Topics for This Session

Understanding System Operations – Today and Tomorrow
• The role of dispatch in keeping the lights on
• Many control areas but one grid
• Realities of loop flows, contract paths and TLRs
• How RTO dispatch replaces TLRs to improve reliability

RTO Spot Markets
• Pricing spot energy -- LMP
• Pricing congestion, redispatch and spot transmission
• Spot market settlements

Implications for Retail Competition
• How RTO spot markets can support retail competition
• Implications for retail pricing
Understanding System Operations
Today and Tomorrow
A Utility Is Commonly Thought of as Having Three Major Operational Functions:

- Generation . . .
- Transmission . . .
- Distribution . . .

A utility with all three functions is “vertically integrated,” but some states are changing that.
These Three Functions Are Then Assumed to Explain How Consumers Get Electricity

But There Is Another Function, and it’s Critical:

System Operations
For Many, System Operations is a Black Box . . . But a Reliable Grid Depends On It

What Do System Operators Do?

- Dispatch generation
- Balance supply/demand
- Keep frequency @60Hz
- Maintain voltage
- Monitor/control grid flows
- Control transmission
- Monitor contingencies
- Manage reserves
- Handle emergencies . . .
- Keep the lights on
A System Operator’s Dispatch Is The Essential Tool For Reliable Operations

• Dispatchers instruct generators to keep electric supply \textit{exactly} balanced with consumer demand.

  • There’s virtually no “storage” in electricity, so balance must be maintained \textit{every moment}

  • Energy dispatch keeps frequency at 60Hz

  • Reactive power dispatch keeps voltage stable

• These and other actions keep the lights on
The System Operator’s Dispatch Also Serves to Meet Demand At Lowest Cost

- Operators try to dispatch *economically*.

UNCONSTRAINED MERIT ORDER DISPATCH

- West Nuke
- East Coal
- South Gen
- West Gas
- East Gas

Running Costs/ Bids ($/MWh)

Must run?

Capacity (MW)

0 100 200 300 400 500

0 20 40 60 80

West Gas

East Gas

System Load

$20

$30

$37

$40

$60

$/MWh
Security-Constrained Economic Dispatch:
Congestion Requires Operators to Dispatch Out of Merit Order, But Still at Least Cost, Given the Constraints
System Operators Work in Local Dispatch Centers That Manage “Control Areas”

A control area may cover only one utility service area, or two or more combined utility grids. An RTO would cover a broad region.

- There are over 140 control areas in the United States alone.
- But there are not 140 separate transmission grids.

In fact, there are only three very large “interconnections.”

- Dozens of separately owned grids/control areas are interconnected.
- And energy flows travel throughout each interconnection along all possible paths – the laws of physics dictate this.
- Each interconnection functions like one huge electrical machine.
Each Control Area Manages Only A Small Part of the Larger Interconnection

In each control area, system operators monitor the flows in their portion of the interconnection, then use their local dispatch to:

- Maintain balance in their own control area.

- Manage the flows going in and out of their control area (“interchange”).

- They must do this every few seconds, every hour, every day, to maintain stable frequency and voltage . . .
  - or the lights go out.
Essential Reliability Functions Center Around Each System Operator’s Dispatch

- Coordinate Inter-utility Flows w/Others
- Grid Operating Instructions
- Monitor Flows, Limits & Contingencies
- Manage Operating Reserves
- Keep Flows Within Limits
- Real-Time Balancing
- Congestion Redispatch (internal only?)
- Maintain Voltage and Frequency
- Security-Constrained Economic Dispatch & Regulation

TLR
The Weak Link in Reliability: Multiple Control Areas, Each With Its Own Dispatch, Must Coordinate Flows Between Each Other

"Interchange" is Preset and Fixed Every 30-60 Min

Timing:
- AGC – regulation = seconds
- Internal dispatch = 5 min
- Inter-CA schedules = 30-60 min
- Flows = near light speed
Many Small Control Areas Makes the Interconnected Grid Harder to Manage

- Actions here affect flows there – it’s one interconnected grid
- Coordination is challenging, unforgiving – every operator must do his/her job and let neighbors know quickly about problems.
- So 100% reliability is harder to assure. The August 14, 2003 blackout was probably inevitable, and could happen again.
- Economic dispatch is balkanized – each local dispatch is less efficient than it should be: we pay more for lower reliability
- Market power is easier to exercise -- the entity that controls the dispatch controls grid access, imbalance pricing, etc.
Contract Path Scheduling and TLRs

In the Eastern Interconnection outside ISOs, control areas allow parties to reserve transmission by selecting and paying for a “contract path.” MISO and PJM are replacing this approach here.

The contract path is only one of many paths along which electricity actually flows from “source” to “sink” for any given schedule.

Although a contract path may be able to accommodate the flows...

- Other possible paths on which the flows actually travel may not be able to accommodate those flows without violating their security limits.

- When this happens, control areas need a system to “unschedule” the overloaded line/equipment to ensure flows stay within security limits.

- The method control area operators use is called “TLR” or Transmission Line Loading Relief – rules developed by NERC.
Contract Path Scheduling Is Flawed Because It Ignores the Actual Flows/Physics

Schedule with flows along the contract path... (not congested)

...causes flows on all other paths

Congestion (flows above line limits) can occur anywhere along any path

Contract path scheduling requires TLRs to “unschedule” the grid by curtailing some schedules/transactions.
Without Centralized Regional Dispatch, Each Control Area Must Resort to TLRs to Control “Loop” Flows That Cause Congestion Within Its Control Area

1. Schedules between these control areas...

2. Can cause congestion in another control area, which has the right to request TLR instead of redispaching, which may be costly.

3. Help!

4. Reliability Coordinator Calls TLR

5. Phew! Thanks!

6. Now each CA must redispach to rebalance

7. Everyone loses with TLRs

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Can We Still Rely On TLRs For Reliability?

There may have been a time when primary reliance of TLRs was sufficient to ensure reliable inter-regional grid coordination. With increasing numbers (100s) of TLRs being called, that time is past.

TLRs are inadequate because . . .

- TLRs can take too long – couldn’t have avoided August 14.
- TLRs require many phone calls between control areas/parties
- TLRs are imprecise in matching curtailment with relief needed
- TLR rules don’t cover all flows, so they discriminate
- TLRs can curtail economic schedules that serve “native loads”
- But . . . TLRs pay no attention to economics
A Regional Dispatch Replaces TLRs By Readjusting Flows Every Five Minutes

Original Control Areas:
- Area A
- Area B
- Area C
- Area D

TLR Functions:
- Coordinate Flows
- Control Grid Operations
- Monitor Grid
- Manage Reserves
- Maintain Voltage and Frequency
- Real-Time Balancing
- Manage Congestion
- Keep Flows W/in Limits
- Coordinate with PJM

Regional Security-Constrained Economic Dispatch

RTO Functions

Manage Reserves

Keep Flows W/in Limits

Coordinate with PJM
Are RTOs the Logical Solution to Reliability?

An RTO that offered a bid-based security-constrained economic dispatch and related monitoring tools across its region would . . .

- Internalize regional loop flows and congestion in a large region
- Solve congestion region-wide every 5 minutes, *before* it happened, and solve much of it day ahead with bid-based day-ahead markets
- Replace reliance on TLRs within its regional dispatch area
- Monitor and react quickly to grid outages on a wide area basis
- Deal more effectively with regional voltage and stability problems
- Vastly simplify the coordination needed to ensure regional reliability
- Reduce/simplify operating reserve requirements (diversity)
An RTO’s Regional Dispatch Creates Open Spot Markets for Energy And Transmission

Open spot markets arise logically from the operation and efficient pricing of a bid-based economic dispatch.

• Parties can use the dispatch to buy and sell spot energy

• Parties can use this market to buy and sell spot transmission

The RTO spot markets provide a foundation for all wholesale and retail trading and competition.
RTOs with Standard Core Features
Enhance Grid Reliability – And Create Spot Markets

Market Inputs

Generator Offers
Load Bids
Bilateral Schedules
Self Schedules

RTO Functions

Ensure Reliability

Regional Security-Constrained Economic Dispatch
Reserves

Calculate Dispatch Prices (LMP)

Settlements at Spot Prices

Real-Time Balancing

Congestion Redispatch (In lieu of TLR)

Allocate & Auction FTRs

Settlements at Spot Prices

Market Support

Reliably Serve All Loads
Cover Imbalances
Buy and Sell Spot Energy
Buy Through Congestion (LMP_B - LMP_A)
Financially Firm Tx (LMP_B - LMP_A)
Pricing Imbalances and Spot Energy At Marginal Cost = Locational Marginal Pricing

Definition: LMP reflects the marginal cost of serving an increment of load at each location, given the dispatch, grid constraints, and the offers/bids.

- Using LMP to charge/pay for imbalances and spot energy encourages generators to follow dispatch instructions.

No subsidies: Using LMP allows parties to use the dispatch to support their bilateral transactions (imbbalances) or to make spot purchases and sales, without any party “leaning” on the system.
Dispatching to Relieve Congestion Causes Prices to Differ By Location

Ignoring Price Differences Creates Problems

LMP supports reliable dispatch

LMP avoids “leaning” on system

LMP avoids “gaming”
LMP Allows RTO to Price Redispatch To Avoid TLR Curtailments

LMP prices congestion redispatch at marginal cost – the change in the cost of the dispatch necessary to relieve congestion and allow a schedule to flow without curtailment.

- Marginal cost of redispatch = MW times (LMP_{sink} – LMP_{source})
- Marginal cost of redispatch = Spot price of transmission
Financial Transmission Rights Provide the Financial Equivalent of Firm Physical Rights

Using Financial Transmission Rights (FTRs) . . .

- FTRs don’t have to match actual transactions
- FTRs don’t undermine economic dispatch
- Those who pay grid fixed costs gain financial hedges against congestion/redispatch costs – just like firm transmission

FTRs entitle the holder to a rebate of the difference in congestion between the price at the FTR sink and the price at the FTR source.

- FTR credit = MW times \((LMP_{\text{sink}} - LMP_{\text{source}})\)
RTO May Operate Multiple Spot Markets

There is always a “real-time” spot (balancing) market

- The Real-time market flows from the real-time dispatch

But an RTO can use the same approach to create a day-ahead (and/or hour-ahead) spot market

- The RTO can accept schedules, offers and bids day ahead, to arrange a *day-ahead* security-constrained economic dispatch

- The RTO then prices the dispatch to define day-ahead prices for spot energy and spot transmission use
PJM and MISO Use A “2-Settlement” System

A party that schedules (or buys/sells) in the Day-ahead (DA) market . . .

- Settles spot sales and purchases at DA spot prices = $LMP_{DA}$
- Settles spot transmission at DA transmission (usage) prices
  - Usage charge = MW times ($LMP_{sink} - LMP_{source}$)
  - FTR Credit = MW times ($LMP_{sink} - LMP_{source}$)

A party that deviates from its day-ahead schedules in real time . . .

- Settles the deviations at the real-time spot prices = $LMP_{RT}$
RTO Markets Can Provide Net Settlements

A party that schedules a transaction from point A to point B is settled on a “net” basis:

- Party receives a credit for its net injections at the source (A)
- Party gets a debit for its net withdrawals at the sink (B)

The settlements are based on LMPs at source (A) and sink (B).

- If there is no congestion, LMPs at A and B are the same
  - Net settlement is zero

- If there is congestion, LMPs will be different at A and B
  - Net Settlement = LMP_B - LMP_A
  - Net Settlement = marginal cost of redispatch
Implications of RTO Markets
For
Retail Competition
RTO Markets Become the Foundation for the Transactions that Define Retail Competition

RTO spot markets can be used by . . .

- The generators that supply the retailers and their customers
- The generators that supply the default customers’ LSE/suppliers
- The LSEs with responsibilities for default supply
- Competitive retailers – they can trade directly in spot markets
- The (larger, metered) customers participating in retail choice
- Suppliers of “green energy” to back up “green supply” contracts
RTOs with Standard Core Features
Enhance Grid Reliability – And Create Spot Markets

Market Inputs → RTO Functions → Market Support

Ensure Reliability

Reserves

Regional Security-Constrained Economic Dispatch

Generator Offers

Load Bids

Bilateral Schedules

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RTO Spot Prices Are Slowly Becoming the Foundation for Retail Pricing

The RTO’s real-time spot prices can be used for . . .

- A default price for “shopping” customers whose suppliers default
- A default price for “shopping” customers’ marginal usage not covered by contracts = Real-time pricing
- The price retailers pay for retail obligations not covered by contracts or own resources
- The price default supply LSEs pay for retail obligations not covered by supply contracts or their own resources
- Averaged over time, a reference price for energy rates charged to default supply customers (a.k.a. standard offer service or POLR)
- A reference price for contracting and other forward markets
Retail Competition Issues with RTOs (e.g.)

Is there a capacity obligation imposed on LSEs?

• If so, how often are LSE/retailer obligations adjusted as customers shift between LSE/retailers?

• All parties should follow the evolving rules of capacity markets, scarcity pricing and market power mitigation.

How are FTRs (or Auction Revenue Rights) allocated?

• How, and how often, does the RTO reallocate these rights?

• Do the rights follow the customers as they switch?
Questions?

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