ERCOT MARKET EDUCATION
Transmission 101
Protocol Disclaimer

This presentation provides a general overview of the Texas Nodal Market and is not intended to be a substitute for the ERCOT Protocols, as amended from time to time. If any conflict exists between this presentation and the ERCOT Protocols, the ERCOT Protocols shall control in all respects.

For more information, please visit:

http://www.ercot.com/mktrules/nprotocols/
Housekeeping

- Restrooms
- Refreshments
- Attendance sheet
- Exam
- Questions

Please turn off cell phones & other electronics
This course is designed for:

- Transmission Service Provider Operators
- ERCOT Transmission System Operators

Other audiences:

- TSP/QSE Outage planning & coordination personnel
- Operations support & planning engineers
- Engineering technicians
- IT staff, Management
Introductions

Please let us know your:

- Name
- Company for which you work
- Market Entity
  - QSE
  - TSP
  - ERCOT
  - Resource Entity
  - Other
- Experience in the industry
Upon completion of this course, be able to describe:

- Overall structure of the ERCOT Nodal Market
- Network modeling rules & processes
- Outage coordination rules & processes
- Constraint management plans
- TSP activities which effect:
  - Congestion Revenue Rights (CRR)
  - Day-Ahead Market (DAM)
  - Adjustment Period
  - Real-Time Operations
Modules in this course include:

- **Module 1**: ERCOT Market at a Glance
- **Module 2**: Network Modeling
- **Module 3**: Outage Coordination
- **Module 4**: Transmission Constraint Management
- **Module 5**: Congestion Revenue Rights
- **Module 6**: Day-Ahead through Real-Time
- **Module 7**: Additional Real-Time Topics
Module 1:
ERCOT Market at a Glance
Upon completion of this module, you will be able to:

- Describe an overview of the ERCOT Nodal Market
- Describe ERCOT, TSP, and QSE/RE responsibilities
- Describe Locational Marginal Price (LMP) basics
- Describe relationships between transmission operations and LMP calculations
Compliance Relationships

[Diagram showing relationships between entities such as LSE, QSE, ERCOT, PUCT, FERC, NERC Regional Entity, and Consumers, with arrows indicating data, operations, and settlement connections.]
Roles and Responsibilities

ERCOT Operations

- Coordinate transmission system planning
- Process Network Model revision requests and outages
- Ensure transmission system reliability
- Facilitate markets [CRR, DAM, RTM, Retail Competition]
- Operate Ancillary Service, Day-Ahead and Real-Time Energy markets
- Provide timely information relevant to the operation of the ERCOT System and markets
Transmission Service Providers (TSP)

• Coordinate transmission system planning
• Update & validate Network Operations Models
• Keep ERCOT continually informed of transmission outages and updates
• Provide accurate and timely operational data
• Comply with ERCOT dispatch instructions
QSE and Resource Entity (QSE/RE)

- Update Network Operations Model through Resource Registration process
- Coordinate transmission operations of Resource interconnect
- Keep ERCOT continually informed of Resource and transmission outages and updates
- Provide accurate and timely operational data
- Comply with ERCOT dispatch instructions
Overview: Registration
All Market Participants are required to register and sign a Standard Form Market Participant Agreement to participate in the ERCOT market.

Registration is not only a “One-time” event; but an ongoing obligation to maintain accurate data in ERCOT systems.
Each Market Participant must register with ERCOT by submitting the applicable registration application.
Registrants demonstrate they are qualified to perform the functions they’ve registered for per Protocol.
Roles of Registrants

All Distribution Service Providers Designate a Transmission Operator.
ERCOT settles financially with QSEs and CRR Account Holders. QSEs and CRR Account Holders must satisfy ERCOT's creditworthiness requirements.
Overview: Network Modeling

Network Modeling
- Network Operations Model
- Network Operations Model Change Request (NOMCR)

CRR Auction
- Semi-Annual & Monthly Auctions
- CRR Offers and Bids
- PTP Options and Obligations

Reliability Unit Commitment
- Transmission Security Analysis
- Resource commitment
- Day-Ahead RUC
- Hourly RUC

Real-Time Operations
- Network Security Analysis
- Security Constrained Economic Dispatch (SCED)
- Load Frequency Control (LFC)

Market Information System (MIS)
- Access Market Reports
- Submit Market Inputs
- Download Information
- Access Market Reports
- Submit Market Inputs
- Download Information
Network Model Management System (NMMS)

- Produces a Network Operations Model
- Provides model information for all other network models
- Provides a single repository for model information and management of model changes
Network Operations Model Operational Impacts

- Real-Time Dispatch
- Reliability Unit Commitment
- Used to produce other Network Models
Network Operations Model Operational Impacts

- Establishes the field for Market Operations
- Basis to modeling supply and demand
- Interface between market and power physics

Important to Market Transparency
Overview: CRR Auction
What is a Congestion Revenue Right (CRR)?

• A financial instrument that may be used as a hedge against congestion costs.

More information available at: http://www.ercot.com/services/training
Overview: Day-Ahead Operations

- Registration
  - Market Participants
  - Relationships
  - Assets
  - Qualification

- CRR Auction
  - Semi-Annual & Monthly Auctions
  - CRR Offers and Bids
  - PTP Options and Obligations

- Reliability Unit Commitment
  - Transmission Security Analysis
  - Resource commitment
  - Day-Ahead RUC
  - Hourly RUC

- Real-Time Operations
  - Network Security Analysis
  - Security Constrained Economic Dispatch (SCED)
  - Load Frequency Control (LFC)

- Market Information System (MIS)
  - Access Market Reports
  - Submit Market Inputs
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  - Download Information

- Day-Ahead Market
  - Energy Offers and Bids
  - Ancillary Service Offers
  - PTP Obligation Bids

- Adjustment Period
  - Energy Offers
  - Trades
  - Current Operating Plans
  - Supplemental Ancillary Services Market (SASM)

- Settlement
  - Statements & Invoices
  - Settlement Disputes
Day-Ahead Market (DAM)

- Daily, “co-optimized” process
- Voluntary participation
- Financially binding
Day-Ahead Market Co-Optimization

Evaluates Offers & bids to ensure best overall cost
Overview: Reliability Unit Commitment

- **Registration**
  - Market Participants
  - Relationships
  - Assets
  - Qualification

- **CRR Auction**
  - Semi-Annual & Monthly Auctions
  - CRR Offers and Bids
  - PTP Options and Obligations

- **Reliability Unit Commitment**
  - Transmission Security Analysis
  - Resource Commitment
  - Day-Ahead RUC
  - Hourly RUC

- **Real-Time Operations**
  - Network Security Analysis
  - Security Constrained Economic Dispatch (SCED)
  - Load Frequency Control (LFC)

**Market Information System (MIS)**
- Access Market Reports
- Submit Market Inputs
- Download Information
- Access Market Reports
- Submit Market Inputs
- Download Information

**LMP**
- Monitor Credit
- Monitor Performance
- Update Outages
- Update and Validate Current Operating Plans (COPs)

- Network Modeling
  - Network Operations Model
  - Network Operations Model Change Request (NOMCR)

- Day-Ahead Market
  - Energy Offers and Bids
  - Ancillary Services Offers
  - PTP Obligation Bids

- Adjustment Period
  - Energy Offers
  - Traces
  - Current Operating Plans
  - Supplemental Ancillary Services Market (SASM)

- Settlement
  - Statements & Invoices
  - Settlement Disputes
Day-Ahead Reliability Unit Commitment (DRUC) Fundamentals

- One instance of RUC
- Ensures reliability - physically and financially binding
- Executed daily after the Day-Ahead Market
Hourly Reliability Unit Commitment (HRUC) Fundamentals

- Another instance of RUC
- Ensures reliability - physically and financially binding
- Executed at least hourly
Overview: Adjustment Period

Market Information System (MIS)

- Access Market Reports
- Submit Market Inputs
- Download Information
- Access Market Reports
- Submit Market Inputs
- Download Information

- Registration
  - Market Participants
  - Relationships
  - Assets
  - Qualification

- CRR Auction
  - Semi-Annual & Monthly Auctions
  - CRR Offers and Bids
  - PTP Options and Obligations

- Reliability Unit Commitment
  - Transmission Security Analysis
  - Resource commitment
  - Day-Ahead RUC
  - Hourly RUC

- Real-Time Operations
  - Network Security Analysis
  - Security Constrained Economic Dispatch (SCED)
  - Load Frequency Control (LFC)

- Adjustment Period
  - Energy Offers
  - Trades
  - Current Operating Plans
  - Supplemental Ancillary Services Market (SASM)
QSE Activities during the Adjustment Period

- Submit offers, trades, schedules
- Request Resource decommitments
Supplemental Ancillary Services Market (SASM)

• If insufficient AS capacity, ERCOT executes a SASM during the Adjustment Period
TSP Activities in the Adjustment Period

- Update the Outage Scheduler as needed

Outage Scheduler impacts:
- Day-Ahead Market
- Reliability Unit Commitment
- Hourly Transmission Security Analysis
Purpose of Real-Time Operations

• Match generation with demand
• Operate transmission system within established limits
• Monitor and maintain voltage support
Process used to determine *optimal* dispatch:

- Security Constrained Economic Dispatch (SCED)

Every 5 minutes, SCED calculates:

- *Resource-specific* Base Points
- Locational Marginal Prices
Real-Time Operations

- Load Frequency Control (LFC)
- Matches generation with demand
- Responds to frequency deviations
- Deploys Regulation Reserve Service

![Frequency Chart]
Overview: Settlements

Market Information System (MIS)
- Access Market Reports
- Submit Market Inputs
- Download Information
- Access Market Reports
- Submit Market Inputs
- Download Information

Real-Time Operations
- Network Security Analysis
- Security Constrained Economic Dispatch (SCED)
- Load Frequency Control (LFC)

Settlement
- Statements & Invoices
- Settlement Disputes

Registration
- Market Participants
- Relationships
- Assets
- Qualification

CRR Auction
- Semi-Annual & Monthly Auctions
- CRR Offers and Bids
- PTP Options and Obligations

Reliability Unit Commitment
- Transmission Security Analysis
- Resource commitment
- Day-Ahead RUC
- Hourly RUC

Adjustment Period
- Energy Offers
- Trades
- Current Operating Plans
- Supplemental Ancillary Services Market (SASM)

Day-Ahead Market
- Energy Offers and Bids
- Ancillary Service Offers
- PTP Obligation Bids

Network Modeling
- Network Operations Model
- Network Operations Model Change Request (NOMCR)
Day-Ahead Settlement

- Daily statements include all Payments due and Charges incurred
- Statements posted to MIS Certified Area for applicable Market Participant
Real-Time Settlement

- Daily statements include all Payments due and Charges incurred
- Statements posted to MIS Certified Area for applicable Market Participant
Single Daily Settlement Invoice

Daily invoices include

- DAM Statement
- RTM Statements

**Diagnosis:**

- ERCOT Issues Invoice
  - DAM
  - RTM Initial
  - RTM Final
  - RTM True-up

**Payment Due:**

- (to ERCOT)
- (to Market Participant)

**Timeline:**

- Invoice Day
- Invoice Day + 2
- Invoice Day + 3

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ERCOT is an energy-only market

... but what does that mean?

It’s all about the recovery of costs to build generation.

In ERCOT, these costs must be recovered with revenues from energy production and operating reserves.
Additional Real-Time pricing component…

• **Reserve Price Adder**: the economic value of reserves that are available for energy dispatch in Real-Time

• LMPs and Reserve Price Adders are used together to form SPPs in Real-Time

LMPs are location-specific. Reserve Price Adders represent the value of reserves ERCOT-wide.
Overview: Market Information System
Three MIS Security Levels

**MIS Public Area**
- Information accessible by the general public
- Also available on ERCOT.com

**MIS Secure Area**
- Restricted access to protected information
- Accessible by applicable Entities
- Requires digital certificate

**MIS Certified Area**
- Information accessible only by individual Market Participant
- Requires digital certificate
Locational Marginal Price Basics
What is **Locational Marginal Pricing** (LMP)?

**Pricing:** Cost

**Marginal:** to serve the next increment of Load

**Locational:** at an Electrical Bus
LMP Components

- Energy
- Congestion

In some markets, LMPs have a component for losses.

The Nodal Market does **NOT** include losses in LMPs.
How often are LMPs & Settlement Point Prices calculated?

- LMPs and Settlement Point Prices
- Every Hour

- LMPs
  - Every 5 minutes*

- Settlement Point Prices
  - Every 15 minutes

* LMPs generated at each SCED cycle (possibly more often than 5 minutes)
Calculating LMPS

• Calculated at “Network Nodes”
• Points of connection to grid
  • Source (injection point)
  • Sink (withdrawal point)
  • Switching station
Calculating LMPS

- DC Power Flow model used to calculate LMPs

Constraints
- Real Power
- Studies: Voltage Stability, Transient Stability

Transmission Limits

Generic Limits

DC Model

LMPs
Three Types of Settlement Points:

- **Resource Nodes**
- **Load Zones**
- **Hubs**
What is a Resource Node?

An Electrical Bus where a Resource’s measured output is settled
Settlement Point Prices for Resource Nodes

Day-Ahead Market
LMP at the Resource Node

Real-Time Operations
Time-Weighted Averages of LMPs at Resource Node
+ Time-Weighted Average of Reserve Price Adders
What is a Load Zone?

A group of Electrical Buses assigned to the same Load Zone

All Load must be assigned to a Load Zone for Settlement purposes
Settlement Point Price for Load Zones

**Day-Ahead Market**
Load-Weighted Average of LMPs at Electrical Buses in Load Zone

**Real-Time Operations**
Load-Weighted and Time-Weighted Averages of LMPs at Electrical Buses in Load Zone

+ Time-Weighted Average of Reserve Price Adders
Three types of Load Zones

- Competitive Load Zones
- Non Opt-in Entity Load Zones
- DC Tie Load Zones
Competitive Load Zones

- North
- South
- West
- Houston

2003 Congestion Management zones
Non Opt-in Entity Load Zones

Established by one or more NOIE(s)

Some large NOIEs required to establish own NOIE Load Zones

NOIEs that don’t establish NOIE Load Zone are assigned to Competitive Load Zone
DC Tie Load Zones

- Used to settle exports across DC Ties
- One for each DC Tie
- Contains only the electrical bus connected to the DC Tie

All Load must be assigned to a Load Zone for Settlement purposes
What is a Hub?

- Group of 345kV Hub-buses
- Defined by Protocols
Six Hubs in ERCOT Market

Four Regional Hubs

- North
- West
- South
- Houston

Two Average Hubs

- ERCOT Hub Average
- ERCOT Bus Average
Settlement Point Prices

Settlement Point Price for Hubs

Day-Ahead Market
Simple average of LMPs at Hub Buses in each Hub

Real-Time Operations
Simple average of Time-Weighted Average LMPs at the Hub Buses in the Hub
+ Time-Weighted Average of Reserve Price Adders
LMP Contour Map

- Day-Ahead Market SPPs
- Real-Time LMPs
- Real-Time SPPs
Transmission Operations and LMP calculations
Telemetry of Real-Time Measurements

Telemetry input into ERCOT system operations

- Power flow on transmission elements
- Bus load
- Voltages
- Tap positions
- Resource statuses
- Device statuses
- and more

Critical for market price formation

Telemetry performance is critical for reliability and market operations
Impact of Outages on Prices

- Outages and limits impact Locational Marginal Prices (LMPs)
- Impact on Settlement Point Prices
- Price changes depend on affected transmission elements

Remember: Different LMPs provide a signal that something reliability related is limiting the network.
In a perfect world there is…
NO Congestion, NO Outages

G1 QSE offers 100 MW @ $30/MWh

G2 QSE offers 200 MW @ $10/MWh
In a perfect world there is…

NO Congestion, NO Outages

SCENARIO

G1 QSE offers 100 MW @ $30/MWh

0 MW dispatched @ $30/MWh

150 MW dispatched @ $10/MWh

G2 QSE offers 200 MW @ $10/MWh

100 MW Load
In a perfect world there is…
NO Congestion, NO Outages

Scenario: Outages and LMPs (continued)

G1 QSE offers 100 MW @ $30/MWh

0 MW dispatched @ $30/MWh

150 MW dispatched @ $10/MWh

G2 QSE offers 200 MW @ $10/MWh

L1 150 MW Load

LMP = $10 / MWh

Paid to Generators (G2)
G1 (0 MW * $30/MWh) = $0
G2 (150 MW * $10/MWh) = $1500

Charged to Loads (L1)
(150 MW * $10/MWh) = $1500
In an **IMPERFECT** world Outages can cause Congestion

G1 QSE offers 100 MW @ $30/MWh

G2 QSE offers 200 MW @ $10/MWh
In an IMPERFECT world Outages can cause Congestion and Cost Increases

G1 QSE offers 100 MW @ $30/MWh

50 MW dispatched @ $30/MWh

100 MW dispatched @ $10/MWh

G2 QSE offers 200 MW @ $10/MWh

150 MW Load

L1

100 MW Limit

SCENARIO
Scenario: Outages and LMPs

In an IMPERFECT world Outages can cause Congestion and Cost Increases

G1 QSE offers 100 MW @ $30/MWh

G2 QSE offers 200 MW @ $10/MWh

50 MW dispatched @ $30/MWh
100 MW dispatched @ $10/MWh

100 MW Limit

L1
150 MW Load
LMP = $30 / MWh

Paid to Generators (G2)
G1 (50 MW * $30/MWh) = $1500
G2 (100 MW * $10/MWh) = $1000

Charged to Loads (L1)
(150 MW * $30/MWh) = $4500
In an IMPERFECT world Outages can cause Congestion and Cost Increases

**SCENARIO**

G1 QSE offers 100 MW @ $30/MWh

- 50 MW dispatched @ $30/MWh
- 100 MW dispatched @ $10/MWh

G2 QSE offers 200 MW @ $10/MWh

- Differences (between payments and charges) goes into congestion rent
- Covered in more detail later

\[ \text{Paid to Generators (G2)} \]

\[ \begin{align*}
\text{G1 (50 MW * $30/MWh) } &= \text{ $1500} \\
\text{G2 (100 MW * $10/MWh) } &= \text{ $1000}
\end{align*} \]

\[ \begin{align*}
\text{Charged to Loads (L1)} \\
\text{(150 MW * $30/MWh) } &= \text{ $4500}
\end{align*} \]
Sometimes Outages **DO NOT** impact LMPs . . .

G1 QSE offers 100 MW @ $30/MWh

0 MW dispatched @ $30/MWh

50 MW dispatched @ $10/MWh

G2 QSE offers 200 MW @ $10/MWh

LMP = $10 / MWh
Sometimes Outages **DO NOT** impact LMPs . . .

**SCENARIO**

G1 QSE offers 100 MW @ $30/MWh

0 MW dispatched @ $30/MWh

50 MW dispatched @ $10/MWh

G2 QSE offers 200 MW @ $10/MWh

L1

50 MW Load

LMP = $10 / MWh

Result:
- Either line can support load
- No change in LMPs
In this module we:

- Introduced the ERCOT Nodal Visual Process Map
- Identified key roles and responsibilities
- Discussed basics of Locational Marginal Prices (LMPs)
- Discussed outage impacts on LMPS