Purpose of Real-Time Operations

- Manage reliability
  - Match generation with demand
  - Operate transmission system within established limits
- Operate the system at least cost
Energy Dispatch Process

Security Constrained Economic Dispatch

Telemetry
Network Operations Model
Contingencies

Real-Time Dispatch
Real-Time Network Security Analysis
Security-Constrained Economic Dispatch

Offers

Pricing
Dispatch Instructions
Locational Marginal Prices (LMPs)

- Produced by SCED
- Combined with Reserve Price Adders to form Real-Time Settlement Point Prices

LMPs are location-specific. Reserve Price Adders represent the value of reserves ERCOT-wide.
Real-Time Reserve Price Adders

- Produced outside of SCED
- Two flavors:
  - **RTORPA** – On-line Reserves
  - **RTOFFPA** – Off-line Reserves

... for each SCED interval
Real-Time Reserve Price Adders

\[ \text{RTRSVPOR} = \frac{\text{Time-Weighted Average}}{\text{RTORPAs}} \]

\[ \text{RTRSVPPOFF} = \frac{\text{Time-Weighted Average}}{\text{RTOFFFPAs}} \]

... for each 15-minute interval

<table>
<thead>
<tr>
<th>RTRSVPOR</th>
<th>Real-Time Reserve Price for On-Line Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRSVPPOFF</td>
<td>Real-Time Reserve Price for Off-Line Reserves</td>
</tr>
</tbody>
</table>
ERCOT added a Reliability Deployment Price Adder on June 1, 2015

• Reliability deployments suppress Real-Time prices
• Price Adder reverses price suppression

Reliability deployments include RUC, Emergency Response Service (ERS), RMR and Load Resources
Reliability Deployment Price Adder

**RTORDPA**  – Captures impact of reliability deployments during SCED Interval

**RTRDP** = Time-Weighted Average **RTORDPAs**

... for each 15-minute interval

<table>
<thead>
<tr>
<th>RTORDPA</th>
<th>Real-Time On-Line Reliability Deployment Price Adder</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRDP</td>
<td>Real-Time On-Line Reliability Deployment Price</td>
</tr>
</tbody>
</table>
Settlement Point Prices:

Average (LMPs)

+ RTRSVPOR

+ RTRDP

… for each 15-minute interval

The way the LMPs are averaged varies by Settlement Point
Real-Time Settlements

Real-Time

Real-Time Activities
- Imbalances
- Base Point Deviations
- Other odds & ends

Settlement of PTP Obligations purchased in the DAM

Real Time Ancillary Service Settlements

Revenue Neutrality
### Fundamentals of Real–Time Energy Imbalances

<table>
<thead>
<tr>
<th>Who:</th>
<th>All QSEs that have Generation, Load, Trades, and DAM purchases or sales at any Settlement Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A charge or payment for the imbalance of Energy at a Settlement Point</td>
</tr>
<tr>
<td>Why:</td>
<td>To pay or charge a QSE for their injection or withdrawal at a Settlement Point</td>
</tr>
</tbody>
</table>
The basic idea at any Settlement Point:

\[ (-1) \left( \text{SUPPLIES} \right) - \left( \text{OBLIGATIONS} \right) \ast \text{RTSPP} \]

Now, we simply fill in the appropriate elements for each Settlement Point.
Real-Time Energy Imbalance at a Hub:

\[
(-1) \left[ \left( \text{DAM Energy Purchases} + \text{Trade Energy Purchases} \right) - \left( \text{DAM Energy Sales} + \text{Trade Energy Sales} \right) \right] \times \text{RTSPP}
\]
At a Hub

RTSPP is used to settle financial transactions

\[
RTSPP = RTRSVPOR + RTRDP + \left\{ \begin{array}{c}
\text{Simple & Time-Weighted Average} \\
\text{LMPs}
\end{array} \right.
\]

<table>
<thead>
<tr>
<th>RTSPP</th>
<th>Real-Time Settlement Point Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRSVPOR</td>
<td>Real-Time Reserve Price for On-Line Reserves</td>
</tr>
<tr>
<td>RTRDP</td>
<td>Real-Time On-Line Reliability Deployment Price</td>
</tr>
</tbody>
</table>
Real-Time Energy Imbalance at a Load Zone:

\[
\text{Real-Time Energy Imbalance} = \left( \text{DAM Energy Purchases} + \text{Trade Energy Purchases} \right) - \left( \text{DAM Energy Sales} + \text{Trade Energy Sales} \right) \times \text{RTSPP} \\
+ \left( \text{Non-Modeled Generation} \right) - \left( \text{Adjusted Metered Load} \right) \times \text{RTSPPEW}
\]
At a Load Zone,

**RTSPP** is used to settle financial transactions

\[
\text{RTSPP} = \text{RTRSVPOR} + \text{RTRDP} + \left( \text{MW-Weighted & Time-Weighted Average LMPs} \right)
\]

<table>
<thead>
<tr>
<th>RTSPP</th>
<th><strong>Real-Time Settlement Point Price</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRSVPOR</td>
<td><strong>Real-Time Reserve Price for On-Line Reserves</strong></td>
</tr>
<tr>
<td>RTRDP</td>
<td><strong>Real-Time On-Line Reliability Deployment Price</strong></td>
</tr>
</tbody>
</table>
At a Load Zone,

RTSPPEW is used to settle physical energy consumption

RTSPPEW = RTRSVPOR + RTRDP + \( \text{(MW} \times \text{Time)} \)

Weighted Average

LMPs

<table>
<thead>
<tr>
<th>RTSPPEW</th>
<th>Real-Time Settlement Point Price Energy-Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRSVPOR</td>
<td>Real-Time Reserve Price for On-Line Reserves</td>
</tr>
<tr>
<td>RTRDP</td>
<td>Real-Time On-Line Reliability Deployment Price</td>
</tr>
</tbody>
</table>
Real-Time Energy Imbalance at a Resource Node:

\[
\begin{align*}
&(-1) \left[ \left( \text{DAM Energy Purchases} + \text{Trade Energy Purchases} \right) - \left( \text{DAM Energy Sales} + \text{Trade Energy Sales} \right) \right] \times \text{RTSPP} \\
&\quad + \ (-1) \left[ \text{Metered Generation} \right] \times \text{RTRMPR}
\end{align*}
\]
At a Resource Node,

**RTSPP** is used to settle financial transactions

\[
RTSPP = \text{RTRSVPOR} + \text{RTRDP} + \text{Time-Weighted Average} \left( \begin{array}{c} \text{LMPs} \end{array} \right)
\]

<table>
<thead>
<tr>
<th>RTSPP</th>
<th><strong>Real-Time Settlement Point Price</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRSVPOR</td>
<td><strong>Real-Time Reserve Price for On-Line Reserves</strong></td>
</tr>
<tr>
<td>RTRDP</td>
<td><strong>Real-Time On-Line Reliability Deployment Price</strong></td>
</tr>
</tbody>
</table>
At a Resource Node,

**RTRMPR** is used to settle physical energy production

\[
RTRMPR = RTRSVPOR + RTRDP + \text{(Base-Point} \times \text{Time)} \quad \text{(Weighted Average of LMPs)}
\]

<table>
<thead>
<tr>
<th><strong>RTRMPR</strong></th>
<th><strong>Real-Time Resource Meter Price</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RTRSVPOR</strong></td>
<td><strong>Real-Time Reserve Price for On-Line Reserves</strong></td>
</tr>
<tr>
<td><strong>RTRDP</strong></td>
<td><strong>Real-Time On-Line Reliability Deployment Price</strong></td>
</tr>
</tbody>
</table>
Real-Time Energy: Triggers

**Trigger #1**
A QSE has Trades, DAM bids or DAM offers at a Hub

**Trigger #2**
A QSE has Generation, Load, Trades, DAM bids or DAM offers at a Load Zone

**Trigger #3**
A QSE has Generation, Trades, DAM bids or DAM offers at a Resource Node
Real-Time Energy Imbalance at a Hub

QSE3

- 8MW DAM Energy Sale (2MWh)
- 12 MW DAM Energy Purchase (3MWh)
- Settlement Point Price is $40/MWh at Hub1

\[
(-1) \times \text{Price} \times (\text{Supplies} – \text{Obligations})
\]

\[
(-1) \times $40/\text{MWh} \times (3\text{MWh} – 2\text{MWh}) = -$40
\]

<table>
<thead>
<tr>
<th>Supplies</th>
<th>Obligations</th>
</tr>
</thead>
</table>
| DAEP  

DAM Energy Purchase  

DAES  

DAM Energy Sale |
| RTQQEP  

Real-Time QSE to QSE Energy Purchase (Trade)  

RTQQQES  

Real-Time QSE to QSE Energy Sale (Trade) |
QSE3

- 8MW DAM Energy Sale (2MWh)
- 12 MW DAM Energy Purchase (3MWh)
- Settlement Point Price is $40/MWh at Hub1

\[
\text{RTEIAMT}_{q,p} = (-1) \times \text{RTSPP}_p \times \{ (\text{DAEP}_{q,p} \times \frac{1}{4}) + (\text{RTQQEP}_{q,p} \times \frac{1}{4}) \\ - (\text{DAES}_{q,p} \times \frac{1}{4}) - (\text{RTQQES}_{q,p} \times \frac{1}{4}) \} \\
-\$40 = (-1) \times \$40/\text{MWh} \times \{ (12\text{MW} \times \frac{1}{4}) \} + (0\text{MW} \times \frac{1}{4}) \\ - (8\text{MW} \times \frac{1}{4}) - (0\text{MW} \times \frac{1}{4}) \} \]
Refer to your Settlements Workbook

In a small group, respond to the questions that relate to Scenario #RT1.

You have 5 minutes to complete your questions.

If you cannot complete all questions, don’t worry – all questions will be reviewed as a class.
Real-Time Energy: Triggers

**Trigger #1**
A QSE has Trades, DAM bids or DAM offers at a Hub

**Trigger #2**
A QSE has Generation, Load, Trades, DAM bids or DAM offers at a Load Zone

**Trigger #3**
A QSE has Generation, Trades, DAM bids or DAM offers at a Resource Node
At a Load Zone a QSE may have:

- Metered Load
- Non-Modeled Generation
- Trades
- DAM Bids & DAM Offers

<table>
<thead>
<tr>
<th>If a QSE has…</th>
<th>The QSE will receive…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Supply</td>
<td>Payment</td>
</tr>
<tr>
<td>Net Obligation</td>
<td>Charge</td>
</tr>
</tbody>
</table>

Don’t forget: Load Zone has two prices
Real-Time Energy Imbalance at a Load Zone

Translated into a Settlement Equation,

\[
\text{RTEIAMT}_{q,p} = (-1) \times \left\{ \begin{array}{l}
\text{RTSPP}_{p} \times \left[ (\text{DAEP}_{q,p} \times \frac{1}{4}) + (\text{RTQQEP}_{q,p} \times \frac{1}{4}) \right] \\
- (\text{DAES}_{q,p} \times \frac{1}{4}) - (\text{RTQQES}_{q,p} \times \frac{1}{4}) \right] \\
+ \left[ \text{RTSPPEW}_{p} \times (\text{RTMGNM}_{q,p} - \text{RTAML}_{q,p}) \right] \end{array} \right\}
\]

<table>
<thead>
<tr>
<th>Supplies</th>
<th>Obligations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAEP</strong></td>
<td>DAM Energy Purchase</td>
</tr>
<tr>
<td><strong>RTQQEP</strong></td>
<td>Real-Time QSE to QSE Energy Purchase (Trade)</td>
</tr>
<tr>
<td><strong>RTMGNM</strong></td>
<td>Real-Time Metered Generation Non-Modeled</td>
</tr>
<tr>
<td><strong>DAES</strong></td>
<td>DAM Energy Sale</td>
</tr>
<tr>
<td><strong>RTQQES</strong></td>
<td>Real-Time QSE to QSE Energy Sale (Trade)</td>
</tr>
<tr>
<td><strong>RTAML</strong></td>
<td>Real-Time Adjusted Metered Load</td>
</tr>
</tbody>
</table>
Real-Time Energy Imbalance at a Load Zone

Outcome #2

QSE4
- Has a 12MW DAM Energy Purchase (3MWh)
- Purchased 20MW through a Trade (5MWh)
- Has Load at LZ3 of 10MWh
- The RTSPP is $100/MWh at LZ3
- The RTSPPEW is $101/MWh at LZ3

\[
\text{RTEIAMT}_{q,p} = (-1) \times \left\{ \left[ \text{RTSPP}_p \times ((\text{DAEP}_{q,p} \times \frac{1}{4}) + (\text{RTQQEP}_{q,p} \times \frac{1}{4})) - (\text{DAES}_{q,p} \times \frac{1}{4}) - (\text{RTQQES}_{q,p} \times \frac{1}{4})) \right] + \left[ \text{RTSPPEW}_p \times (\text{RTMGNM}_{q,p} - \text{RTAML}_{q,p}) \right] \right\}
\]

\[
\$210 = (-1) \times \left\{ \left[ \$100/\text{MWh} \times ((12\text{MW} \times \frac{1}{4}) + (20\text{MW} \times \frac{1}{4}) - (0\text{MW} \times \frac{1}{4}) - (0\text{MW} \times \frac{1}{4})) \right] + \left[ \$101/\text{MWh} \times (0\text{MW} - 10\text{MWh}) \right] \right\}
\]
In a small group, respond to the questions that relate to Scenario #RT2.

You have 10 minutes to complete your questions.

If you cannot complete all questions, don’t worry – all questions will be reviewed as a class.
A QSE has Trades, DAM bids or DAM offers at a Hub

A QSE has Generation, Load, Trades, DAM bids or DAM offers at a Load Zone

A QSE has Generation, Trades, DAM bids or DAM offers at a Resource Node

Real-Time Energy: Triggers
At a Resource Node A QSE may have:

- Metered Generation
- Trades
- DAM Bids & DAM Offers

<table>
<thead>
<tr>
<th>If a QSE has…</th>
<th>The QSE will receive…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Supply</td>
<td>Payment</td>
</tr>
<tr>
<td>Net Obligation</td>
<td>Charge</td>
</tr>
</tbody>
</table>

**Don’t forget:** Resource node has multiple prices
Real-Time Energy Imbalance at a Resource Node =

\[
\left(-1\right) \left(\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales}\right)\right) \times \text{RTSPP}
\]

\[
+ \left(-1\right) \left(\text{Metered Generation}\right) \times \text{RTRMPR}
\]
But in reality . . .

Many Generation Sites are complex

- Multiple generators per meter
- Multiple owners
- Load and generation
- Combined Cycle Resources

ERCOT uses a single methodology to settle all Generation Sites
Real-Time Energy Imbalance at a Resource Node =

\[
(-1) \left[ \left( \text{DAM Energy Purchases} + \text{Trade Energy Purchases} \right) - \left( \text{DAM Energy Sales} + \text{Trade Energy Sales} \right) \right] \times \text{RTSPP} + (-1) \left( \text{Splitting Percentage} \times \text{Total Site Payment} \right)
\]
Real-Time Energy Imbalance at a Resource Node

\[ \text{RESREV}_{q,r} = \left( \text{Splitting Percentage} \right) \times \text{Total Site Payment} \]

Splitting Percentage: \text{GSPLITPER}

- QSE’s per Resource share of Total Site Payment
- Calculated from SCADA telemetry

Total Site Payment: \text{NMSAMTTTOT}

- For all Resources at Site
- For all QSEs at Site

<table>
<thead>
<tr>
<th>GSPLITPER</th>
<th>Generation Resource SCADA Splitting Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMSAMTTTOT</td>
<td>Net Metering Site Amount Total</td>
</tr>
<tr>
<td>RESREV</td>
<td>Resource Share Revenue Settlement Payment for QSE</td>
</tr>
</tbody>
</table>
Total Site Payment:

\[ NMSAMTTOT = \sum (RTRMPR \times MEB) \]

Net negative energy is settled at a Load Zone.
QSE1

- Has one Resource with 60% of the generation at this site
- The metered energy at Bus 1 is 10MWh
- The metered energy at Bus 2 is 20MWh
- The Real Time Resource Meter Price is $30/MWh at both Bus 1 & Bus 2.

**Total Site Payment:**

\[
NMSAMTTOT = \sum (RTRMPR * MEB)
\]

\[
= \$30/MWh \times (10\text{MWh} + 20\text{MWh})
\]

\[
= \$900
\]

QSE1 **RESREV** = GSPLITPER * NMSAMTTOT

\[
= 60\% \times \$900
\]

\[
= \$540
\]
Don’t forget: The Resource Node can have other transactions

\[
RTEIAMT_{q, p} = (-1) \star \left\{ \sum_{r} \left( RESREV_{q, r} \right) + RTSP\p \star \left[ (DAEP_{q, p} \star \frac{1}{4}) \right. \right.
\]
\[
+ (RTQQEP_{q, p} \star \frac{1}{4}) - (DAES_{q, p} \star \frac{1}{4}) - (RTQQES_{q, p} \star \frac{1}{4}) \right\} \}
\]

<table>
<thead>
<tr>
<th>Supplies</th>
<th>Obligations</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAEP</td>
<td>DAES</td>
</tr>
<tr>
<td>DAM Energy Purchase</td>
<td>DAM Energy Sale</td>
</tr>
<tr>
<td>RTQQEP</td>
<td>Real-Time QSE to QSE Energy Purchase (Trade)</td>
</tr>
<tr>
<td>Real-Time QSE to QSE Energy Purchase (Trade)</td>
<td>RTQQQES</td>
</tr>
<tr>
<td>RESREV</td>
<td>Resource Share Revenue Settlement Payment for QSE</td>
</tr>
<tr>
<td></td>
<td>DAM Energy Sale (Trade)</td>
</tr>
</tbody>
</table>
Activity: Now it’s your turn!

Refer to your Settlements Workbook

In a small group, respond to the questions that relate to Scenario #RT3.

You have 5 minutes to complete your questions.

If you cannot complete all questions, don’t worry – all questions will be reviewed as a class.
Volumetric determinants for Real-Time Energy Imbalance:

\[
\text{RESMEB}_q = \text{GSPLITPER} \times \sum \text{MEB} \text{ for Generation Site}
\]

\[
\text{RNIMBAL}_q = \text{MWh Imbalance for all transactions at Resource Node}
\]

\[
\text{LZIMBAL}_q = \text{MWh Imbalance for all transactions at Load Zone}
\]

\[
\text{HBIMBAL}_q = \text{MWh Imbalance for all transactions at Hub}
\]

For information only; not used in Settlements

<table>
<thead>
<tr>
<th>RESMEB</th>
<th>Resource Share of total Metered Energy at Bus for QSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNIMBAL</td>
<td>Resource Node Energy Imbalance per QSE</td>
</tr>
<tr>
<td>LZIMBAL</td>
<td>Load Zone Energy Imbalance per QSE</td>
</tr>
<tr>
<td>HBIMBAL</td>
<td>Hub Energy Imbalance per QSE</td>
</tr>
</tbody>
</table>
SCED will dispatch only the CCGR that is currently online. Metered generation is settled at the Logical Resource Node.
<table>
<thead>
<tr>
<th>Bill Determinant</th>
<th>Description</th>
<th>Logical Resource Node</th>
<th>Physical Resource Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTEIAMT</td>
<td>Real Time Energy Imbalance</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DAES</td>
<td>Day Ahead Energy Sales</td>
<td>X (3PO)</td>
<td></td>
</tr>
<tr>
<td>GSPLITPER</td>
<td>Generation Unit Splitting Percentage</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RTEIAMT</td>
<td>Real Time Energy Imbalance</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DAEP</td>
<td>Day Ahead Energy Purchase</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>DAES</td>
<td>Day Ahead Energy Sales</td>
<td>X (Energy only)</td>
<td></td>
</tr>
<tr>
<td>RTQQEP</td>
<td>Real Time QSE to QSE Purchase</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RTQQES</td>
<td>Real Time QSE to QSE Sale</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Fundamentals of Payment for DC Tie Import

Who: A QSE that has a DC Tie import

What: A Payment for the Energy that is imported into the ERCOT grid through a DC Tie

Why: When a QSE brings Power into the ERCOT grid they need to receive a payment for it
A QSE Schedules a DC Tie to import power into ERCOT area
DC Tie Import Payment

• A QSE Schedules a DC Tie to import energy into ERCOT area

• The QSE receives a payment for the injection of energy
A QSE1

- Schedules 100 MW import on DC Tie one
- The Settlement Point Price is $50/MWh at DCTIE1

\[
\text{RTDCIMPAMT}_{q, p} = (-1) \times \text{RTSPP}_p \times (\text{RTDCIMP}_{q, p} \times \frac{1}{4})
\]

\[
\text{$-1250 = (-1) \times $50 \times (100\text{MW} \times \frac{1}{4})}
\]
### Fundamentals of Real–Time Ancillary Service Imbalances

<table>
<thead>
<tr>
<th>Who:</th>
<th>All QSEs that have Resource Capacity available to ERCOT during Real-Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A charge or payment based on the imbalance between available Capacity and Ancillary Service Reserves</td>
</tr>
<tr>
<td>Why:</td>
<td>To make Resources indifferent to the utilization of their capacity for energy or Ancillary Service reserves</td>
</tr>
</tbody>
</table>
The Basic Idea:

\[
(-1) \left( \left( \text{On-Line Reserve SUPPLIES} \right) - \left( \text{On-Line Reserve OBLIGATIONS} \right) \right) \times \text{On-line Reserve Price}
\]

\[
+ \left( \left( \text{Off-Line Reserve SUPPLIES} \right) - \left( \text{Off-Line Reserve OBLIGATIONS} \right) \right) \times \text{Off-line Reserve Price}
\]

Calculated ERCOT-wide per QSE
Real-Time Ancillary Service Imbalance Overview

For Generation Resources:

- HSL = 125 MW
  - 100 MW

Paid in RTEIMB

\[ \text{LMP} + \text{ADDER} \]

Paid in RTASIMB

\[ \text{ADDER} \]

Paid in RTEIMB

\[ \text{LMP} + \text{ADDER} \]
Real-Time Ancillary Service Imbalance Overview

For Generation Resources:

HSL=125MW

100MW

Energy Dispatched

AS Undeployed

Paid in DAM or SASM

LMP + ADDER

Paid in RTEIMB

Charge (at Adder)

HSL=125MW

100MW

Energy Dispatched

AS Deployed

Paid in RTEIMB

LMP + ADDER
Real-Time Ancillary Service Imbalance Overview

For Load Resources:

Paid in RTASIMB
\[\text{ADDER}\]

\[\text{HSL}=125\text{MW}\]
\[100\text{MW}\]
\[\text{LSL}\]

Charged in RTEIMB
\[\text{LMP + ADDER}\]

Paid in DAM or SASM

Paid in RTASIMB
\[\text{ADDER}\]

\[\text{HSL}=125\text{MW}\]
\[100\text{MW}\]
\[\text{LSL}\]

\[\text{AS Undeployed}\]

Charged in RTEIMB
\[\text{LMP + ADDER}\]
Ancillary Service Imbalance Details:

\[
(-1) \left( \begin{array}{c}
\text{Ancillary Service On-Line Reserve Imbalance} \\
\text{Ancillary Service Off-Line Reserve Imbalance}
\end{array} \right) \times \text{On-line Reserve Price} + \begin{array}{c}
\text{Ancillary Service Off-Line Reserve Imbalance} \\
\text{Ancillary Service On-Line Reserve Imbalance}
\end{array} \times \text{Off-line Reserve Price}
\]
Ancillary Service On-Line Reserve Imbalance

\[ \text{RTASOLIMB}_q = \text{RTOLCAP}_q - [\text{Online Capacity already reserved}] \]

Online Capacity in Real-Time:

RTASOLIMB

<table>
<thead>
<tr>
<th>RTASOLIMB</th>
<th>Real Time Ancillary Service On-Line Reserve Imbalance</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTOLCAP</td>
<td>Real-Time On-Line Reserve Capacity</td>
</tr>
</tbody>
</table>
Real-Time Ancillary Service Imbalance

Ancillary Service On-Line Reserve Imbalance

\[
RTASOLIMB_q = RTOLCAP_q - \text{[Online Capacity already reserved]}
\]

Online Capacity in Real-Time:

- Capacity from Non-Controllable Load Resources Carrying Responsive Reserve (RTNCLRCAP)
- Capacity from Controllable Load Resources (RTCLRCAP)
- High Sustained Limits – Metered Generation (RTOLHSL - RTGMQ)

Telemetered and Integrated to 15-minutes
Ancillary Service On-Line Reserve Imbalance

\[
RTASOLIMB_q = RTOLCAP_q - [\text{Online Capacity already reserved}]
\]

Online Capacity in Real-Time:

- Ancillary Service Supply Responsibility
  - RUC Ancillary Service Supply Responsibility
  - Ancillary Service Schedule for Off-line Generation
  - Controllable Load Resource Non-Spin Responsibility
  - Ancillary Service Supply Responsibility for RMR Units
### Ancillary Service On-Line Reserve Imbalance

\[
RTASOLIMB_q = RTOLCAP_q - [(RTASRESP_q \times \frac{1}{4}) - RTASOFF_q - RTRUCNBBRESP_q - RTCLRNSRESP_q - RTRMRRESP_q]
\]

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTASRESP</td>
<td>Real-Time Ancillary Service Supply Responsibility</td>
</tr>
<tr>
<td>RTASOFF</td>
<td>Real-Time Ancillary Service Schedule for the Off-Line Generation Resource</td>
</tr>
<tr>
<td>RTRUCNBBRESP</td>
<td>Real-Time RUC Ancillary Service Supply Responsibility in Non-Buy-Back hours</td>
</tr>
<tr>
<td>RTCLRNSRESP</td>
<td>Real-Time Controllable Load Resource Non-Spin Responsibility</td>
</tr>
<tr>
<td>RTRMRRESP</td>
<td>Real-Time Ancillary Service Supply Responsibility for RMR Units</td>
</tr>
</tbody>
</table>
Ancillary Service Imbalance Details:

\[
(-1) \left( \text{Ancillary Service On-Line Reserve Imbalance} \right) \times \text{On-line Reserve Price} + \left( \text{Ancillary Service Off-Line Reserve Imbalance} \right) \times \text{Off-line Reserve Price}
\]
Ancillary Service Off-Line Reserve Imbalance

\[
\text{RTASOFFIMB}_q = \text{RTOFFCAP}_q - \text{[Offline Capacity already reserved]}
\]

Offline Capacity in Real-Time:

<table>
<thead>
<tr>
<th>RTASOFFIMB</th>
<th>Real Time Ancillary Service Off-Line Reserve Imbalance</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTOFFCAP</td>
<td>Real-Time Off-Line Reserve Capacity</td>
</tr>
</tbody>
</table>
Ancillary Service Off-Line Reserve Imbalance

\[ \text{RTASOFFIMB}_q = \text{RTOFFCAP}_q - [\text{Offline Capacity already reserved}] \]

Offline Capacity in Real-Time:

- Non-Spin Schedule for Controllable Load Resources (RTCLRNS)
- Generation Resources with Off-Line Non-Spin Schedule (RTOFFNSHSL)
- Generation Resources with Cold Start Available in 30 Minutes (RTCST30HSL)

\text{Converted to 15-minutes}
Ancillary Service Off-Line Reserve Imbalance

\[ \text{RTASOFFIMB}_q = \text{RTOFFFCAP}_q - [\text{Offline Capacity already reserved}] \]

Offline Capacity in Real-Time:

- Controllable Load Resource Non-Spin Responsibility (RTCLRNSRESP)
- Ancillary Service Schedule for Off-Line Generation Resources (RTASOFF)
Putting it all back together . . .

\[
\text{RTASIAMT}_q = (-1) \times [(\text{RTASOLIMB}_q \times \text{RTRSVPOR}) + (\text{RTASOFFIMB}_q \times \text{RTRSVPOFF})]
\]

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTASIAMT</td>
<td>Real-Time Ancillary Service Imbalance Amount</td>
</tr>
<tr>
<td>RTASOLIMB</td>
<td>Real-Time Ancillary Service On-Line Reserve Imbalance</td>
</tr>
<tr>
<td>RTRSVPOR</td>
<td>Real-Time Reserve Price for On-Line Reserves</td>
</tr>
<tr>
<td>RTASOFFIMB</td>
<td>Real-Time Ancillary Service Off-Line Reserve Imbalance</td>
</tr>
<tr>
<td>RTRSVPOFF</td>
<td>Real-Time Reserve Price for Off-Line Reserves</td>
</tr>
</tbody>
</table>
Real-Time Ancillary Service Imbalance: Triggers

**Trigger #1**
A QSE has On-Line Reserves in Real-Time

**Trigger #2**
A QSE has Off-Line Reserves in Real-Time
Real-Time Ancillary Service Imbalance

QSE1
- One Generation Resource online
- HSL is 200 MW (50MWh for 15 minutes)
- Metered Generation is 40 MWh
- No Ancillary Service commitments
- No other Resources available within the hour
- On-line Reserve Price is $20/MWh
- Off-line Reserve Price is $5/MWh

\[ \text{RTASIAMT}_q = (-1) \times [(\text{RTASOLIMB}_q \times \text{RTRSVPOR}) + (\text{RTASOFFIMB}_q \times \text{RTRSVPOFF})] \]
Outcome #1

RTASOLIMB\(_q\) = RTOLCAP\(_q\) – [Capacity already reserved]

= (RTOLHSL – RTMGQ) – [0]

= 50 MWh – 40 MWh

= 10 MWh

RTASIAMT\(_q\) = (-1) * [(RTASOLIMB\(_q\) * RTRSVPOR) + (RTASOFFIMB\(_q\) * RTRSVPOFF)]

= (-1) * [(10 MWh * $20/MWh) + (0 * $5/MWh)]

= -$200
Real-Time Ancillary Service Imbalance: Triggers

**Trigger #1**
A QSE has On-Line Reserves in Real-Time

**Trigger #2**
A QSE has Off-Line Reserves in Real-Time
QSE4

- No Resources online
- One Generation Resource offline and available within the hour
- HSL is 100 MW (25MWh for 15 minutes)
- Entire Resource is reserved for Non-Spin
- No other Resources available within the hour
- On-line Reserve Price is $20/MWh
- Off-line Reserve Price is $5/MWh

\[
RTASIAMT_q = (-1) \times [(RTASOLIMB_q \times RTRSVPOR) + (RTASOFFIMB_q \times RTRSVPOFF)]
\]
Real-Time Ancillary Service Imbalance

**Outcome #2**

\[ RTASOLIMB_q = RTOLCAP_q - \text{[Capacity already reserved]} \]
\[ = 0 - [(RTASRESP \cdot \frac{1}{4}) - RTASOFF] \]
\[ = 0 - [(100MW \cdot \frac{1}{4}h) - 25MWh] \]
\[ = 0 \text{ MWh} \]

\[ RTASOFFIMB_q = RTOFFCAP_q - \text{[Reserved Capacity]} \]
\[ = RTOFFNSHSL - [RTASOFF] \]
\[ = 25MWh - [25MWh] \]
\[ = 0 \text{ MWh} \]

\[ RTASIAMT_q = (-1) \cdot [(RTASOLIMB_q \cdot RTRSVPOR) + (RTASOFFIMB_q \cdot RTRSVPOFF)] \]
\[ = (-1) \cdot [(0 \cdot $20/MWh) + (0 \cdot $5/MWh)] \]
\[ = $0 \]
Refer to your Settlements Workbook

In a small group, respond to the questions that relate to Scenario #RT4.

You have 10 minutes to complete your questions.

If you cannot complete all questions, don’t worry – all questions will be reviewed as a class.
### Fundamentals of Real–Time Reliability Deployment Ancillary Service Imbalances

<table>
<thead>
<tr>
<th>Who:</th>
<th>All QSEs that have Resource Capacity available to ERCOT during Reliability Deployments in Real-Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A charge or payment based on the imbalance between available Capacity and Ancillary Service Reserves</td>
</tr>
<tr>
<td>Why:</td>
<td>To make Resources indifferent to the utilization of their capacity for energy or Ancillary Service reserves</td>
</tr>
</tbody>
</table>
A QSE has On-Line Reserves in Real-Time
QSE1

- Had a Real-Time Ancillary Service Online Reserve Imbalance

\[
RTRDASIAMT_q = (-1) \times (RTASOLIMB_q \times RTRDP)
\]

<table>
<thead>
<tr>
<th>RTRDASIAMT</th>
<th>Real-Time Reliability Deployment Ancillary Service Imbalance Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTASOLIMB</td>
<td>Real Time Ancillary Service On-Line Reserve Imbalance</td>
</tr>
<tr>
<td>RTRDP</td>
<td>Real-Time On-Line Reliability Deployment Price</td>
</tr>
</tbody>
</table>
## Fundamentals of Base Point Deviation Charge

### Who:
QSEs that have Resources that do not follow Base Points as dictated by SCED

### What:
A charge for over generation or under generation – May not receive this charge when helping frequency

### Why:
The Resource did not follow Dispatch Instructions and Ancillary Services deployments within defined tolerances

### Real-Time

**Real-Time Activities**
- Imbalances
- Base Point Deviations
- Other odds & ends
Base Point Deviation Charge

• Resource did not follow Dispatch Instructions and Ancillary Services Deployments within defined tolerances

• Tolerances

± 5% or ± 5MW, whichever is greater

+ 10% for Intermittent Renewable Resources (when curtailed)
Base Point Deviation Charge

- **Exclusions**
  - No charge during a Frequency deviation greater than 0.05 Hz if the QSEs deviation helps frequency.
  - No charge for any intervals with Responsive Reserve deployments.

Subject to Base Point Deviation Charge.

SCED Base Point
Base Point Deviation Charge

- Exemptions
  - RMR Units
  - Qualifying Facilities (QFs) that do not submit Energy Offer Curves
  - Quick Start Generation Resources (QSGRs) exempt for the first Settlement Interval in which they are deployed
Determining Basepoint Deviation Charges

ERCOT compares Adjusted Aggregated Base Points to the Time-Weighted Telemetered Generation.
Calculating Adjusted Aggregated Base Point

\[
\text{Adjusted Aggregated Base Point} = \text{Average Base Point} + \text{Average Regulation}
\]

- Adjusted Aggregated Base Point
- Average Base Point
- Average Regulation
- 15 Minute Value
- Considers Ramping
Base Point Deviation Charge: Triggers

**Trigger #1**
Resource did not follow Dispatch Instructions and OVER Generated

**Trigger #2**
Resource did not follow Dispatch Instructions and UNDER Generated
• Resource did not follow Dispatch Instructions and OVER Generated

• The Over Generation is outside of the 5% or 5 MW tolerance

• QSE is charged:

  Settlement Point Price * the MW above Tolerance

  *If system frequency dipped below 59.95 Hz during the settlement interval, then the QSE would not be charged.*
QSE1 unit 5

- Adjusted Aggregated Base Point of 40MW
- Time Weighted Telemetered Generation of 12MWh (Operated at 48MW)
- Tolerances are 5% or 5MW
- Settlement Point Price is $20/MWh at RN5

Base Point Deviation Charge

\[ \text{Base Point Deviation Charge} = \text{Price} \times (\text{Generation} - \frac{1}{4}h \times \text{Max (AABP + 5\% or AABP + 5MW)}) \]

\[ = \$20/\text{MWh} \times (12\text{MWh} - \frac{1}{4}h \times \text{Max (42MW or 45MW)}) \]

\[ = \$20/\text{MWh} \times (12\text{MWh} - 11.25\text{MWh}) \]

\[ = \$15 \]
Translated into Settlement Equations,

**BPDAMT** = Max (**PR1**, **RTSPP**) * **OGEN**

**OGEN** = Max \(0, \left(TWTG - \frac{1}{4} \times \text{Max} \left(1 + K1\right) \times \text{AABP}, (\text{AABP} + Q1)\right)\)

<table>
<thead>
<tr>
<th><strong>BPDAMT</strong> (_{q, r, p})</th>
<th><strong>Base Point Deviation Amount</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OGEN</strong></td>
<td><strong>Over Generation Volume</strong></td>
</tr>
<tr>
<td><strong>TWTG</strong> (_{q, r, p})</td>
<td><strong>Time Weighted Telemetered Generation</strong></td>
</tr>
<tr>
<td><strong>AABP</strong> (_{q, r, p})</td>
<td><strong>Adjusted Aggregated Base Point</strong></td>
</tr>
<tr>
<td><strong>PR1</strong></td>
<td>Minimum price for over-generation, $20.</td>
</tr>
<tr>
<td><strong>K1</strong></td>
<td>The percentage tolerance for over-generation, 5%.</td>
</tr>
<tr>
<td><strong>Q1</strong></td>
<td>The MW tolerance for over-generation, 5 MW.</td>
</tr>
</tbody>
</table>
Outcomes

QSE1 unit 5

- Adjusted Aggregated Base Point of 40MW
- Time Weighted Telemetered Generation of 12MWh (Operated at 48MW)
- Tolerances are 5% or 5MW
- Settlement Point Price is $20/MWh at RN5

\[ \text{BPDAMT} = \max (\text{PR1}, \text{RTSPP}) \times \text{OGEN} \]

\[ \text{OGEN} = \max \left( 0, \left( \text{TWTG} - \frac{1}{4} \times \max \left( (1 + K1) \times \text{AABP}, \left( \text{AABP} + Q1 \right) \right) \right) \right) \]

\[ \text{OGEN} = \max \left( 0, \left( 12\text{MWh} - \frac{1}{4} \times \max \left( 42 \text{ MW}, 45\text{MW} \right) \right) \right) = 0.75 \text{ MWh} \]

\[ \text{BPDAMT} = \max \left( \$20/\text{MWh}, \$20/\text{MWh} \right) \times \text{OGEN} = \$15 \]
Key Differences between Intermittent Renewable Resources (IRRs) & Conventional Resources

**IRR must be Curtailed**
- Curtailment Flag

**IRR must be Over-Generating**
- Telemetered Generation
- Instructed Base Point

**Wider tolerance for deviation from Base Point**
**When are IRRs exposed to deviation charges?**

<table>
<thead>
<tr>
<th>Curtailment Flag</th>
<th>IRR output within 10% acceptable range</th>
<th>IRR output exceeds 10% acceptable range</th>
</tr>
</thead>
<tbody>
<tr>
<td>is not set</td>
<td>No Charge</td>
<td>No Charge</td>
</tr>
<tr>
<td>is set</td>
<td>No Charge</td>
<td><strong>Charge</strong></td>
</tr>
</tbody>
</table>
Base Point Deviation Charge – IRRs

Translated into Settlement Equations,

If $SBPBHDLFLAG = 1$, then

$$BPDAMT = \text{Max} \left( PR1, \text{RTSPP} \right) \times \text{OGENIRR}$$

$$\text{OGENIRR} = \text{Max} \left( 0, \left( TWTG - \frac{1}{4} \times AABP \times (1 + KIRR) \right) \right)$$

<table>
<thead>
<tr>
<th>SBPBHDLFLAG</th>
<th>SCED Base Point Below HDL FLAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$BPDAMT_{q, r, p}$</td>
<td>Base Point Deviation Amount</td>
</tr>
<tr>
<td>$\text{OGENIRR}$</td>
<td>Over Generation Volume per IRR Generation Resource</td>
</tr>
<tr>
<td>$TWTG_{q, r, p}$</td>
<td>Time Weighted Telemetered Generation</td>
</tr>
<tr>
<td>$AABP_{q, r, p}$</td>
<td>Adjusted Aggregated Base Point</td>
</tr>
<tr>
<td>$PR1$</td>
<td>Minimum price for over-generation, $20.</td>
</tr>
<tr>
<td>$KIRR$</td>
<td>The percentage tolerance for IRRs, 10%.</td>
</tr>
</tbody>
</table>
Refer to your Settlements Workbook

In a small group, respond to the questions that relate to Scenario #RT5.

You have 5 minutes to complete your questions.

If you cannot complete all questions, don’t worry – all questions will be reviewed as a class.
Base Point Deviation Charge: Triggers

**Trigger #1**
Resource did not follow Dispatch Instructions and OVER Generated

**Trigger #2**
Resource did not follow Dispatch Instructions and UNDER Generated
• Resource did not follow Dispatch Instructions and UNDER Generated
• The Under Generation is outside of the 5% or 5 MW tolerance

• QSE is charged:
Settlement Point Price * the MW below Tolerance

*If system frequency rose above 60.05 Hz during the settlement interval, then the QSE would not be charged.*
QSE4 unit 8

- Adjusted Aggregated Base Point of 40MW
- Time Weighted Telemetered Generation of 8MWh (Operated at 32MW)
- Tolerances are 5% or 5MW
- Settlement Point Price is -$20/MWh at RN8

**Base Point Deviation Charge**

\[
= (-1) \times \text{Price} \times \left(\frac{1}{4}\text{h} \times \text{Min}(\text{AABP} - 5\% \text{ or } \text{AABP} - 5\text{MW}) - \text{Generation}\right)
\]

\[
= (-1) \times -$20/\text{MWh} \times \left(\frac{1}{4}\text{h} \times \text{Min}(38\text{MW} \text{ or } 35\text{MW}) - 8\text{MWh}\right)
\]

\[
= (-1) \times -$20/\text{MWh} \times (8.75\text{MWh} - 8\text{MWh})
\]

\[
= $15
\]
Transcribed into Settlement Equations,

\[
\text{BPDAMT} = (-1) \times \min (\text{PR2, RTSPP}) \times \min(1, \text{KP}) \times \text{UGEN}
\]

\[
\text{UGEN} = \max \left(0, \min \left( \left(1 - K2 \right) \times \frac{1}{4} \text{AABP}, \frac{1}{4} \left( \text{AABP} - Q2 \right) \right) - \text{TWTG} \right)
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPDAMT</td>
<td>Base Point Deviation Amount</td>
</tr>
<tr>
<td>UGEN</td>
<td>Under Generation Volume</td>
</tr>
<tr>
<td>TWTG</td>
<td>Time Weighted Telemetered Generation</td>
</tr>
<tr>
<td>AABP</td>
<td>Adjusted Aggregated Base Point</td>
</tr>
<tr>
<td>PR2</td>
<td>Minimum price for under-generation, -$20.</td>
</tr>
<tr>
<td>K2</td>
<td>The percentage tolerance for under-generation, 5%.</td>
</tr>
<tr>
<td>Q2</td>
<td>The MW tolerance for under-generation, 5 MW.</td>
</tr>
<tr>
<td>KP</td>
<td>Settlement Point Price coefficient, (1.0, for now)</td>
</tr>
</tbody>
</table>
QSE4 unit 8

- Adjusted Aggregated Base Point of 40MW
- Time Weighted Telemetered Generation of 8MWh (Operated at 32MW)
- Tolerances are 5% or 5MW
- Settlement Point Price is -$20/MWh at RN8

\[
\text{UGEN} = \max\left(0, \left[\min\left(1 - K2, \frac{1}{4} \text{AABP}, \frac{1}{4} (\text{AABP} - Q2)\right) - \text{TWTG}\right]\right)
\]

\[
\text{UGEN} = \max\left(0, \min\left(9.5\text{MWh}, 8.75\text{MWh}\right) - 8\text{MWh}\right) = 0.75\text{MWh}
\]

\[
\text{BPDAMT} = (-1) \times \min\left(\text{PR2, RTSPP}\right) \times \min\left(1, \text{KP}\right) \times \text{UGEN}
\]

\[
\text{BPDAMT} = (-1) \times \min\left(-20/\text{MWh}, -20/\text{MWh}\right) \times \min\left(1, 1\right) \times \text{UGEN} = 15
\]
Fundamentals of Base Point Deviation Payment

Who: QSEs that have load

What: Distributes the funds collected from Base Point Deviation Charges.

Why: To keep ERCOT revenue neutral
Charges for Base Point Deviations are collected
• Resources Over or Under Generated
• ERCOT charges the QSEs representing the Resources

• Sum Base Point Deviation charges for the interval
• Calculate each QSE’s Load Ratio Share
• Pay each QSE their portion of the revenue
For interval one ERCOT charged for deviation

- Total Charges $255

QSE 5 has thirty percent of Load

- QSE 5 is paid for 30 percent of the $255

\[
LABPDAMT_q = (-1) \times BPDAMTTOT \times LRS_q
\]

\[
$-76.50 = (-1) \times $255 \times 0.30
\]

<table>
<thead>
<tr>
<th>LABPDAMT_q</th>
<th>Load-Assigned Base Point Deviation Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPDAMTTOT</td>
<td>Base Point Deviation Amount Total</td>
</tr>
<tr>
<td>LRS_q</td>
<td>Load Ratio Share</td>
</tr>
</tbody>
</table>
Fundamentals of PTP Obligations Settled in Real-Time

Who: QSEs that have purchased PTP obligations in the DAM

What: A Charge or Payment based on Real-Time Congestion

Why: To Hedge the Cost of congestion in Real-Time
Payments or Charges for PTP Obligations in Real-Time

Day-Ahead Market
A QSE Purchases PTP Obligation in Day-Ahead Market.

Real-Time Settlements
PTP Obligation settled in the Real-Time market
A QSE buys a PTP obligation in the DAM
• A QSE buys a PTP obligation in the Day-Ahead Market.

• The Price is the Difference between the RTSPP of the Source and Sink
  • If Sink price is higher, the QSE is paid
  • If Source price is higher, the QSE is charged
Settlement for DAM PTP Obligations

\[ RTOBLAMT_{q, (j, k)} = (-1) \times RTOBLPR_{(j, k)} \times RTOBL_{q, (j, k)} \]

\[ RTOBLPR_{(j, k)} = \sum (RTSPP_k - RTSPP_j) / 4 \]

- **Determinants**
  - Real-Time Obligation Amount
  - Real-Time Obligation Price
  - Real-Time Obligation
  - Real-Time Settlement Point Price

- \( q = QSE \)
- \( j = Source \ Settlement \ Point \)
- \( k = Sink \ Settlement \ Point \)
• QSE3 bought 40 MW of PTP obligations in the Day-Ahead Market.

• RT Settlement Point Prices during the hour

<table>
<thead>
<tr>
<th>Interval</th>
<th>Source</th>
<th>Sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>0415</td>
<td>$17</td>
<td>$21</td>
</tr>
<tr>
<td>0430</td>
<td>$17</td>
<td>$22</td>
</tr>
<tr>
<td>0445</td>
<td>$16</td>
<td>$21</td>
</tr>
<tr>
<td>0500</td>
<td>$15</td>
<td>$21</td>
</tr>
</tbody>
</table>

• QSE3 receives a payment
Payments or Charges for PTP Obligations in Real-Time

**Outcome #1**

$$\text{RTOBLPR}_{(j, k)} = \frac{\sum (\text{RTSPP}_{k, i} - \text{RTSPP}_{j, i})}{4}$$

$$\text{$5/MW}_{(j, k)} = \left[ \left( \frac{21}{MWh} - \frac{17}{MWh} \right) + \left( \frac{22}{MWh} - \frac{17}{MWh} \right) + \left( \frac{21}{MWh} - \frac{16}{MWh} \right) + \left( \frac{21}{MWh} - \frac{15}{MWh} \right) \right] / 4$$

QSE3 receives a payment

$$\text{RTOBLAMT}_{q, (j, k)} = (-1) \times \text{RTOBLPR}_{(j, k)} \times \text{RTOBL}_{q, (j, k)}$$

$$-\$200 = (-1) \times \$5/MW \times 40 \text{ MW}$$
## Real-time Settlement of DAM PTP Obligations with Links to Options

<table>
<thead>
<tr>
<th>Who:</th>
<th>NOIE that owns PTP Options before DAM and buys PTP Obligations in DAM linked to those Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A Payment based on Real-Time Congestion</td>
</tr>
<tr>
<td>Why:</td>
<td>To Hedge the Cost of congestion in Real-Time</td>
</tr>
</tbody>
</table>
Payments for PTP Obligations with Links to Options

NOIE buys DAM PTP Obligations based on PTP Options they own
Settlement for DAM PTP Obligations with Links to Options

\[
\text{RTOBLLOAMT}_{q, (j, k)} = (-1) \times \text{Max} (0, \text{RTOBLPR}_{(j, k)}) \times \text{RTOBLLO}_{q, (j, k)}
\]

\[
\text{RTOBLPR}_{(j, k)} = \sum (\text{RTSPP}_k - \text{RTSPP}_j) / 4
\]

Determinants

- **Real-Time Obligation with Links to an Option Amount**
- **Real-Time Obligation Price**
- **Real-Time Obligation with Links to an Option**
- **Real-Time Settlement Point Price**

\( q = \text{QSE} \)
\( j = \text{Source Settlement Point} \)
\( k = \text{Sink Settlement Point} \)
Fundamentals of Payments for Services Sold in SASM

Who: QSEs that sold Reg-Up, Reg-Down, Responsive, or Non-Spin in a SASM

What: A Payment for the services sold in a SASM

Why: To cover the costs of a service to ensure ERCOT reliability
Reasons ERCOT may procure Ancillary Services in the Adjustment Period

- Failure to Provide by a QSE
- Infeasible due to Transmission Constraints
- Increased need after DAM
- Insufficient Ancillary Service Offers in DAM
ERCOT executes a SASM and Ancillary Services are sold
Payments for Ancillary Services Sold in a SASM

In SASM1

- QSE1, 50 MW of Regulation Up at $8/MW
- QSE4, 10 MW of Regulation Down at $4/MW
- QSE4, 20 MW of Responsive Reserve at $8/MW
- QSE1, 40 MW of Non-Spin at $12/MW

\[
\begin{align*}
\text{RTPCRUAMT}_{q, M} &= (-1) \times \text{MCPCRU}_M \times \text{RTPCRU}_{q, M} \\
\text{RTPCRDAMT}_{q, M} &= (-1) \times \text{MCPCRD}_M \times \text{RTPCRD}_{q, M} \\
\text{RTPCRRAMT}_{q, M} &= (-1) \times \text{MCPCRR}_M \times \text{RTPCRR}_{q, M} \\
\text{RTPCNSAMT}_{q, M} &= (-1) \times \text{MCPCNS}_M \times \text{RTPCNS}_{q, M}
\end{align*}
\]

- $400_{q, M} = (-1) \times 8/\text{MW} \times 50\text{MW}_{q, M}
- $40_{q, M} = (-1) \times 4/\text{MW} \times 10\text{MW}_{q, M}
- $160_{q, M} = (-1) \times 8/\text{MW} \times 20\text{MW}_{q, M}
- $480_{q, M} = (-1) \times 12/\text{MW} \times 40\text{MW}_{q, M}
## Fundamentals of Payments for AS Procured through RUC

<table>
<thead>
<tr>
<th>Who:</th>
<th>QSEs who were committed to provide AS through RUC and Opted out of the RUC commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A Payment for the reserved capacity</td>
</tr>
<tr>
<td>Why:</td>
<td>To cover the value of the reserved capacity</td>
</tr>
</tbody>
</table>
Payments for Ancillary Services Procured through RUC

HSL=125MW
100MW

Energy Dispatched

Ancillary Service

- Paid at Adder
- Paid in RTEIMB
  - LMP + ADDER

Available only for QSEs who opt out of RUC
Payments for Ancillary Services Procured through RUC

QSE1

- Was committed to provide Ancillary Services on several Resources
- Opted out of RUC commitment

\[
RTRUCRSVAMT_q = (-1) \times (RTRUCRESP_q \times RTRSVPOR)
\]

Where \( RTRUCRESP_q = \sum_r RTRUCASA_{q,r} \times \frac{1}{4} \)

<table>
<thead>
<tr>
<th>RTRUCRSVAMT</th>
<th>Real-Time RUC Ancillary Service Reserve Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRUCRESP</td>
<td>Real-Time RUC Ancillary Service Supply Responsibility</td>
</tr>
<tr>
<td>RTRSVPOR</td>
<td>Real-Time Reserve Price for On-Line Reserves</td>
</tr>
<tr>
<td>RTRUCASA</td>
<td>Real-Time RUC Ancillary Service Awards</td>
</tr>
</tbody>
</table>
QSE1

- Was committed to provide Ancillary Services on several Resources
- Opted out of RUC commitment before the end of the Adjustment Period

Also,

\[ RTRDRUCRSVAMT_q = (-1) \times (RTRUCRESP_q \times RTRDP) \]

<table>
<thead>
<tr>
<th>RTRDRUCRSVAMT</th>
<th>Real-Time Reliability Deployment RUC Ancillary Service Reserve Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRUCRESP</td>
<td>Real-Time RUC Ancillary Service Supply Responsibility</td>
</tr>
<tr>
<td>RTRDP</td>
<td>Real-Time On-Line Reliability Deployment Price</td>
</tr>
</tbody>
</table>
### Fundamentals of Charges for Failure to Provide

<table>
<thead>
<tr>
<th><strong>Who:</strong></th>
<th>QSEs that fail to provide their Ancillary Service Supply Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What:</strong></td>
<td>A charge for the Failure to Provide Ancillary Service Capacity</td>
</tr>
<tr>
<td><strong>Why:</strong></td>
<td>To ensure costs are met in order to replace Failed Ancillary Service Capacity</td>
</tr>
</tbody>
</table>
Charge for Failure to Provide

Max Price of AS Markets * Failed Quantity

\[
\begin{align*}
RUFQAMT_q &= \text{Max} (MCPCRU_m) \times RUFQ_q, \\
RDFQAMT_q &= \text{Max} (MCPCRD_m) \times RDFQ_q, \\
RRFQAMT_q &= \text{Max} (MCPCRR_m) \times RRFQ_q, \\
NSFQAMT_q &= \text{Max} (MCPCNS_m) \times NSFQ_q,
\end{align*}
\]

Similar for other AS Types

<table>
<thead>
<tr>
<th>RUFQAMT</th>
<th>Reg-Up Failure Quantity Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCPCRU</td>
<td>Market Clearing Price for Capacity for Reg-Up</td>
</tr>
<tr>
<td>RUFQ</td>
<td>Reg-Up Failure Quantity</td>
</tr>
</tbody>
</table>
**Charges for Reconfiguration SASM**

**Charge for Failure to Provide**

Reconfiguration SASM Price * Failed Quantity

\[
\begin{align*}
RRUFQAMT_q &= MCPCRU_{rs} \times RRUFQ_q, \\
RRDFQAMT_q &= MCPCRD_{rs} \times RRDFQ_q, \\
RRRFQAMT_q &= MCPCRR_{rs} \times RRFQ_q, \\
RNSFQAMT_q &= MCPCNS_{rs} \times RNSFQ_q,
\end{align*}
\]

**Similar for other AS Types**

<table>
<thead>
<tr>
<th>RRUFQAMT</th>
<th>Reconfiguration Reg-Up Failure Quantity Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCPCRU_{rs}</td>
<td>Market Clearing Price for Capacity for Reg-Up by RSASM</td>
</tr>
<tr>
<td>RRUFQ</td>
<td>Reconfiguration Reg-Up Failure Quantity</td>
</tr>
</tbody>
</table>
### Fundamentals of Charges for Infeasibility

<table>
<thead>
<tr>
<th>Who:</th>
<th>QSEs with Ancillary Service Supply Responsibility that is deemed infeasible by ERCOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A charge for the Infeasible Ancillary Service Capacity</td>
</tr>
<tr>
<td>Why:</td>
<td>To recover payments made for Ancillary Service Capacity in the DAM</td>
</tr>
</tbody>
</table>
Charges for Infeasibility

**Outcome #1**

**Charge for Infeasibility**

DAM Price of AS Markets * Infeasible Quantity

\[
\begin{align*}
\text{RUINFQAMT}_q &= \text{MCPCRU}_{\text{DAM}} \ast \text{RUINFQ}_q, \\
\text{RDINFQAMT}_q &= \text{MCPCRD}_{\text{DAM}} \ast \text{RDINFQ}_q, \\
\text{RRINFQAMT}_q &= \text{MCPCRR}_{\text{DAM}} \ast \text{RRINFQ}_q, \\
\text{NSINFQAMT}_q &= \text{MCPCNS}_{\text{DAM}} \ast \text{NSINFQ}_q,
\end{align*}
\]

**Similar for other AS Types**

<table>
<thead>
<tr>
<th>RUINFQAMT</th>
<th>Reg-Up Infeasible Quantity Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCPCRU_{\text{DAM}}</td>
<td>Market Clearing Price for Capacity for Reg-Up in DAM</td>
</tr>
<tr>
<td>RUINFQ</td>
<td>Reg-Up Infeasible Quantity</td>
</tr>
</tbody>
</table>
# Fundamentals of Adjustments to Cost for Ancillary Service

**Real-Time**

**Real-Time Ancillary Service Settlements**

## Adjustments to Costs for Ancillary Services Procurement

<table>
<thead>
<tr>
<th>Who:</th>
<th>QSEs that have Ancillary Service obligations</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>A charge to the QSE for its share of the net total costs incurred in both DAM and SASMs less its DAM charge</td>
</tr>
<tr>
<td>Why:</td>
<td>To cover the costs of a services to ensure ERCOT reliability</td>
</tr>
</tbody>
</table>
ERCOT has net costs for AS that must be collected from the market
Adjustments to Costs for Ancillary Services Procurement

Failed AS Amounts
Infeasible AS Amounts

DAM Procured Amounts
SASM Procured Amounts

Total AS Costs
A QSE’s share of the net total cost for an Ancillary Service for an Operating Hour is simply

\[(\text{AS Price}) \times (\text{AS Quantity}_q)\]

\[
\text{AS Price} = \left( \frac{\text{Total Ancillary Service Costs}}{\text{Total Ancillary Service Quantity}} \right)
\]

\[
\text{Total AS Quantity} = \sum_{\text{All QSEs}} \text{AS Quantity}_q
\]

\[
\text{AS Quantity}_q = \text{AS Obligation}_q - \text{Self-Arranged Quantity}_q
\]
Finding the Ancillary Service Obligation for a QSE

\[
\text{Ancillary Service Obligation}_q = \sum_{\text{All QSEs}} \left( \begin{array}{c}
\text{Self-Arranged Qty in all Markets} \\
\text{AS Procured in Real-Time} \\
\text{AS Procured in DAM} \\
\text{AS Failed Quantities}
\end{array} \right) \times \text{HLRS}
\]
Now, the QSE’s Ancillary Service Cost is simply

$$\text{AS Price} \times (\text{AS Obligation}_q - \text{Self-Arranged Quantity}_q)$$

Is this what the QSE pays for each Ancillary Service in Real-Time?
The QSE already paid part of this AS Cost in the Day-Ahead Market.

In Real-Time, the QSE pays or is paid for any difference between their AS Cost and their Day-Ahead AS Charge.

\[
\text{RT AS Amount} = \text{AS Cost} - \text{Day-Ahead AS Amount}
\]
Refer to your Settlements Workbook

In a small group, respond to the questions that relate to Scenario #RT6.

You have 15 minutes to complete your questions.

If you cannot complete all questions, don’t worry – all questions will be reviewed as a class.
Outcomes

Outcome #1

QSE’s Net Cost for Reg-Up is calculated as

\[ \text{RUCOST}_q = \text{RUPR} \times \text{RUQ}_q \]

Where:

Net price for Reg-Up

\[ \text{RUPR} = \frac{\text{RUCOSTTOT}}{\text{RUQTOT}} \]

A QSE’s net quantity for Reg-Up

\[ \text{RUQ}_q = \text{RUO}_q - \text{SARUQ}_q \]
QSE’s Net Cost for Reg-Up is calculated as:

\[ \text{RUCOST}_q = \text{RUPR}_q \times \text{RUQ}_q \]

Where:

A QSE’s obligation for Reg-Up

\[ \text{RUO}_q = \sum_q (\text{SARUQ}_q + \sum_m (\text{RTPCRU}_{q,m}) + \text{PCRU}_q \]

\[ - \text{RUFQ}_q - \text{RRUFQ}_q) \times \text{HLRS}_q \]
Finally, the QSE is charged the difference between their net Reg-Up Cost and their Day-Ahead Reg-Up Charge.

The Real-Time Reg-Up Amount for a QSE

\[ RTRUAMT_q = RUCOST_q - DARUAMT_q \]

There is a similar Charge Type for each Ancillary Service Type.
Real-Time Revenue Neutrality Allocation

**Fundamentals of Real-Time Revenue Neutrality Allocation**

<table>
<thead>
<tr>
<th>Who:</th>
<th>QSEs that have load</th>
</tr>
</thead>
<tbody>
<tr>
<td>What:</td>
<td>An Allocation on of a QSEs Load Ratio Share</td>
</tr>
<tr>
<td>Why:</td>
<td>To keep ERCOT revenue neutral</td>
</tr>
</tbody>
</table>
ERCOT Must Be Revenue Neutral
Left over funds paid out to QSEs by Load Ratio Share
Short funds are collected from QSEs by Load Ratio Share
ERCOT has issued energy-related charges and payments and must achieve Revenue Neutrality

Trigger #1

ERCOT has issued AS Imbalance charges and payments and must achieve Revenue Neutrality

Trigger #2
Real-Time Revenue Neutrality Allocation

**Outcome #1**

- All charges and payments related to energy are summed
- Allocated to QSEs with Load

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTEIAMTTOT</td>
<td>Real-Time Energy Imbalance Amount Total</td>
</tr>
<tr>
<td>BLTRAMTTOT</td>
<td>Block Load Transfer Resource Amount Total</td>
</tr>
<tr>
<td>RTDCIMPAMTTOT</td>
<td>Real-Time DC Import Amount Total</td>
</tr>
<tr>
<td>RTDCEXPAMTTOT</td>
<td>Real-Time DC Export Amount Total (Oklahoma)</td>
</tr>
<tr>
<td>RTCCAMTTOT</td>
<td>Real-Time Energy Congestion Cost Amount Total</td>
</tr>
<tr>
<td>RTOBLAMTTOT</td>
<td>Real-Time Obligation Amount Total</td>
</tr>
<tr>
<td>RTOBLLOAMTTOT</td>
<td>Real-Time Obligation with Links to an Option Amount Total</td>
</tr>
</tbody>
</table>
Hourly values must be divided by 4

Allocated based on Load Ratio Share

\[ LARTRNAMT_q = (-1) \times \left( \begin{array}{c}
RTEIAMTTOT + BLTRAMTTOT \\
+ RTDCIMPAMTTOT + RTDCEXPAMTTOT \\
+ RTCCAMTTOT \\
+ RTOBLAMTTOT/4 + RTOBLLOAMTTOT/4 \\
\end{array} \right) \times LRS_q \]
Outcome #1

- RT Energy Imbalance Total = $1500
- DC Tie Import Amount Total = -$400
- RT Obligation Amount Total = -$1200
- QSE 4 has 20% of the load

\[
\text{LARTRNAMT}_q = (-1) \times \left( \text{RTEIAMTTOT} + \text{BLTRAMTTOT} + \text{RTDCIMPAMTTOT} + \text{RTDCEXPAMTTOT} + \text{RTCCAMTTOT} + \frac{\text{RTOBLAMTTOT}}{4} + \frac{\text{RTOBLLOAMTTOT}}{4} \right) \times \text{LRS}_q
\]

\[
= (-1) \times ($1500 - $400 - $1200/4) \times 0.20
\]

\[
= (-1) \times ($800) \times 0.20
\]

\[
= -$160
\]
ERCOT has issued energy-related charges and payments and must achieve Revenue Neutrality

Trigger #1

ERCOT has issued AS Imbalance charges and payments and must achieve Revenue Neutrality

Trigger #2
Real-Time AS Imbalance Revenue Neutrality Allocation

Outcome #2

- All charges and payments related to AS Imbalance are summed
- Allocated to QSEs with Load

LAASIRNAMT_q = (-1) * [(RTASIAMTTOT + RTRUCRCSVAMTTOT) * LRS_q]

<table>
<thead>
<tr>
<th>LAASIRNAMT</th>
<th>Load-Allocated Ancillary Service Imbalance Revenue Neutrality Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTASIAMTTOT</td>
<td>Real-Time Ancillary Service Imbalance Market Total Amount</td>
</tr>
<tr>
<td>RTRUCRCSVAMTTOT</td>
<td>Real-Time RUC Ancillary Service Reserve Market Total Amount</td>
</tr>
</tbody>
</table>
• RT AS Imbalance Total = $1200
• RT RUC AS Reserve Total = -$300
• QSE 5 has 30% of the load

LAASIRNAMT_q = (-1) * [(RTASIAMTTOT + RTRUCRSVAMTTOT) * LRS_q]
= (-1) * [($1200 - $300) * 0.30]
= (-1) * [$900 * 0.30]
= - $270
Outcomes #2

But wait, there’s more!

• All charges and payments related to Reliability Deployment AS Imbalance are summed
• Allocated to QSEs with Load

LARDASIRNAMT\textsubscript{q} = (-1) \times [(RTRDASIAMTTOT + RTRDRUCRSVAMTTOT) \times LRS_{q}]

<table>
<thead>
<tr>
<th>LARDASIRNAMT</th>
<th>Load-Allocated Reliability Deployment Ancillary Service Imbalance Revenue Neutrality Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTRDASIAMTTOT</td>
<td>Real-Time Reliability Deployment Ancillary Service Imbalance Market Total Amount</td>
</tr>
<tr>
<td>RTRDRUCRSVAMTTOT</td>
<td>Real-Time Reliability Deployment RUC Ancillary Service Reserve Market Total Amount</td>
</tr>
</tbody>
</table>
Module Conclusion

CRR Auction
- Charges & Payments for CRRs
- Revenue Distribution

CRR Balancing Account
- Reconcile CRR Short payments

DAM
- Participation in DAM
  - Energy
  - AS
  - PTP Obligations
- DAM Commitment
  - Make-Whole
- Settlement of CRRs purchased in the Auction

RUC
- Commitment
  - Make-Whole
  - Clawback
- Decommitment

Real-Time
- Real-Time Activities
  - Imbalances
  - Base Point Deviations
  - Other odds & ends

- Settlement of PTP Obligations purchased in the DAM
- Real Time Ancillary Service Settlements
- Revenue Neutrality