead basis for each hour of the Day-Ahead Energy Market at 1700 hours EST.

4.2.1 LMP Components

In each hour of the Day-Ahead Energy Market, Midwest ISO calculates the LMP for each CPNode, which is equal to the marginal cost of Energy available at the CPNode in the hour, based on the Offers of sellers and Bids of buyers selected in the Day-Ahead Energy Market. Midwest ISO designates a Reference Bus, *r*, for all other buses in the power system. The Marginal Energy Component (MEC_r) is the marginal cost of energy available to the Reference Bus, based on Offers and Bids selected in the Day-Ahead Energy Market. For each bus other than the Reference Bus, Midwest ISO determines separate components of the LMP for the

marginal costs of energy, congestion, and losses relative to the Reference Bus, consistent with the following equation:

$$\text{(4-1)} \quad LMP_i = MEC_r + MCC_i + MLC_i$$

$$\text{(4-2)} \quad LMP_r = MEC_r$$

where:

- MEC_r is the LMP component representing the marginal cost of Energy (also referred to as λ) at the Reference Bus, *r*
- MCC_i is the LMP component representing the marginal cost of congestion (also referred to as ρ) at bus *i* relative to the Reference Bus
- MLC_i is the LMP component representing the marginal cost of losses (also referred to as γ) at bus *i* relative to the Reference Bus

4.2.2 Marginal Congestion Component Calculation

Midwest ISO calculates the marginal costs of congestion at each bus as a component of the bus-level LMP. The Marginal Congestion Component (MCC_i) of the LMP at bus *i* is calculated using the equation:

$$\text{(4-3)} \quad \mathrm{MCC}_i = -(\sum_{k=1}^{K} \mathrm{GSF}_{ik} * \mathrm{FSP}_k)$$

where:

- *K* is the number of thermal or interface transmission constraints (also called Flowgate)
- GSF_{ik} is the Generation Shift Factor for the generator at bus *i* on Flowgate *k* which limits flows across that constraint when an increment of power is injected at bus *i* and an equivalent amount of power is withdrawn at the Reference Bus. The industry convention is to ignore the effect of losses in the determination of GSFs.
- FSP_k is the Flowgate Shadow Price on Flowgate *k* and is equivalent to the reduction in system cost expressed in $/MWh that results from an increase of 1 MW of the capacity on Flowgate *k*.

4.2.3 Marginal Losses Component Calculation

Midwest ISO calculates the Marginal Losses Component (MLC_i) at each bus *i*. The MLC of the LMP at any bus *i* within Midwest ISO's Market Footprint is calculated using the equation:

$$\text{(4-4)} \quad \mathrm{MLC}_i = (\mathrm{DF}_i - 1) * \mathrm{MEC}_r$$

where:

- DF_i is the Delivery Factor for bus *i* to the system Reference Bus
- DF_i is equal to $(1 - \partial L/\partial G_i)$, where: L is system losses, G_i is "generation injection" at bus *i*, $\partial L/\partial G_i$ is the partial derivative of system losses with respect to generation injection at bus *i*, that is, the incremental change in system losses associated with an incremental change in the generation injections at bus *i* holding constant other injection and withdrawals at all buses other than the Reference Bus and bus *i*.
- MEC_r is the LMP component representing the marginal cost of energy at the Reference Bus, *r*

4.2.4 Hub Price Calculation

Midwest ISO calculates a hub price based on the LMPs for a set of buses that comprise the hub. These hub prices are the weighted average of the LMPs at the buses that comprise the hub. The weights are pre-determined by Midwest ISO and remain fixed.

The price for Hub *j* is:

$$\text{(4-5)} \quad \text{Hub Price}_j = \sum_{i=1}^{NH} \left(W_{Hi} * \mathrm{LMP}_i \right)$$

where:

- *NH* is the number of buses in Hub *j*
- W_{Hi} is the weighting factor for bus *i* in Hub *j*. The sum of the weighting factors must add up to 1.

4.2.5 Load Zone Price Calculation

Midwest ISO calculates a Load Zone price based on the LMPs for a set of buses that comprise the Load Zone. These Load Zone prices are the weighted average of the LMPs at the set of

buses that comprise the Load Zone. The Load Zone bus weight is equal to the fractional share of each Load bus in the total Load in the Load Zone in the hour.

The price for Load Zone *j* is:

$$\text{(4-6)} \quad \text{Load Zone Price}_j = \sum_{i=1}^{NZ} \left(\text{W}_{Zi} * \text{LMP}_i \right)$$

where:

- *NZ* is the number of Load buses in Load Zone *j*
- W_{Zi} is the load-weighting factor for bus *i* in Load Zone *j*. The sum of the weighting factors must add up to 1. These weights are based on State Estimator results from the 24-hour period, seven days prior to the Operating Day.

When the Load Zone Price is used for Settlements, it is subject to the following rules:

- Each Load Zone includes only the buses of Asset Owners who are in the zone and who have Load that is represented by that zone's definition. Asset Owners that have metered Load must either be settled at a zone defined by their Load points (zonal settlement) or must have a separate Load Zone created for each Load point (nodal settlement). Asset owners in retail choice areas where profiling, rather than metering is used, can be settled at an aggregate of all Load buses in the BA area.
- MPs who want to be billed at a zonal price must include in their zone all of the buses where energy deliveries are billed at the zonal price.

4.2.6 Multi-Element Flowgate Shadow Price Calculation

Midwest ISO, in addition to the calculation of the LMPs, calculates Flowgate Shadow Prices (FSPs) on sets of transmission constraints. Midwest ISO calculates the FSP on the set of transmission elements designated as a Flowgate, based on a weighted average of the transmission FSPs that comprise the Flowgate:

$$\text{(4-7)} \quad \text{Flowgate Shadow Price } f = \sum_{k=1}^{M} \left(\text{W}_k * \text{FSP}_k \right)$$

where:

- *f* is the index of Flowgates

- *k* is a transmission element in the Flowgate *f*
- *M* is the set of the transmission elements that comprise Flowgate *f*
- W_k is the weights attached to each of the *M* transmission elements that comprise Flowgate *f*. The sum of the weighting factors adds up to 1. For Flowgates comprised of one transmission element, the W_k for that element is equal to 1. Midwest ISO determines the W_k for transmission elements defined as Flowgates.
- FSP_k is the Flowgate Shadow Price on transmission element *k* and is equivalent to the reduction in system cost expressed in $/MWh that results from an increase of 1MW of the capacity on transmission element *k*.

4.2.7 External Interface Price Calculation

Midwest ISO calculates an External Interface price for all non-Midwest ISO Balancing Authorities. These prices are based on the LMPs for a set of generator buses that exist in external Balancing Authorities. Generally speaking, the set of buses used for an External Interface price is the set of generators in the external Balancing Authority for which the calculation is being done. If the external Balancing Authority is not in the Midwest ISO Network model, then an electrically equivalent Balancing Authority will be assigned for the Balancing Authority and the interface price for that non-modeled Balancing Authority will use the same interface price as is used for the electrical equivalent. Midwest ISO may need to change, which EPNodes are used in the External Interface price calculations as operational experience dictates.

The price for an External Interface *j* is:

$$\text{(4-8)}\quad \text{External Interface Price} = \left(\sum_{i=1}^{NE} LMP_i \right) / NE \qquad average\ \ of\ \ LMPs$$

where:

- *NE* is the number of buses in External Interface *j*

4.3 Market Participant Activities

The Energy Markets Instruments that are available for MP use in the Day-Ahead Energy Market must be submitted to Midwest ISO by 1100 hours EST the day prior to the Operating Day. Exhibit 2-1 of this BPM summarizes these Energy Markets Instruments. A detailed description of the input data requirements is provided in the *BPM for Energy Markets Instruments*.

5. Real-Time Energy Market Activities

The Real-Time Energy Market provides a continuous process for least cost balancing of supply and demand while recognizing current operating conditions. Midwest ISO uses a network model to accurately dispatch resources to match short-term demand forecast and manage congestion in Real-Time.

The Real-Time Energy Market creates resource dispatch basepoints and provides indicative Real-Time LMPs for injections and withdrawals within Midwest ISO's Market Footprint. Midwest ISO uses a Real-Time SCED optimization program to simultaneously balance injections and withdrawals, manage congestion, and produce LMPs. The Real-Time Energy Market clearing operates continuously on a five-minute basis. The SCED runs every five minutes to develop resource dispatch basepoints and NSI targets for the end of the next dispatch interval.

Exhibit 5-1 presents the timeline of the activities that are involved in the Real-Time Energy Market.

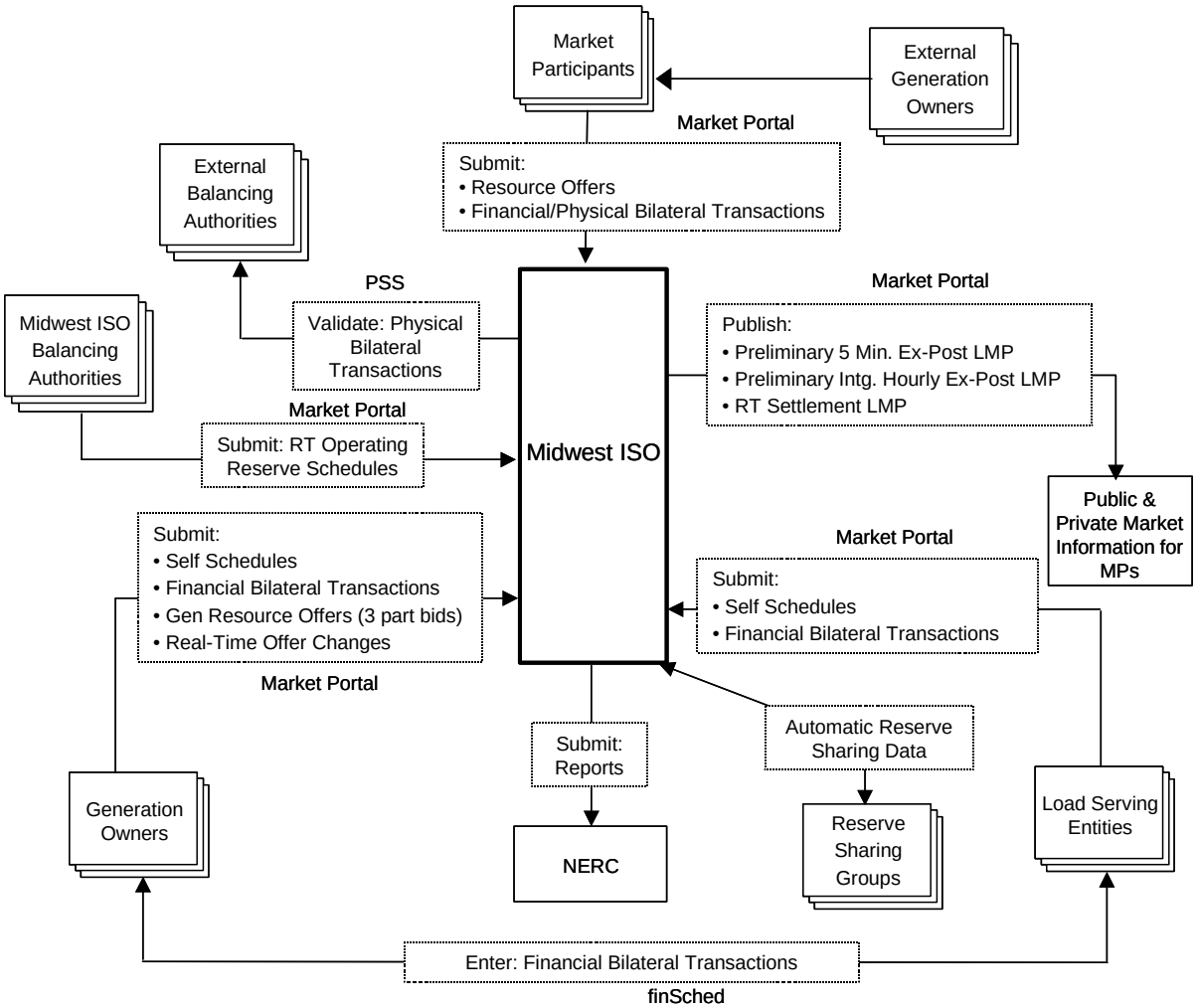
Exhibit 5-1: Real-Time Energy Market Activities Timeline

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
Data Required for Real-Time Energy Market		
OD-7 @ 0000	OD @ OH-30	Fixed Physical Bilateral Transactions into the Real-Time Energy Market
OD-7 @ 0000	OD @ OH-30	Dispatchable (Import Only) Dynamic Physical Bilateral Transactions into the Real-Time Energy Market
OD-7 @ 0000	OD+1 @ 1200	Financial Bilateral Transactions for the Real-Time Energy Markets
OD-7 @ 0000	OD @ OH-30	Generation Resource Offers into the Real-Time Energy Market
OD-7 @ 0000	OD @ OH-30	Demand Response Resource (DRR) Offers into the Real-Time Energy Market
Ongoing	OD @ RT-10 min.	Constraint limits applied and removed based on Midwest ISO's power system security analyses
	OD @ RT-10 min.	Automatic Reserve Sharing events upon initiation by Reserve Sharing Groups
Real-Time Energy Market Activities		
OD-1 @ 2000	OD-1 @ 2300	Review Load Forecasts and Reports
	OD @ 0000	Open/Close Operator's Log
OD @ 0600	OD @ 0800	Perform UDS 4 Hour Look-Ahead, as required
OD @ 1000	OD @ 1200	Perform UDS 4 Hour Look-Ahead, as required
OD @ 1400	OD @ 1600	Perform UDS 4 Hour Look-Ahead, as required
OD @ 0000 to OD @ 2300	OD @ 0045 to OD @ 2345	Perform UDS 1 Hour Look-Ahead (beginning at top of each OH) and notify affected Resources

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
	OD @ OH-30	Close the Real-Time Energy Market 30 minutes prior to the top of each Operating Hour
OD @ RT-10 Starts every 5 minutes	OD @ RT-5 Ends within 5 min. of start	Execute UDS
	OD @ RT-5	▪ Send Resource dispatch basepoints to BAs and Resource Operators ▪ Send NSIs to BAs
Real-Time LMP Calculation Sequence (see Section 6.1)		
OD = Operating Day OH = Operating Hour (00 to 23) RT = Real-Time (target time for UDS base points) UDS = Unit Dispatch System		DRR = Demand Response Resource LMP = Locational Marginal Price NSI = Net Scheduled Interchange BA = Balancing Authority

The interactions and data flows between the entities that participate in the Real-Time Energy Market are shown in Exhibit 5-2, excluding RAC.

Exhibit 5-2: Data Flow for Real-Time Energy Market (Excluding RAC)



5.1 Midwest ISO Activities

Midwest ISO clears the Real-Time Energy Market by determining the security-constrained dispatch that is the least costly means of balancing generation and Load (supply/demand) within the Market Footprint based on actual conditions, forecasted conditions, and on Resource Offers. The inputs to the SCED are identified and described below:

- ***Load Forecast*** – Midwest ISO forecasts Real-Time demand for use in the Real-Time Energy Market. The forecast is distributed to individual Load buses using the most recent State Estimator results.

- ***Network Model*** – The Real-Time Energy Markets network model is populated with the most recent State Estimator results before starting the Real-Time Energy Market clearing process. This includes the current output of Generation Resources. In addition, the current set of active constraints is obtained from the Constraint Logger (CLOGGER).

- ***Physical Bilateral Transactions*** – The expected values of Physical Bilateral Transactions for the following five-minute period, including any Transmission Load Relief (TLR), are obtained from the Physical Scheduling Software (PSS).

- ***Resource Information*** – The Real-Time Energy Market clears the Generation Resource and Demand Response Resource Offers for the next five-minute period.

- ***Reserve Sharing Groups*** – When the Midwest ISO is notified that a Reserve Sharing Group is active, Midwest ISO accounts for the Energy in the Offers of Generation Resources providing these reserves from within the identified BA areas. Each Generation Resource contributes a share of the reserve in proportion to the relative participation specified for that resource, subject to resource-specified constraints. Refer to Attachment B of the *BPM for Coordinated Reliability, Dispatch, & Control*.

Midwest ISO economically dispatches, subject to ramp rate and other resource constraints, Generation Resources and DRRs that effectively meet forecast Load and interchange requirements, subject to activated network constraints. The objective of the SCED algorithm is to minimize the as-offered Energy prices of Real-Time Energy procurement over the next dispatch interval, subject to network constraints and Resource operating constraints. Midwest ISO performs market dispatch functions primarily through the BAs. Basepoint information is also communicated directly to Generation Resources and DRRs. Specific generation units and DRRs interact directly with Midwest ISO to provide system support during Emergency situations.

The SCED program produces the following outputs:

- ***Generation Resource and DRR Basepoints*** – The Real-Time Energy Market clearing process develops the cleared amount of each offered Generation Resource and DRR for the five-minute period. Midwest ISO communicates Resource basepoints to the relevant BA, as well as to each Resource selected on a five-minute basis. Deviation from Dispatch Instructions may result in an Uninstructed Deviation penalty. Midwest ISO communicates Dispatch Instructions electronically to the MP responsible for scheduling and dispatching the Resource. All MPs responsible for responding to Dispatch Instructions must have the ability to receive electronic Dispatch Instructions from Midwest ISO. The basepoints are the end of period target for the five-minute period. All units that are on-line receive a basepoint instruction, regardless of whether they have submitted Offers or are Self-Scheduled. DRRs are not subject to Uninstructed Deviation penalties.

- ***Net Scheduled Interchange*** – Midwest ISO communicates the NSI to BAs on a four-second basis via ICCP and every five minutes via XML data transfers. The NSI is ramped linearly between five-minute targets and augmented with any new reserve sharing events to develop the four-second values. A backup NSI is also provided via XML every five minutes that does not include ramping information or immediate reserve sharing information. This five minute NSI is the desired NSI at the end of the five-minute period.

- ***Ex-Ante LMPs*** – The Real-Time Energy Market clearing process also develops ex-ante LMPs for the five-minute period. These values are not posted, but rather are used to establish the Resource basepoints.

The Real-Time Energy Market utilizes the same Network Model that is used in the Day-Ahead Energy Market, with all Real-Time network configurations and constraints as determined from the most recent State Estimator results.

Generation Resource ramping limits are enforced on expected generation from the current actual generation.

- For a Generation Resource providing regulation, the ramping range is calculated from the target basepoint of the preceding Real-Time Energy Market cycle and the offered ramp rate.

- For a Generation Resource not providing regulation, the ramping range is calculated from the target basepoint of the preceding Real-Time Energy Market cycle, the actual generation output according to the State Estimator, and the offered ramp rate.

5.1.1 Settling Uninstructed Deviations

Settlement of deviations from Dispatch Instructions (Uninstructed Deviations) is conducted subject to a Tolerance Band with minimum and maximum amounts as specified below. Penalties are assessed for deviations outside this band level.

Revenue Distribution from Uninstructed Deviation Charges

Midwest ISO distributes excess revenue received from Uninstructed Deviation charges to loads based on Load ratio share.

Tolerance Band

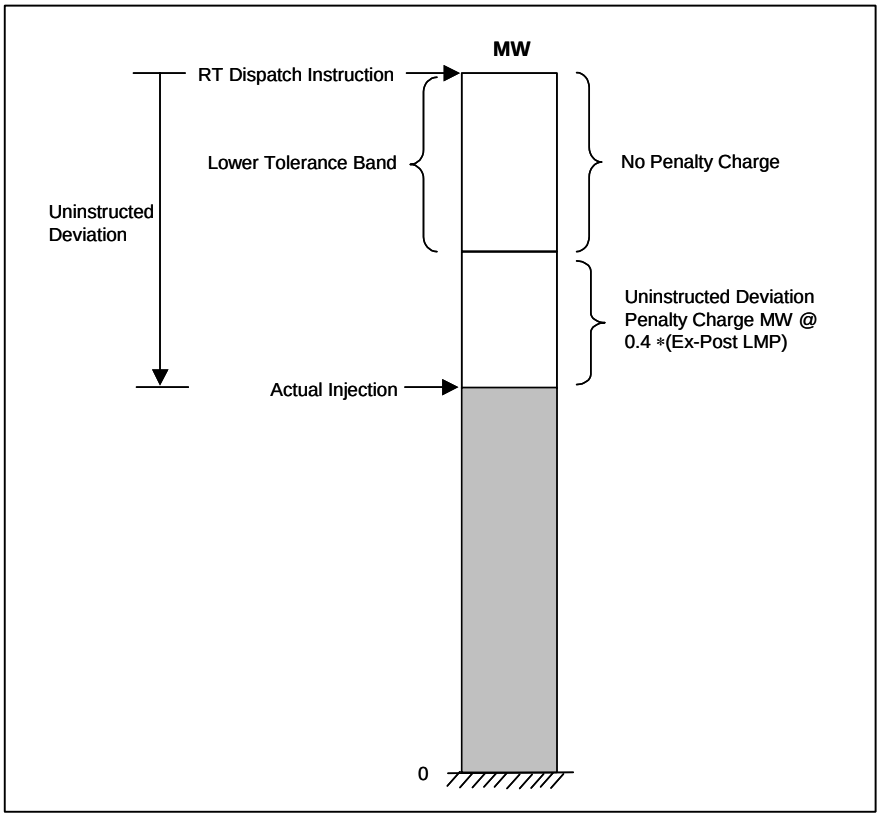
- ***Tolerance Band*** – The Tolerance Band consists of Actual Injections that are within plus 10% or minus 10% of the hourly average Dispatch Instructions for that Hour.
- ***Minimum and Maximum Amounts*** – The Tolerance Band as specified above is adjusted so that it is 5 MW at a minimum and 25 MW at a maximum.
- ***Regulation Capacity*** – The Tolerance Band is adjusted by adding the MW of Regulation Up and Regulation Down capacity that is provided by the Resource.

5.1.1.1 Settlement when Actual Injections are Less than the Dispatch Instructions in the Real-Time Energy Market

- ***Within the Tolerance Band*** – Transactions are settled with no additional penalty.
- ***Outside the Tolerance Band*** – In addition to the payments and charges settled, the Market Participant pays a penalty of the product of: (i) 40% of the hourly Ex-Post LMP calculated for that Hour at the applicable Market Participant's CPNode; and (ii) the positive difference between the Tolerance Band lower limit and the Actual Injections at that CPNode. The maximum penalty for Uninstructed Deviations below the Tolerance Band is calculated as the product of: (i) 40% of the Ex-Post LMP calculated for that Hour at the applicable Market Participant's CPNode; and (ii) the lower tolerance band limit MW. Exhibit 5-3 illustrates the penalty.

Note to Reader: Pumped storage units are treated as loads when pumping, therefore, Uninstructed Deviation does not apply in the pumping mode.

Exhibit 5-3: Uninstructed Deviation Penalty Charge when Actual Injection is less than Real-Time Dispatch Instruction

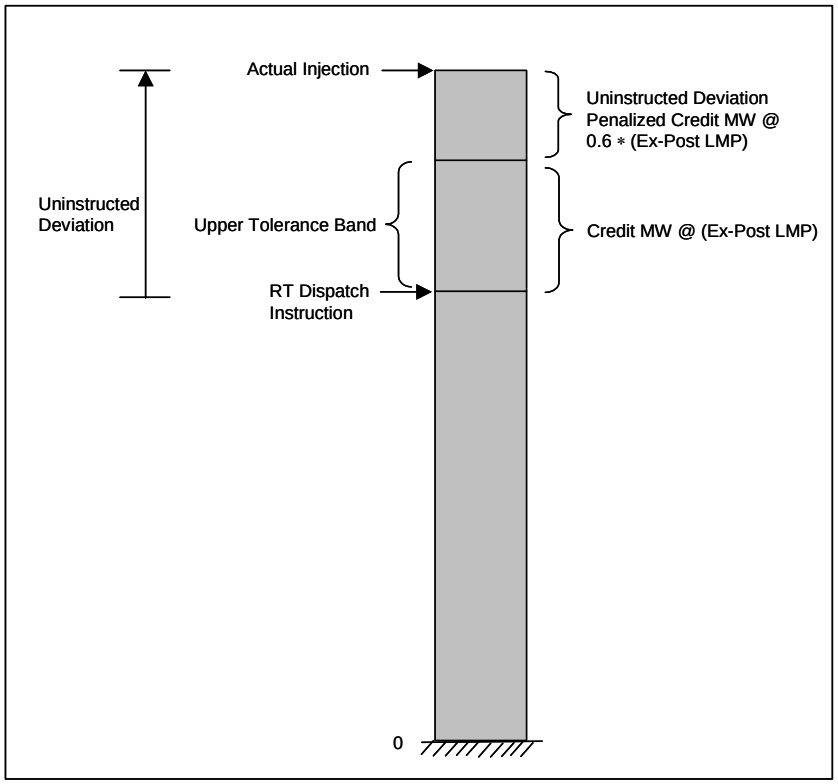


5.1.1.2 Settlement when Actual Injections are Greater than the Dispatch Instructions in the Real-Time Market

- ***Within The Tolerance Band*** – Transactions are settled with no additional penalty.

- ***Outside of the Tolerance Band*** – In addition to the payments and charges settled, the Market Participant is penalized by being paid only the product of: (i) 60% of the hourly Ex-Post LMP calculated for that Hour at the applicable Market Participant's CPNode; and (ii) the positive difference between the Actual Injections at that CPNode and the Tolerance Band upper limit. Exhibit 5-4 illustrates the penalty.

Exhibit 5-4: Uninstructed Deviation Penalized Credit when Actual Injection is Greater than Real-Time Dispatch Instructions



5.1.1.3 Exemption from Uninstructed Deviation Penalties

- ***Treatment of Intermittent Resources*** – Notwithstanding any provisions of the EMT to the contrary, Generating Resources certified by Midwest ISO to be Intermittent Resources are not subject to any penalties for Uninstructed Deviations.

- ***Treatment of Demand Response Resources*** – Notwithstanding any provisions of the EMT to the contrary, Demand Response Resources certified by Midwest ISO are not subject to any penalties for Uninstructed Deviations.

5.1.2 Calculating Inadvertent Interchange

Midwest ISO calculates Inadvertent Interchange Energy on a Balancing Authority basis but reports it on a Midwest ISO basis. The Inadvertent Interchange Energy is the difference between Net Scheduled Interchange (NSI) and Net Actual Interchange for Midwest ISO and is calculated separately for Peak and Off-Peak hours. Inadvertent Interchange is tracked on a monthly basis per individual Balancing Authority. At the end of the month, the inadvertent balances from the individual Balancing Authority are transferred to the Midwest ISO inadvertent

account. Inadvertent payback processes are included in the *BPM for Coordinated Reliability, Dispatch, & Control*.

5.1.3 Calculating Real-Time Energy Market Prices

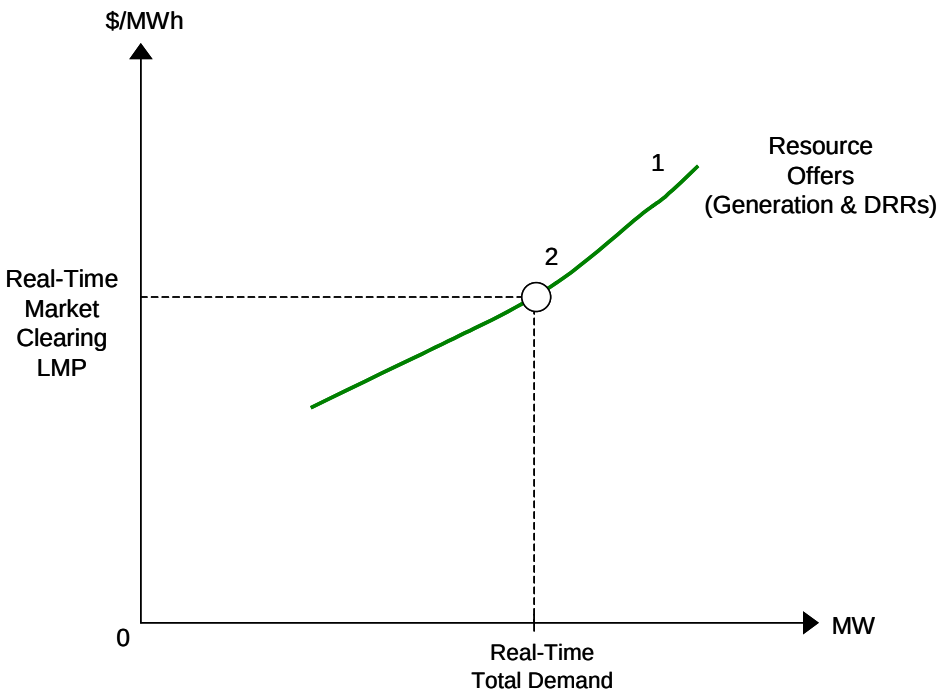
The Real-Time Energy Market clearing LMPs are determined as illustrated in Exhibit 5-5 for a specific five-minute time period. For this illustration, we ignore the effects of transmission losses and transmission constraints, i.e., all the LMPs have the same value. The procedure is:

1) Build the total Resource Offer curve

2) Establish the clearing price, which is the point where the Real-Time total demand intersects the total Resource Offer curve.

Real-time demand (loads) are charged (or credited) depending on their deviations from their Day-Ahead Energy Market schedules. Demand Bids (fixed or price-sensitive) do not apply to the Real-Time Energy Market.

Exhibit 5-5: Real-Time Energy Market Clearing LMP



5.1.4 Monitoring & Mitigating Real-Time Energy Market

Any Bid, Offer, scheduling adjustment, or changes in availability submitted to Midwest ISO by MPs to the Real-Time Energy Market are subject to Market Monitoring and Mitigation. Market power mitigation measures are described in the *BPM for Market Monitoring & Mitigation*.

5.1.5 Calculating Ex-Post LMPs

Midwest ISO calculates ex-post Real-Time Energy Market LMPs consistent with Real-Time operation. Only certain Resources are eligible to participate in setting the ex-post Real-Time LMPs. In principle, a Resource must be accepting and following Midwest ISO Dispatch Instructions to be eligible to set LMPs. A Generation or Demand Response Resource is considered to be following Dispatch Instructions if one of the following criteria is met:

- The Resource Offer price corresponding to the actual Resource output is less than or equal to the ex-ante Real-Time price for the Resource
- The Resource is operating within a defined threshold from the dispatch target
- The Generation or Demand Response Resource is logged as dispatched because of a transmission constraint

Refer to Section 6 of this BPM for further descriptions of the Ex-Post LMP Calculations.

5.2 Balancing Authority Activities

BAs perform the following activities to support the Real-time Energy Market:

- Provide Load Forecast
- Implement Midwest ISO Dispatch Instructions
- Manage Regulation Service
- Manage Operating Reserve Service
- Implement Automatic Reserve Sharing

5.2.1 Providing Load Forecast

Midwest ISO determines the Load forecast for the Real-Time Energy Market. Midwest ISO requires each BA within the Market Footprint to send an hourly, rolling seven-day Load forecast to Midwest ISO. This forecast must be at an hourly granularity and reflects the amount of Load in the BA area that is served by the generation that is modeled by Midwest ISO.

BAs submit the actual BA area Load via ICCP and may submit a short-term forecast of non-conforming Load via ICCP if desired. If non-conforming Load forecast data is not submitted, Midwest ISO assumes all Load is conforming in its short-term Load forecast for the Real-Time Energy Market.

When it is necessary to indicate the expected performance of a non-conforming Load or to make a correction to Midwest ISO's Real-Time Load forecast, the BA may indicate a Load forecast adjustment through the ICCP.

The *BPM for Coordinated Reliability, Dispatch, & Control* describes the load forecast process in greater detail.

5.2.2 Implementing Midwest ISO Dispatch Instructions

Dispatch is the process of signaling controllable resources to follow Resource basepoints and NSI. The BA (and the selected Resource) receives the five-minute basepoints and four-second NSI, as well as back-up NSI every five minutes via XML from Midwest ISO. The BA then implements this Dispatch Instruction through its AGC system. It should be noted that some Resources, e.g., Independent Power Producers (IPPs), might respond to the Dispatch Instructions from Midwest ISO rather than from a BA.

Dynamic schedules require Real-Time telemetry between the Native BA and the Attaining BA. Both apply adjustments to their four-second NSI target received from Midwest ISO, which is the Real-Time dynamic schedule amount from the telemetry observed by the two BAs.

Please refer to the *BPM for Coordinated Reliability, Dispatch, & Control* for further description of the Resource control process at the local level.

5.2.3 Managing Regulation Service

Regulation service is the process of coordinating the very-short-term dispatch of controllable Resources to maintain the balance between generation and demand requirements of a BA. It is the responsibility of the BAs to meet the NERC control performance standards.

BAs calculate Area Control Error (ACE) using scheduled interchange information, actual interchange information, and frequency bias information. BAs deploy regulation resources, both those owned by their affiliates and those self-provided by Transmission Customers pursuant to their option under Schedule 3, Regulation and Frequency Response Service, of the EMT. Each BA ensures that sufficient Resources are controlled to meet the applicable reliability standards for regulation performance.

5.2.4 Managing Operating Reserve Service

Operating reserve service is provided by the BAs and falls into two categories:

- ***Spinning Reserve*** – provided by generating units that are on-line and loaded at less than the Emergency Maximum Limit, ready to serve additional demand and which can be fully applied within 10 minutes.

- ***Supplemental Reserve*** – provided from the following resources:
  - Quick-start generation capable of serving demand within 10 minutes
  - Interruptible Load or DRRs that can be removed within 10 minutes

These reserves play an important role and have a direct impact on Midwest ISO's dispatch of Resources in the event that Automatic Reserve Sharing is invoked.

5.2.5 Implementing Automatic Reserve Sharing

When there is a call for reserves by one of the three Reserve Sharing Groups within Midwest ISO, it is the responsibility of the BA to respond in accordance with the provisions specified for their Reserve Sharing Group. Refer to the *BPM for Coordinated Reliability, Dispatch, & Control* for a detailed description.

5.3 Market Participant Activities

The Energy Markets Instruments that are available for MP use in the Real-Time Energy Market must be submitted at least 30 minutes prior to the start of the Operating Hour. Exhibit 2-1 of this BPM summarizes these Energy Markets Instruments. A detailed description of the input data requirements is provided in the *BPM for Energy Markets Instruments*.

5.4 Supply Shortage/Surplus Conditions

In the Real-Time Energy Market, actual conditions can change drastically from the planned environment. The supply shortage and supply surplus conditions that impact the Real-Time Energy Market are discussed in the following subsections.

5.4.1 Responding to System Shortage Conditions

If Midwest ISO's forecast of Real-Time demand within the Market Footprint or any transmission-constrained sub-region of the Market Footprint cannot be satisfied with all available Resource Offers (Generation, Self-Scheduled Resources, and Demand Response Resources) within the Market Footprint or the transmission-constrained sub-region of the Market Footprint at its hourly Dispatch Maximum Limit (MW), Midwest ISO issues a Maximum Generation Emergency (MGE)

warning message due to a shortage of economic Resources. The Midwest ISO will attempt to provide 60 minutes notice in declaring this event. Market Participants can then update their offers for the emergency ranges of their resources. Resource Offers for the upper Emergency Dispatch Range of each unit are used to calculate the least-cost dispatch solution. In addition to accepting emergency purchases from external resources as described in the emergency Energy Purchases section below, the Midwest ISO follows the steps listed below to clear the Real-Time Energy Market:

- ***Step One*** – employs the upper Emergency Dispatch Range of all on-line Generation Resources as required to clear the Real-Time Energy Market using SCED and calculates LMPs. Resource Offers for the upper Emergency Dispatch Range are used in the calculation.

- ***Step Two*** **–** calls on Operating Reserves to attempt to achieve the Energy balance. If so, the Operating Reserve capacity segments are dispatched in merit order and are Offered at $1000/MWh and are eligible to set the Ex-Post LMP

- ***Step Three*** – employs off-line Generation Resources that are designated as available only for Emergency Maximum Limit conditions to clear the Real-Time Energy Market using SCED

- ***Step Four*** – if the Energy balance is still not achieved, Midwest ISO resorts to Load shedding pursuant to Attachment Q, NERC Transmission Loading Relief Procedures Reference, of the EMT, until balance is achieved and the Real-Time Energy Market is cleared through SCED.

5.4.2 Responding to Contingency Reserve Dispatch During Capacity Shortage Event

During periods where there appears to be insufficient resources committed and available to serve Real-Time energy plus minimum operating reserve requirements in all or a portion of the Market Footprint, Midwest ISO follows procedures, as the Reliability Authority, leading to the declaration of an Energy Emergency Alert (EEA).

Following the declaration of an EEA level 2 or level 3, Midwest ISO may make contingency reserve capacity available to serve system Energy requirements in order to avoid interruption of firm Load.

In the event that Midwest ISO makes contingency reserve capacity available for dispatch to serve energy requirements during an EEA level 2 or level 3:

- The submitted offer price for a contingency reserve capacity segment released for dispatch in the Real-Time Energy Market is replaced with a floor price.
- Contingency reserve capacity segments dispatched in merit order (based on offer equal to the floor price) are eligible to set and receive Real-Time LMPs.

5.4.3 Responding to System Surplus Conditions

If the sum of the Self-Scheduled Resources and bilateral scheduled supply within the Market Footprint or any transmission-constrained sub-region of the Market Footprint exceeds Midwest ISO's forecast of Real-Time demand within the Market Footprint or the transmission-constrained sub-region of the Market Footprint, Midwest ISO follows the steps listed below to clear the Real-Time Energy Market:

- ***Step One*** – employs the lower Emergency Dispatch Range of all on-line Resources as required to clear the Real-Time Energy Market using SCED and calculates LMPs. Resource offers for this lower Emergency Dispatch Range are used in the calculation. The specifications for these lower Emergency Dispatch Range Resource Offers are developed in the *BPM for Energy Markets Instruments*.
- ***Step Two*** – if the Energy balance is not achieved after the first step, Midwest ISO reduces supply according to specified scheduling priorities, listed from highest to lowest. All supply is reduced by decommitting units with the shortest Start-Up times in the appropriate area. Supply associated with Financial Bilateral Transactions will not be reduced to the extent feasible. In these cases, Offers are set at negative $30/MWh.

5.5 Emergency Energy Purchases

During a Maximum Generation Emergency, the Midwest ISO will contact neighboring external Operators and indicate that emergency energy is needed. The Midwest ISO will select energy offers from these external entities that offer emergency energy as necessary and these emergency offers shall be implemented in the form of a schedule in the PSS. Note that transmission service on external non-Midwest ISO transmission provided may be needed to effectuate the schedule. The Midwest ISO will implement and curtail these schedules with as much notice as practical to allow for a reasonable transition into and out of the Maximum Generation Emergency condition.

5.6 Real-Time Energy Market Backup Procedures

Refer to the *BPM for Coordinated Reliability, Dispatch, & Control* for details.

6. Energy Market Closure Activities

This section describes the activities that take place after the closure of the Day-Ahead and Real-Time Energy Markets, and prior to the "Day 7" settlements. These activities are separated into two parts:

- Real-Time LMP calculations that occur on a five-minute periodic basis
- Hourly and daily LMP calculations and verification in preparation for settlement and billing

6.1 Real-Time LMP Calculation

Midwest ISO calculates the Real-Time price of Energy at the CPNodes. The LMPs, Hub prices, External Interface prices, and Load Zone prices include separate components for the marginal costs of energy, congestion, and losses. Preliminary Real-time Energy Market LMPs are calculated and posted every five minutes. The five-minute LMPs are combined to form the hourly Real-time Energy Market LMPs used for Settlement. This section describes the process by which after-the-fact prices (called ex-post LMPs) are calculated.

6.1.1 Real-Time LMP Calculation Sequence

The calculation of Real-Time LMPs is performed periodically every five minutes. The sequence of operations that is repeated every five minutes is shown in Exhibit 6-1.

Exhibit 6-1: Real-Time LMP Calculation - Timeline

Beginning Time in minutes	Ending Time in minutes	Description of Processes and Events
Unit Dispatch System – Repeat Every 5 Minutes		
	RT-10	Acquire initial conditions data and RT Load forecast for UDS
RT-10	RT-5	Execute UDS for RT, producing desired resource outputs, NSIs, and ex-ante LMPs
	RT-5	Send resource basepoint and NSI targets for RT to BAs
Balancing Authority – Automatic Generation Control – Execute Continuously		
	RT-5	Receive resource basepoint and NSI targets from Midwest ISO
RT-5	RT	Send control signals to resources to ramp towards their RT basepoints
Ex-Post LMP Calculator – Repeat Every 5 Minutes		
	RT	Acquire Real-Time and State Estimator data
RT	RT+5	Calculate Preliminary Ex-Post LMPs for RT
	RT+5	Post Preliminary Ex-Post LMPs for CPNodes and save for hourly calculations

RT = Real-Time (target time for UDS basepoints) BA = Balancing Authority
UDS = Unit Dispatch System
NSI = Net Scheduled Interchange

The following sequence of processes produces the ex-post LMPs:

- ***Real-Time Unit Dispatch System (UDS)*** – executes during the five-minute period, beginning at (RT-10 minutes), where the time "RT" serves as a reference point for discussion purposes. At time (RT-5 minutes), the results of the UDS Security Constrained Economic Dispatch (SCED) for power system conditions projected at (RT minutes) are published. The UDS outputs include:
  - Generator and DRR Dispatch Instructions
  - Dispatchable Dynamic Physical Bilateral Transaction MW Dispatch
  - Balancing Authority Net Scheduled Interchange (NSI)
- ***Balancing Authority Generation Control*** – the Dispatch Instructions from UDS are sent to the respective Market Participants and to their respective BA computer systems that in turn produce control signals, which are sent to the power plants for generation adjustment and Real-Time system control.
- ***Ex-Post LMPs*** – a set of preliminary ex-post LMPs is produced at (RT+5 minutes) using the UDS Dispatch Instructions for (RT minutes) and actual power system conditions and the generator outputs at (RT minutes).

6.1.2 Ex-Post LMP Calculation

The ex-post LMP calculation is scheduled to execute automatically every five minutes. Ex-post LMPs are calculated by combining the observed state of the power system at (RT minutes) and the UDS Dispatch Instructions for the expected conditions for (RT minutes). The ex-post LMP calculation process monitors the performance of Generation Resources with respect to the Dispatch Instructions to determine the eligibility of Resources to set the ex-post LMP.

Specifically, this activity, called pre-processing, is essentially a performance-monitoring program that measures the actual Resource response against the desired response to determine if a Resource is following Dispatch Instructions. The pre-processor accepts the input data and determines which Resources are eligible to participate in the LMP calculation and the price at which they are considered. Eligible Resources are deemed flexible and given a small tolerance around their State Estimator rate of Energy production or consumption to allow flexibility in finding a feasible solution while at the same time holding the LMP calculations near the observed operating point. The price assigned for each eligible Resource is constant for the entire flexible range allocated to the Resource. The outputs of the pre-processing stage are:

- Resource eligibility (fixed or flexible status) for LMP calculations
- Limits on the rate of Energy production or consumption for flexible Resource

- The single price at which the flexible Resource participates in setting the LMP for the entire allocated flexible range of that Resource

Ex-post LMPs are then calculated determining the marginal value of energy at buses and CPNodes based on the system state and observed performance. Input data to the ex-post LMP calculation includes:

- Resource Offers describing the Resource's price and quantity Offer curves and Resource status, which describe the operating mode of the Resource (e.g., on for market economics, on for transmission, on for company)
- Dispatchable Dynamic Physical Bilateral Transaction Offer prices
- Dispatch Instructions including the ex-ante LMPs calculated by the Real-Time UDS.
- Active constraints are those system constraints logged by the Real-Time Operator as being actively controlled. Active constraint data includes the sensitivities (or shift factors) of all CPNodes to that specific constraint.
- The State Estimator solution is a complete set of injection and withdrawal data at a particular time. This data determines the observed level of injection or withdrawal for each Resource and is used for performance monitoring.
- Network topology files for the current topology

All of this data is dynamic to some degree. However, all inputs to the LMP Calculator are applied to the same time at (RT minutes) to calculate the ex-post LMPs. The automatically calculated ex-post LMPs are posted as preliminary LMPs and not used for Settlement purposes until the daily verification of ex-post LMPs is completed.

6.2 Hourly LMP Calculation

The Real-Time ex-post LMPs are integrated to produce hourly values that are verified as Settlement quality after the Operating Day. Exhibit 6-2 presents the sequence of processes following Real-Time and culminating in Settlement.

Exhibit 6-2: Hourly & Daily LMP Calculation/Verification - Timeline

Beginning Day @ Time	Ending Day @ Time	Description of Processes and Events
Preliminary Hourly Ex-Post LMP Calculator – Repeat Following Each OH		
	OD @ OH+1:00	Acquire the Preliminary 5-minute Ex-Post LMPs that were calculated for the OH
OD @ OH+1:00	OD @ OH+1:mm	Calculate the Preliminary Hourly Ex-Post LMP
	OD @ OH+1:mm	Post the Preliminary Hourly Ex-Post LMP for information only
Real-Time Ex-Post LMP Verification Window – Repeat Following Each OD		
OD+1 @ hhmm	OD+5B @ 1200	Acquire Ex-Post LMP data for the OD and make any necessary corrections
	OD+1@ 1200	Post the preliminary hourly ex-post LMPs for the OD
	OD+5B @ 1200	Posting Deadline for the Final Hourly Ex-Post LMPs for the OD
Bilateral Transactions & Interchange Schedules – Repeat for Each OD		
OD-7 @ 0000	OD+1 @ 1200	Financial Bilateral Transactions can be entered for the Day-Ahead and Real-Time Energy Markets
OD+1 @ 0000	OD+1 @ 1200	ATF Checkout of area interchange schedules for the OD is performed by the BAs and Midwest ISO
OD @ OH+1:00	OD+2B @ 1200	ATF Entry of Reserve Sharing and other Emergency Schedules for the OD is performed by the BAs and Midwest ISO
Energy Markets Settlements – Repeat Following Each OD		
	OD+6 @ 1200	Acquire all validated settlement data
OD+6 @ 1200	OD+7@ hhmm	Prepare Energy Markets Settlements
	OD+7+1B @ 0800	Publish the Energy Markets Settlements (privately to MPs)

OD = Operating Day
OH = Operating Hour (00 to 23)
B = Business Day
ATF = After-the-Fact
BA = Balancing Authority

6.2.1 Hourly Bus LMPs

Hourly average LMPs are computed to be the time-weighted average of 5-minute Real-Time ex-post LMPs. These calculations are defined below.

Hourly system marginal price for Energy at node ei:

$$\text{(6-1)} \quad \overline{\lambda}_{ei,h} = \begin{cases} \dfrac{\sum_{t \in Hour(h)} P_{ei,t} * \lambda_t * AMinutes_t}{\sum_{t \in Hour(h)} P_{ei,t} * AMinutes_t}, & \text{if denominator is not zero} \\ \dfrac{\sum_{t \in Hour(h)} \lambda_t * AMinutes_t}{\sum_{t \in Hour(h)} AMinutes_t}, & \text{otherwise} \end{cases}$$

Where

- *Aminutes*$_t$ is the number of minutes the LMP Calculator case is active for. The active minutes is calculated to be the number of minutes between the current case and the previous successful LMP Calculator case.

- λ_t is the system marginal price for Energy for interval *t*

For EPNodes:

- $P_{ei,t}$ is the total Real-Time MW injection at node *ei* and interval *t*

For External Interface CPNodes:

- $P_{ei,t}$ is the net scheduled Real-Time transaction MW at interface node *ei* and interval *t*

Hourly marginal transmission loss price at node *ei*:

$$\text{(6-2)} \quad \overline{\gamma}_{ei,h} = \begin{cases} \dfrac{\sum_{t \in Hour(h)} P_{ei,t} * \gamma_{ei,t} * AMinutes_t}{\sum_{t \in Hour(h)} P_{ei,t} * AMinutes_t}, & \text{if denominator is not zero} \\ \dfrac{\sum_{t \in Hour(h)} \gamma_{ei,t} * AMinutes_t}{\sum_{t \in Hour(h)} AMinutes_t}, & \text{otherwise} \end{cases}$$

Where:

- *AMinutes*$_t$ is the number of minutes the LMP Calculator case is active for. The active minutes is calculated to be the number of minutes between the current case and the previous successful LMP Calculator case.

- $\gamma_{ei,t}$ is the Transmission Loss Price at node *ei* for interval *t*

For EPNodes:

- $P_{ei,t}$ is the total Real-Time MW injection at node *ei* and interval *t*

For External Interface CPNodes:

- $P_{ei,t}$ is the net scheduled Real-Time transaction MW at interface node *ei* and interval *t*

Hourly marginal transmission congestion price at node *ei*:

$$\text{(6-3)} \qquad \overline{\rho}_{ei,h} = \begin{cases} \dfrac{\sum_{t \in Hour(h)} P_{ei,t} * \rho_{ei,t} * AMinutes_t}{\sum_{t \in Hour(h)} P_{ei,t} * AMinutes_t}, & \text{if denominator is not zero} \\ \dfrac{\sum_{t \in Hour(h)} \rho_{ei,t} * AMinutes_t}{\sum_{t \in Hour(h)} AMinutes_t}, & \text{otherwise} \end{cases}$$

Where:

- *AMinutes*$_t$ is the number of minutes the LMP Calculator case is active for. The active minutes is calculated to be the number of minutes between the current case and the previous successful LMP Calculator case.

- $\rho_{ei,t}$ is the Transmission Congestion Price at node *ei* for interval *t*

For EPNodes:

- $P_{ei,t}$ is the Total Real-Time MW injection at node *ei* and interval *t*

For External Interface CPNodes:

- $P_{ei,t}$ is the net scheduled Real-Time transaction MW at interface node *ei* and interval *t*

Composite hourly LMP at node *ei*:

$$\text{(6-4)} \quad \overline{LMP}_{ei,h} = \overline{\lambda}_{ei.h} + \overline{\gamma}_{ei,h} + \overline{\rho}_{ei,h}$$

6.2.2 Hourly Aggregate Node LMPs

The following are hourly average calculations for aggregate nodes. A distinction is made between the calculation for aggregates that represent a combined cycle (and cross compound) and all other aggregate nodes (which include hub and zone aggregates).

Hourly system marginal price for energy at aggregate pnode api:

The hourly energy prices at aggregate nodes are weighted averages of Energy prices at participating electrical nodes. This is expressed as follows:

$$\text{(6-5)} \quad \overline{\lambda}_{api,h} = \frac{\sum_{ei \in pNode(api)} \overline{w}_{ei,h} * \overline{\lambda}_{ei,h}}{\sum_{ei \in pNode(api)} \overline{w}_{ei,h}}$$

Where:

For combined cycle (and cross compound) aggregates the hourly average weighting factor for electrical node *ei* participating in aggregate combined cycle (and cross compound) pnode *api* is:

$$\text{(6-6)} \quad \overline{w}_{ei,h} = \frac{\sum_{t \in Hour(h)} P_{ei,t} * AMinutes_t}{\sum_{ei \in pNode(api)} \left(\sum_{t \in Hour(h)} P_{ei,t} * AMinutes_t \right)}$$

Where:

- $AMinutes_t$ is the number of minutes the LMP Calculator case is active for. The active minutes is calculated to be the number of minutes between the current case and the previous successful LMP Calculator case.
- $P_{ei,t}$ is the Total Real-Time MW injection at node *ei* and the interval *t*

For all other aggregates (including hub and zone aggregates):

- $\overline{w}_{ei,h}$ is the weighting factor from the database for electrical node ei participating in aggregate pnode *api*

Hourly marginal transmission loss price at aggregate pnode *api*:

The hourly marginal losses prices at aggregate nodes are weighted averages of marginal losses prices at participating electrical nodes. This is expressed as follows:

$$\text{(6-7)} \quad \overline{\gamma}_{api,h} = \frac{\sum_{ei \in pNode(api)} \overline{w}_{ei,h} * \overline{\gamma}_{ei,h}}{\sum_{ei \in pNode(api)} \overline{w}_{ei,h}}$$

Where:

- $\overline{\gamma}_{ei,h}$ is the hourly marginal transmission loss price at node *ei* (see Equation 6-2)

Hourly marginal transmission congestion price at aggregate pnode *api*:

The hourly marginal transmission congestion prices at aggregate nodes are weighted averages of transmission congestion prices at participating electrical nodes. This is expressed as follows:

$$\text{(6-8)} \quad \overline{\rho}_{api,h} = \frac{\sum_{ei \in pNode(api)} \overline{w}_{ei,h} * \overline{\rho}_{ei,h}}{\sum_{ei \in pNode(api)} \overline{w}_{ei,h}}$$

Where:

- $\overline{\rho}_{ei,h}$ is the hourly marginal transmission congestion price at node *ei* (see Equation 6-3)

Composite LMPs at aggregate node api:

$$\text{(6-9)} \quad \overline{LMP}_{api,h} = \overline{\lambda}_{api,h} + \overline{\gamma}_{api,h} + \overline{\rho}_{api,h}$$

6.2.3 LMP Replacements

In the event of a data input failure or program failure that make 5-minute LMPs unavailable, ‘replacements’ are considered in the calculation of the time-weighted hourly average in the following way:

- Where the stale data or program failure exists for eleven or fewer intervals within the same Hour, the affected intervals are replaced with data from the last successful interval or the next successful interval, as appropriate, within the same Hour.

- Where the stale data or program failure exists for all intervals within the same Hour, the following occurs:

  – Where the Hour is unconstrained, the Hourly Ex-Post LMP is replaced with the loss-adjusted hourly integrated Dispatch Instruction

  – Where the system is constrained, the Ex-Post LMP values are recalculated using data from the best available sources. The Ex-Post LMP values are recalculated for each five-minute dispatch interval and then integrated and weighted in accordance with the standard procedure.

6.3 Ex-Post LMP Verification

The LMP verification process is an off-line analysis that occurs after the Operating Day. The purpose of the verification process is to identify and correct any periods with error conditions or incorrect results (as determined by the verification operator). The verification process ensures the ex-post LMPs used for the Real-Time Energy Market Settlement accurately reflect the real-time power system conditions and Real-Time Operator actions. Following the verification process, the hourly average LMPs based on the verified five-minute ex-post LMPs are sent to the Settlement system.

6.3.1 Verification Process

The verification process is an audit of the 5-minute Real-Time Ex-Post LMPs for the Operating Day. The verification staff actively monitors both inputs and outputs of the LMP calculation process. Predetermined limits have been established for these inputs and outputs, and whenever these limits are violated, the specific interval case is flagged for in-depth analysis. In addition to the cases flagged for violating a limit, the verification staff may randomly flag LMP cases for audit to ensure that a sufficient cross-section of cases has been analyzed. For these flagged cases, the verification staff then performs a detailed review of the inputs/outputs to the LMP calculation process, operator actions affecting each 5-minute case audited, and all records available describing the Midwest ISO system state during the 5-minute period of time for which the LMP was calculated. The verification process is intended to ensure appropriate and accurate inputs were fed into the LMP calculation process leading to appropriate and accurate 5-minute interval level and hourly settlement-grade LMPs, as well as to ensure LMPs accurately reflect actual system conditions, which occurred. If the in-depth analysis of flagged cases reveals an error, the verification staff will determine a proposed correction in an off-line

environment. The Market Pricing Analyst will then review the proposed solution with a second analyst (peer review) to determine that the most appropriate resolution is achieved. If the peer review concurs, the changes are then made in the production environment, and LMPs are approved for settlements.

6.3.2 Verification Staff Actions

The verification staff drives the verification process from the LMP Market Operator Interface (MOI). Five-minute inputs and results describing pricing nodes, Binding Transmission Constraints, and any manual overrides specified in the Real-Time LMP process are available for review. The displays will help to identify any problem intervals and to examine the data within those intervals. If a problem is uncovered the verification operator can change specific inputs for the case from the LMP MOI. As with the Real-Time Operator overrides, the verification operator is able to specify the include/exclude overrides. Once the verification operator has changed the inputs, the affected intervals can be re-run. Such changes may be required due to logging errors, data errors, or other misrepresentation of actual operating conditions. The same interval may be re-run multiple times if additional data changes are required. The final modifications made to a case are captured in a daily modification file stored with the other case files.

Results from the re-run are reviewed from the LMP MOI summary screens with the later run replacing the original output data on the displays. The process of reviewing results, changing inputs and re-running is repeated for all problem intervals from the verification day. Once the market pricing analyst is satisfied with the day's results, the day is 'approved.' The approval process recalculates hourly averages and indicates the results are suitable for distribution. The market pricing analyst performs the LMP verification process after the Operating Day. Once an Operating Day is approved, Real-Time Energy Market results may no longer be modified.

6.3.3 LMP Results Posting

Preliminary hourly ex-post LMPs and their components are normally posted for all CPNodes by 1200 hours EST the day after the Operating Day (OD+1). Any posting of final Hourly Ex-Post LMPs exceeding five Business Days from the applicable Operating Day requires approval by Midwest ISO's Board of Directors.[1]

[1] Refer to EMT Section 40.2.12(c).