Key Features of the ERCOT Grid

- Represents 90% of Texas Load
- 74,000 MW of generation capacity
- 43,000 miles of transmission lines
- Electrical island with several DC Ties
- Peak load of 71,197 MW on 8/11/16
ERCOT’s Primary Responsibility is Reliability

- Match generation with demand
- Operate transmission system within established limits

Execute competitive markets for reliability services
Reliability and Competitive Markets

- Markets support reliability
- Reliability makes the markets possible

ERCOT finds the balance between Reliability and Economics.
Capacity Market

Capacity Reserved for Ancillary Services

Ancillary Services needed to respond quickly to changing system conditions.

System Capacity

System Demand

Forecast
Ancillary Service Capacity

Acquired through competitive markets
Ancillary Service Capacity

Three types of Ancillary Services

- Regulation Reserve
- Responsive Reserve
- Non-Spin Reserve

System Capacity
Transmission Congestion

- Generators and Loads separated by distance
- Transmission system has limits

Congestion management keeps transmission system operating within limits
Network Operations Model

Models allow ERCOT to:

- “See” grid at any point in time
- Predict how various actions affect grid
Network Operations Model

- Physical characteristics
- Ratings
- Operational limits

Including
- Transmission Elements
- Resources
- Topology
- Telemetry mapping
Market Introduction
Market Participants

Who are the Players?

- **QSE**: Qualified Scheduling Entities
- **LSE**: Load Serving Entities
- **TDSP**: Transmission and/or Distribution Service Providers
- **Resource Entity**: Resource Entities
Commercial Markets

- Bilateral Market
- ERCOT Facilitated Markets
  - Day-Ahead Ancillary Services Market
  - Day-Ahead Energy Market
  - Real-Time Energy Market
Energy Dispatch

- Resource-specific offers
- Resource-specific dispatch

Goal

- Balance generation & demand
- Manage congestion

Energy Pricing

- Location-specific prices for energy
- Prices include congestion costs
Congestion Costs

- All costs are directly assigned
- Congestion Revenue Rights available for hedging
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.*
ERCOT is an *energy-only* market ... *but what does that mean?*

Energy Pricing must support investment in new generation

*Scarcity pricing* – higher energy prices during periods where energy reserves are scarce
An Independent Market Information System Registered Entity (IMRE) may register with ERCOT solely to access MIS Secure.
LMPs and Settlement Point Prices

- LMPs at Electrical Buses
- Settlement Points used for financial settlement
- Settlement Point Prices calculated using LMPs
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.
How often are LMPs & Settlement Point Prices calculated?

LMPs and Settlement Point Prices
• Every Hour

LMPs and Reserve Price Adders
• Every 5 minutes*

Settlement Point Prices
• Every 15 minutes

* LMPs and Reserve Price Adders generated at each SCED cycle (possibly more often than 5 minutes)
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

Settlement Point Prices for Resource Nodes

Day-Ahead Market
LMP at the Resource Node

Real-Time Operations
Time-Weighted Average of LMPs at the Resource Node

+ Time-Weighted Average of Reserve Price Adders
What is a Load Zone?

A group of Electrical Buses assigned to the same geographical zone

Every Electrical Bus with Load must be assigned to a Load Zone for Settlement purposes
Settlement Point Prices

Settlement Point Price for Load Zones

Day-Ahead Market
Load-Weighted Average of LMPs in Load Zone

Real-Time Operations
Load-Weighted and Time-Weighted Averages of LMPs 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
Nodal Market Operations
Market Components

- CRR Auction
- Day-Ahead Market
- Reliability Unit Commitment
- Real-Time Operations
Congestion Revenue Rights
Topics in this lesson...

- Purpose of CRRs
- CRR Account Holders
- Types of CRRs
- How CRRs are acquired
- Settlements
- Market Information System
Purpose of Congestion Revenue Rights

- Financial instruments
  - Hedge against congestion costs
  - Financial investment
- Payment or charge when Grid is congested

A CRR is *not* a right to deliver physical energy
Congestion costs are built in to the Settlement Point prices.
Introducing a new player:
CRR Account Holder
To own CRRs, Market Participants:

- Must be registered with ERCOT
- Must qualify as CRR Account Holders
Barred from owning CRRs:
- TSPs & DSPs
- ERCOT
Congestion Revenue Rights as Financial Instruments

- Designated point of injection (source) and point of withdrawal (sink)

- Settlement based on difference between sink and source Settlement Point Prices

- Two Instruments:
  - PTP Options – *payment only*
  - PTP Obligations – *payment or charge*
EXAMPLE

Point-to-Point (PTP) Obligations

Source A

$5/MWh

Sink B

$10/MWh

Source C

$15/MWh

Obligation \( AB \) Payment = $5.00

Obligation \( CB \) Payment = ?
Point-to-Point (PTP) Options

Example Congestion Revenue Rights

Source A

Source C

Sink B

$5/MWh

$15/MWh

$10/MWh

Option $_{AB}$ Payment = $5.00

Option $_{CB}$ Payment = ?
Three ways of acquiring CRRs:

- CRR Auction
- Allocation (Special Case)
- Bilateral Trades
CRRs are auctioned and allocated by:

- Time-of-Use Blocks
- One month strips

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<td>Off-Peak (2300 – 2400)</td>
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</table>
• CRR Auction
• Monthly and Semi-Annual Auctions
• Based on Network Operations Model
Allocation of CRRs

- **Pre-Assigned CRRs (PCRRs)**
- Allocated to Non-Opt-In Entities (NOIEs)
- Based on long-term supply contracts
- May be allocated as Options or Obligations
- No charge or a percentage of the Auction clearing price
Trading CRRs Bilaterally

- PTP Options
- PTP Obligations
- Characteristics remain unchanged
- Both parties must meet credit requirements.
CRR Settlements

Three Settlement Processes
- CRR Auction Settlement
- CRR Settlement
- CRR Balancing Account
CRR Auction Settlements
CRR Auction Settlements Timeline

- **Auction Completed**
- **Day 1***: Auction Invoice
- **Day 2**: Auction Results
- **Day 3**: Payments Due to ERCOT
- **Day 4**: Payments Due to CRR Account Holders
- **Day 5**:

* Business Day
** Bank Business Day
*** Business Day and Bank Business Day
CRR Auction Settlement

CRR Auction Revenues + PCRR Revenues

Monthly

CRR Auction Revenues

Pay to QSEs representing Load
CRR Settlement

CRRs are settled in the Day-Ahead Market
CRR Settlement

Hourly

Payment due to CRR Account Holders

Congestion Rent

CRR Balancing Account
CRR Settlement

Payment due to CRR Account Holders

may be short paid in some hours
CRR Balancing Account

Pay to QSEs representing Load

Payment due to CRR Account Holders

Monthly
CRR Balancing Account

Payment due to CRR Account Holders

may remain short paid
Posted after each Auction:

- CRRs awarded
- CRR Account Holders
- Auction clearing prices
- CRR Bids and offers
Day-Ahead Market
Topics in this lesson . . .

- Purpose of Day-Ahead Market
- Market Participants
- Day-Ahead Market Process
- Process Inputs and Outputs
- Settlements
- Market Information System
Purpose of the Day-Ahead Market

- Centralized Forward Market
- Buy and sell Energy
- Sell Ancillary Services to ERCOT
- Forward market provides price certainty
Only QSEs participate in the Day-Ahead Market.
CRRs are settled with Day-Ahead Market Prices
When does the Day-Ahead Market occur?

- Market opens at 0600
- Clearing Process begins at 1000
- Results posted by 1330
An Offer is a proposal to sell:
- A Product
- At a Location
- For a Price

A Bid is a proposal to buy:
- A Product
- At a Location
- For a Price
The Day-Ahead Market

- Offers
- Bids
- Current Operating Plans
- Network Operations Model

Day-Ahead Market

Pricing

Awards
The Day-Ahead Market

Types of Offers:
• Three-Part Supply Offer
• Ancillary Service (AS) Offer
• Day-Ahead Market Energy-Only Offer
Three-Part Supply Offer

- **Startup Offer**: $ / Start
- **Minimum-Energy Offer**: $ / MWh (at LSL)
- **Energy Offer Curve**: $ / MWh (above LSL)

Energy Offer Curve can be submitted without Start-up or Minimum Energy Offers
Ancillary Service (AS) Offers:

- Resource specific
  - Regulation Reserve
  - Responsive Reserve
  - Non-Spinning Reserve

- A Resource may be offered
  - For multiple Ancillary Services
  - For Energy and Ancillary Services
Day-Ahead Market Energy-Only Offer

• Proposal to sell energy in DAM
• Offered at any Settlement Point

Valid only in the Day-Ahead Market

Financial obligation in Real-Time
The Day-Ahead Market

Types of Bids:
- Energy Bid
- PTP Obligation Bid

Day-Ahead Market

Offers

Bids

Current Operating Plans

Network Operations Model

Pricing

Awards
Day-Ahead Market Energy Bid

- Proposal to buy energy
- Submitted at any Settlement Point

Valid only in the Day-Ahead Market

Financial credit in Real-Time
Purpose of DAM PTP Obligations

- Hedge against congestion costs in Real-Time
- Charge or payment when Grid is congested in Real-Time
Day-Ahead Market PTP Obligation Bids

- Like coupled Energy Bid and Energy Offer
- Purchased at DAM Settlement Point Price Spread
- Settled at Real-Time Settlement Point Price Spread

Source A → PTP Obligation → Sink B

Energy Offer

Energy Bid

DAM PTP Obligation can result in a payment or charge
**Example**

**Day-Ahead Market PTP Obligations**

**DAM:**
- Source A: $10/MWh
- Sink B: $12/MWh

**Real-Time:**
- Source A: $8/MWh
- Sink B: $15/MWh

QSE charge in Day Ahead Market = ?

QSE payment in Real Time = ?
Day-Ahead Market

CRR Auction → Day-Ahead Market → Real-Time

- Acquired in CRR Auction
- Settled at DAM Price Spread
- Acquired in Day-Ahead Market
- Settled at RT Price Spread

PTP Obligations

DAM PTP Obligations
The Day-Ahead Market

- Offers
- Bids
- Current Operating Plans
- Network Operations Model

Day-Ahead Market

- Pricing
- Awards
The Current Operating Plan (COP)

- Anticipated Resource operating conditions
  - Resource Status
  - Resource Limits
  - Ancillary Service Commitments

- Submitted by QSE

QSE must maintain the COP for each hour of the next 7 days
The Day-Ahead Market

- Offers
- Bids
- Current Operating Plans
- Network Operations Model

Day-Ahead Market

- Pricing
- Awards
The Network Model in the Day-Ahead Market

- Day-Ahead Market does not solve reliability issues
- System must support the Day-Ahead Market solution

The Network Operations Model ensures that DAM solution respects system limits
The Day-Ahead Market

Day-Ahead Market

Offers

Bids

Current Operating Plans

Network Operations Model

Pricing

Awards
The Day-Ahead Market

Cleared Offers = Costs
Cleared Bids = Revenues
The Day-Ahead Market clearing process

Maximize The Gap

Bid-based Revenues

Offer-based Costs
The Day-Ahead Market clearing process

The Day-Ahead Market is a *Co-optimized* Market

Maximize The Gap

Bid-based Revenues

Energy & Ancillary Service Costs

Energy & Ancillary Service Costs
The Day-Ahead Market

- Offers
- Bids
- Current Operating Plans
- Network Operations Model

Day-Ahead Market

Pricing

Awards
After Day-Ahead Market

- QSEs may update COP
  - Awarded Energy Offers
  - Ancillary Service Commitments
- QSEs may submit Trades
Trades

- QSE-QSE transactions
- Transfers financial responsibility
- Types
  - Capacity
  - Energy
  - Ancillary Service

Trades are used only in Settlements
Day-Ahead Market Settlements

Settlement Point Prices
Ancillary Service Prices (MCPCs)

Awarded Bids
Awarded Offers

Payments
Charges

Settlements
Day-Ahead Settlement Timeline

Daily statements include

- Payments due
- Charges incurred
Single Daily Settlement Invoice

Daily invoices include

- DAM Statements
- RTM Statements

- ERCOT Issues DAM Statement & Invoice
  Payment Due (to ERCOT)

- ERCOT Issues RTM Statement & Invoice
  Payment Due (to Market Participant)

- 1700 Payment Due (to ERCOT)
Posted by 0600 Day-Ahead:

- Network Operations Model
- Weather Assumptions
- Load Forecasts (next 7 days)
- Forecasted Load Profiles
Posted by 1330 Day-Ahead:

- LMPs
- Settlement Point Prices
- MCPCs for each Ancillary Service
- Energy bought and sold
Reliability Unit Commitment
Topics in this lesson . . .

- Purpose of Reliability Unit Commitment (RUC)
- Market Participants involved
- The RUC Process
- Settlements
- Capacity Shortfall
- Market Information System
Market Information System (MIS)

- Access Market Reports • Submit Market Inputs • Download Information • Review Market Outputs • Submit Market Inputs • Download Information •
It ensures:

- Enough capacity is committed to serve the forecasted load
- Committed capacity in the right locations
Operational impacts on:
QSEs with Resources
Funds collected from:
- Capacity-Short QSEs
- QSEs representing Load
Reliability Unit Commitment

The Reliability Unit Commitment Process

- Current Operating Plans
- Network Operations Model
- Contingencies
- Load Forecast

Offers → Three-Part Supply Offers → Transmission Security Analysis → Reliability Unit Commitment → Commitments

- Resource Commitments
- Resource Decommitments
Committed Enough Capacity

- Current Operating Plans
- Network Operations Model
- Contingencies
- Load Forecast

Three-Part Supply Offers

Transmission Security Analysis

Reliability Unit Commitment

Commissions
- Resource Commitments
- Resource Decommissions
Reliability Unit Commitment

Committing Capacity in the Right Locations

Current Operating Plans

Network Operations Model

Contingencies

Load Forecast

Offers

Three-Part Supply Offers

Transmission Security Analysis

Reliability Unit Commitment

Commitments

Resource Commitments

Resource Decommitments
What if ERCOT must commit additional capacity?
Potential Results of RUC Process:

- Resource Commitments
- Resource Decommitments
- No additional Commitments
When does Reliability Unit Commitment (RUC) occur?

- Day-Ahead Reliability Unit Commitment (DRUC)
- Hourly Reliability Unit Commitment (HRUC)
Reliability Unit Commitment

*RUC-Committed Resources*
• Make-Whole Payments
• RUC-committed Resources recover their commitment costs
QSEs with Capacity Shortfall may be assessed Capacity Short Charges

Capacity Shortfall

Capacity Obligations

Capacity Supply
What is included in the QSE’s capacity obligation?

- Load (Adjusted Metered Load)
- Capacity Trades where the QSE is a seller
- Energy Trade where the QSE is a seller
- Cleared DAM Energy Offer
How can a QSE arrange to meet these obligations?

• Show capacity from its Resources in its COP
• Capacity Trades where the QSE is a buyer
• Energy Trades where the QSE is a buyer
• Cleared DAM Energy bids
To Minimize Capacity Short Charges...

QSE must arrange for enough Capacity to meet Obligations
Revenues may not be enough for make-Whole Payments

Difference uplifted to QSEs representing Load
RUC Payments and Charges are included in Real-Time Settlements
Posted after process completion:

- Resources committed
- Resources decommitted
- Active transmission constraints
Real-Time Operations
Topics in this lesson . . .

• Purpose of Real-Time Operations
• Market Participants
• Real-Time Operations Process
  • Security Constrained Economic Dispatch
  • Load Frequency Control
• Settlements
• Market Information System
Purpose of Real-Time Operations

• Manage reliability
  • Match generation with demand
  • Operate transmission system within established limits
• Operate the system at least cost
ERCOT provides dispatch instructions to QSEs with Resources.
ERCOT may also provide dispatch instructions to TSPs.
When do Real-Time Operations occur?

- Operating Period
- Includes Operating Hour and Hour-Ahead
The Operating Period includes:

- Operating Hour - Real-Time dispatch of energy
- Hour-Ahead – Preparations for Real-Time Operations
Network Security Analysis and SCED

- Network Security Analysis identifies transmission constraints
- Security Constrained Economic Dispatch (SCED) determines least-cost solution
Real-Time Operations

Provide Real-Time system data

Real-Time Network Security Analysis

Security-Constrained Economic Dispatch

Real-Time Operations

Offers
- Energy Offer Curves
- Proxy Energy Offer Curves

Pricing
- Locational Marginal Prices

Dispatch Instructions
- Base Points

Telemetry

Network Operations Model

Contingencies
Identify **Constraints**, both **Transmission** & **Resource**
SCED evaluates **Offers** to determine least-cost solution
SCED uses Energy Offer Curves:

Submitted by QSEs:
- Three-Part Supply Offer
- Stand Alone Energy Offer Curve

During:
- Day-Ahead Market
- Adjustment Period
SCED produces **Prices** and **Dispatch Instructions**

Real-Time Operations

**Offers**
- Energy Offer Curves
- Proxy Energy Offer Curves

- **Telemetry**
- **Network Operations Model**
- **Contingencies**

**Real-Time Network Security Analysis**

**Security-Constrained Economic Dispatch**

**Pricing**
- Locational Marginal Prices

**Dispatch Instructions**
- Base Points
Real-Time Operations

How often does all this happen?

At least every 5 minutes
Real-Time Price Calculations

Every 5 minutes (when SCED runs)

LMPs
  • Electrical buses

Every 15 minutes

Settlement Point Prices
  • Resource Nodes
  • Load Zones
  • Hubs

Reserve Price Adders
  • ERCOT-wide
Security Constrained Economic Dispatch (SCED)

- Matches generation with demand
- Manages congestion
- Achieves least cost dispatch
Load Frequency Control (LFC)

- Matches generation with demand
- Responds to frequency deviations
- Deploys Regulation Reserve Service
Real-Time Operations Settlements

Payment for Net Supply

Charge for Net Obligation

Settlements

Settlement point prices

Energy Supplies

Energy Obligations
Examples

- ______________________
- ______________________
- ______________________
Real-Time Operations Settlements

Examples

- ____________________
- ____________________
- ____________________

Energy Supplies

Energy Obligations
Real-Time Settlement Timeline

- Daily statements include
  - Payments due
  - Charges incurred
Single Daily Settlement Invoice

Daily invoices include

- DAM Statement
- RTM Statements
Posted after completion of SCED:

- Locational Marginal Prices
- Settlement Point Prices
- Active transmission constraints