PJM Overview
for
CRE

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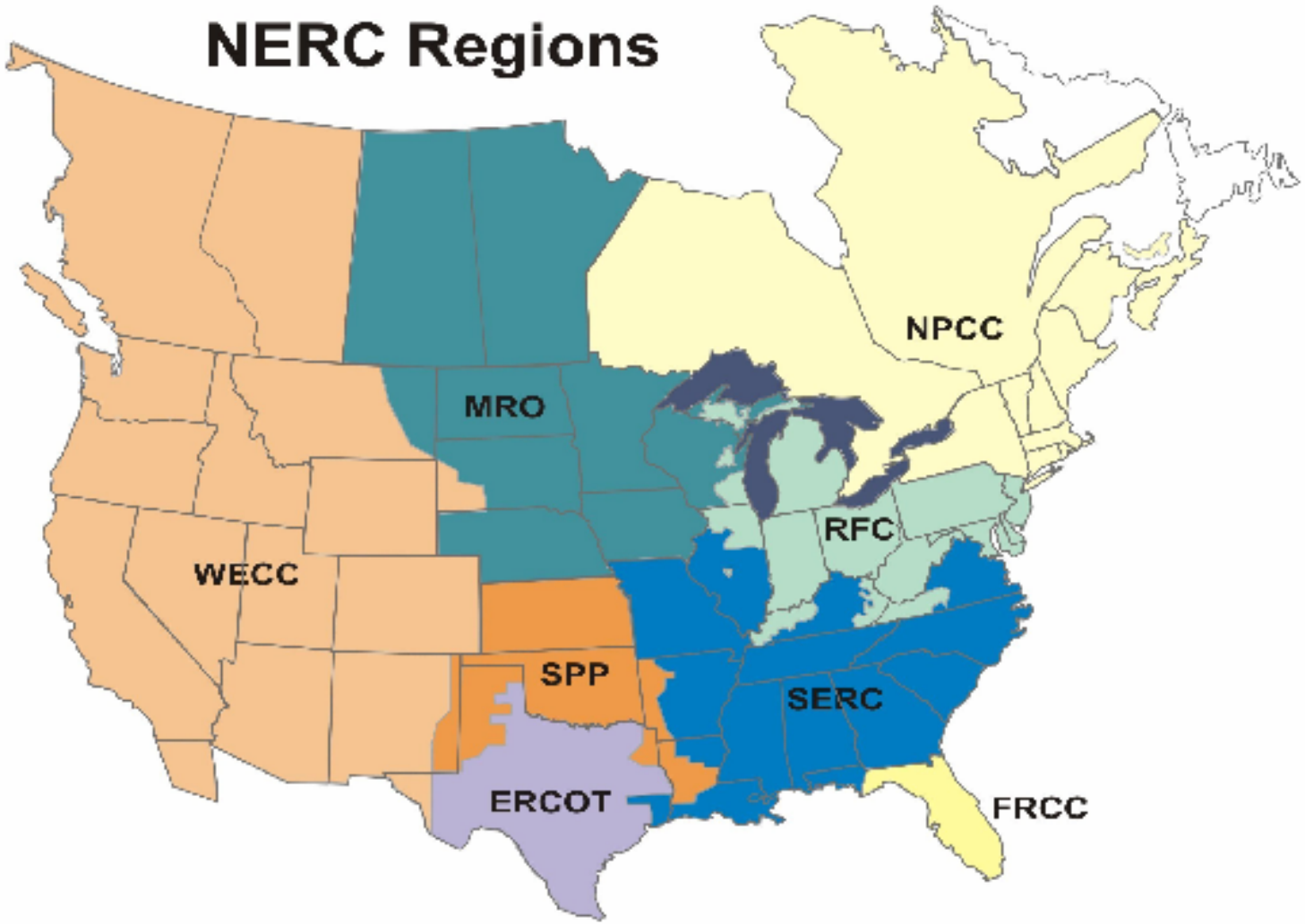
PJM Market Monitoring Unit

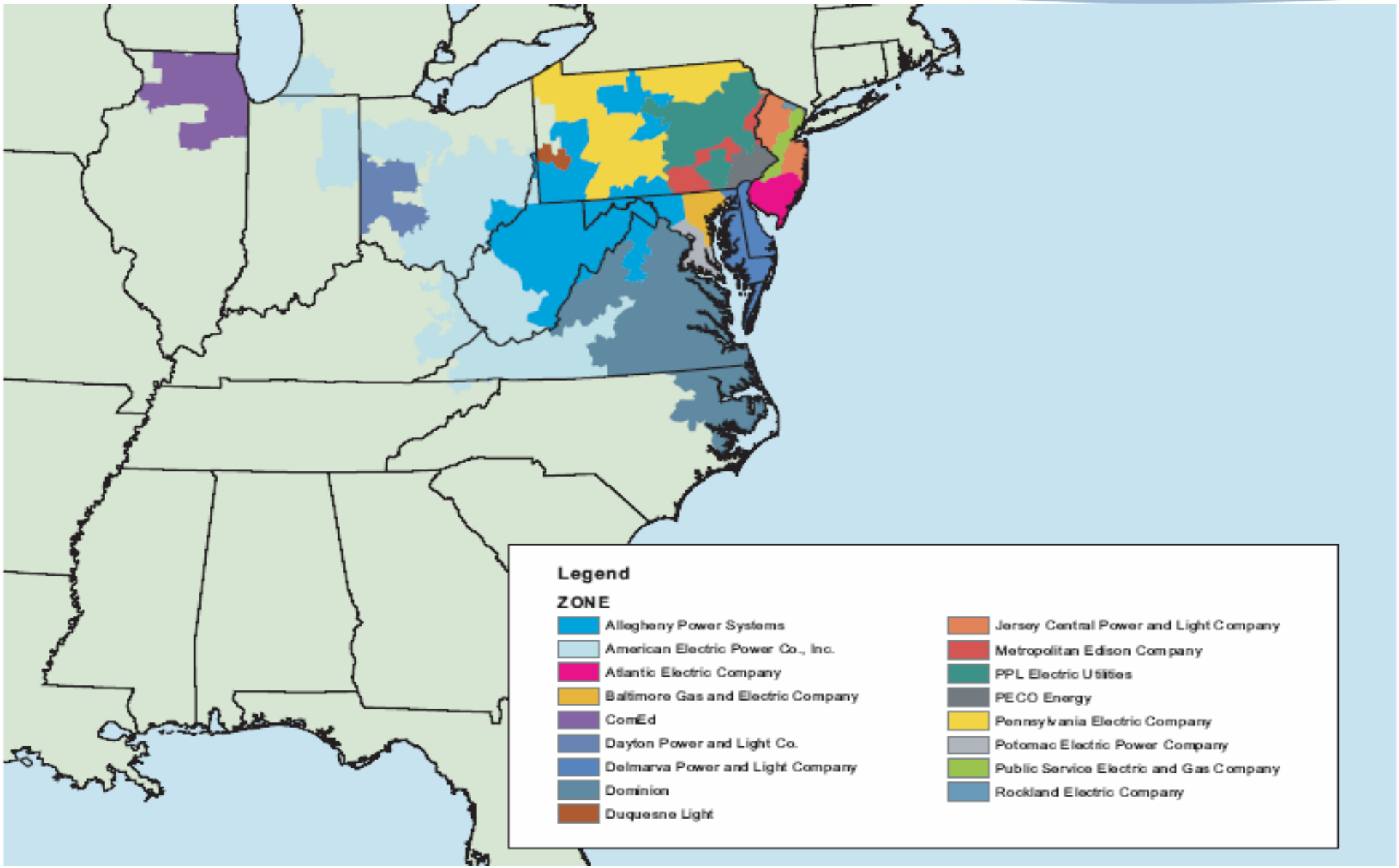
RTO Overview

Regional Transmission Organization (RTO)

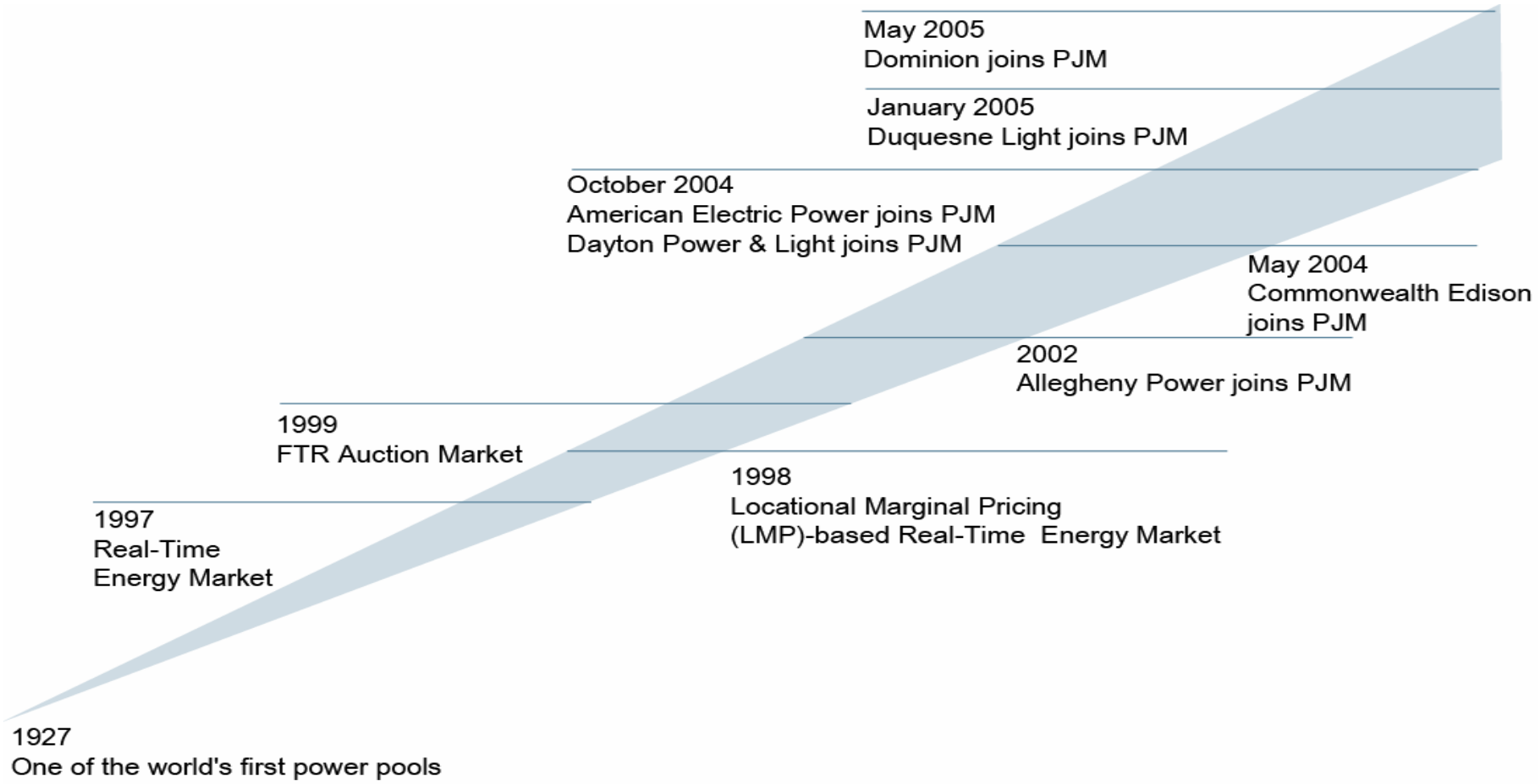
An establishment that coordinates the movement of wholesale electricity, acting neutrally and independently, operating the competitive wholesale electricity market and ensures the reliability in managing the regional transmission system and the wholesale electricity market.



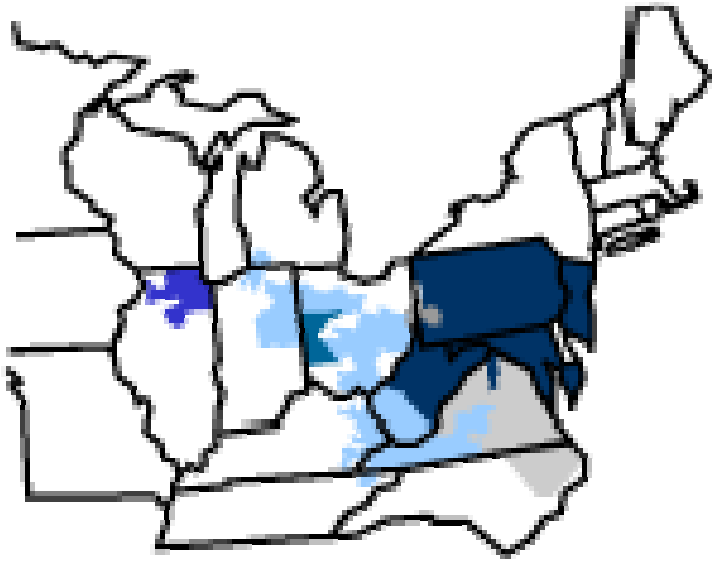
PJM Transmission Owners



History of PJM Markets



PJM RTO After Market Integrations



PJM RTO

Generating Units	1,082
Generation Capacity	163,806 MW
Peak Load	144,796 MW
Annual Energy	700 million MWh
Area (Square Miles)	164,260
Miles of Transmission	56,070
Population Served	51 Million
States (+ D.C.)	13 states + D.C.
Members	430+
Transmission Customers	100+

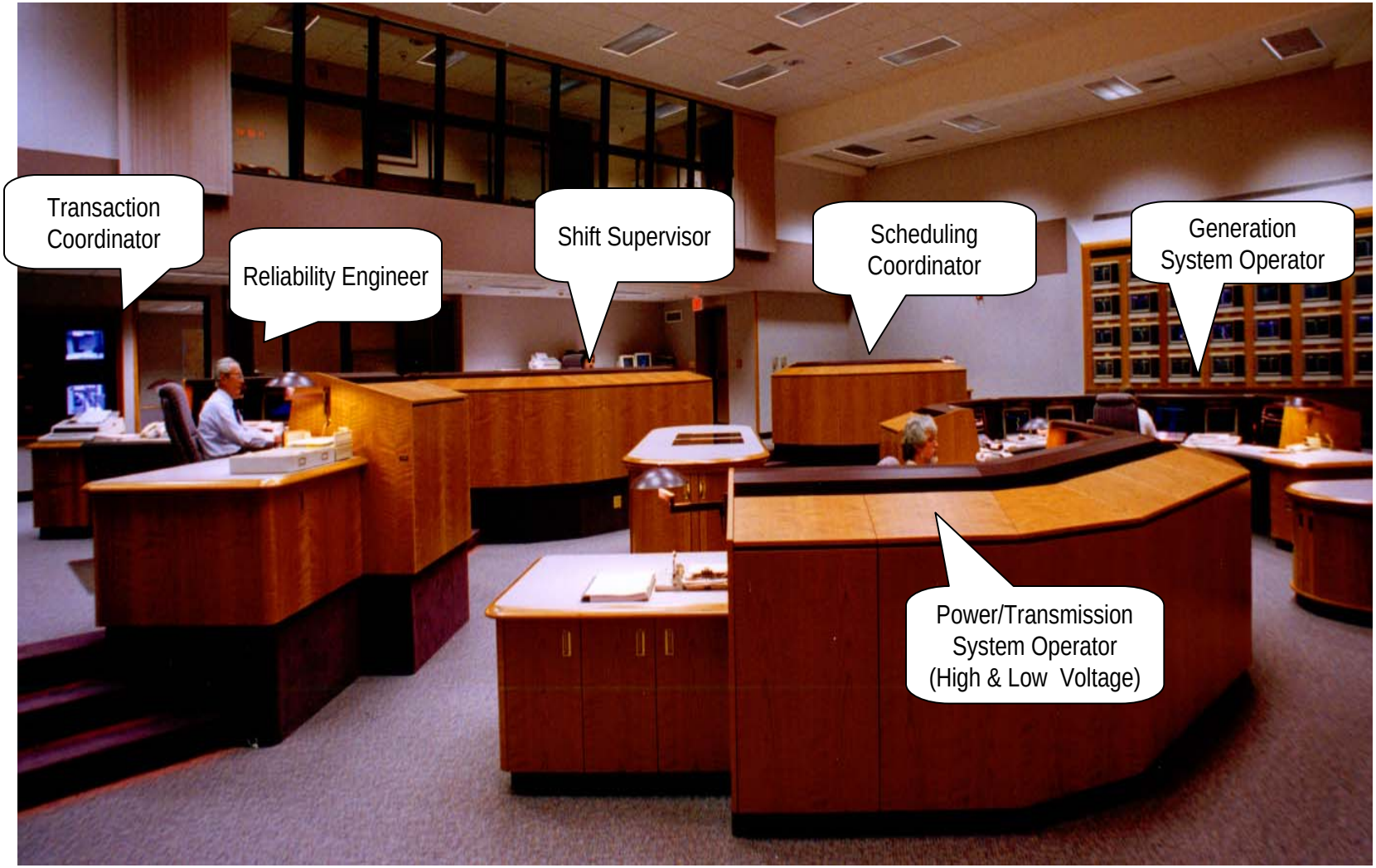
PJM - Full Service RTO

- Control Area Operator
- Transmission Provider
- Market Administrator
- Regional Transmission Planner
- NERC Reliability Coordinator

- **Reliability Pricing Model (RPM) Auction**
- **2 Energy Markets**
  - **Day Ahead**
  - **Real Time**
- **Financial Transmission Rights Auction**
- **Ancillary Services**
  - **Regulation Market**
  - **Spinning Reserve Market**
  - **Blackstart Service**
  - **Reactive Services**

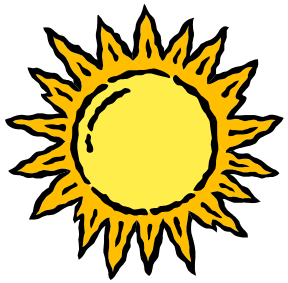
Generation Dispatch

Dispatch Operations Center



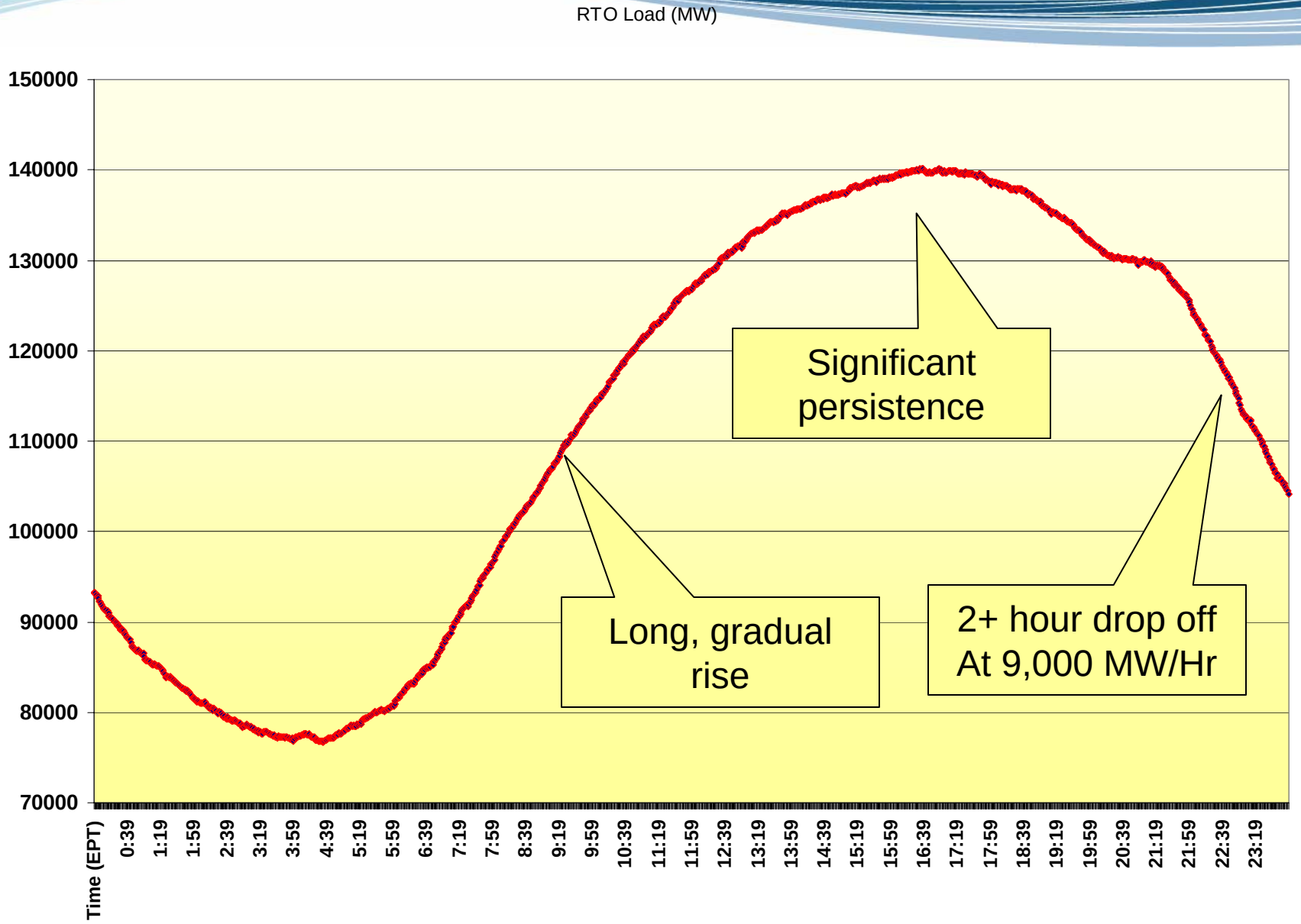
What Affects Load (Customer Demand)

- Weather
  - Temperature
  - Dew point
  - Wind speed
  - Clouds
  - Time of day
- Season
  - Fall, Winter, Spring, Summer
- Human behavior

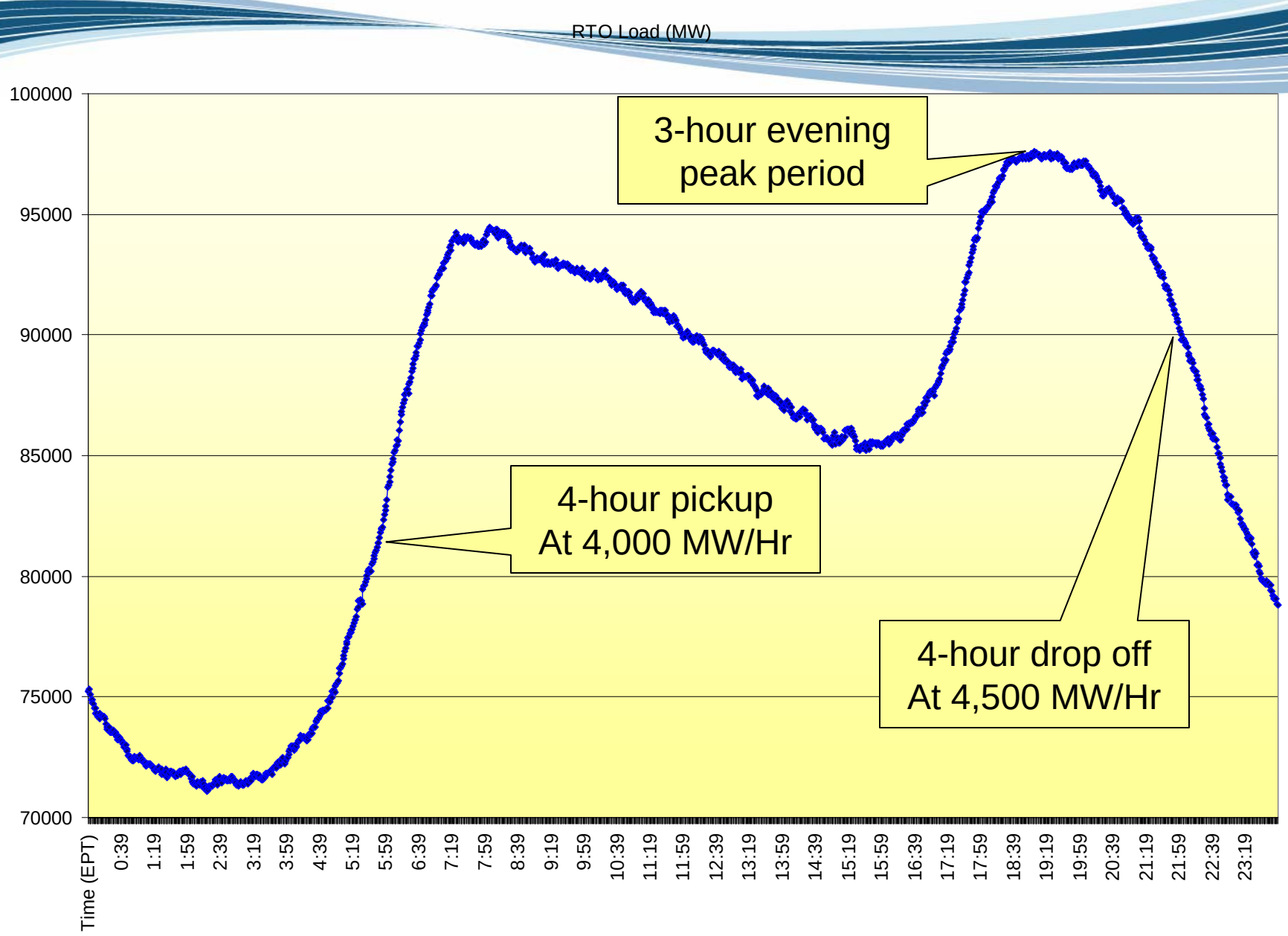


- Maintain System Control
  - Generation / Demand Balance
- Maintain Adequate Reserves
  - Operate on Contingency Basis
- Implement Emergency Procedures
  - To Keep the Lights on!

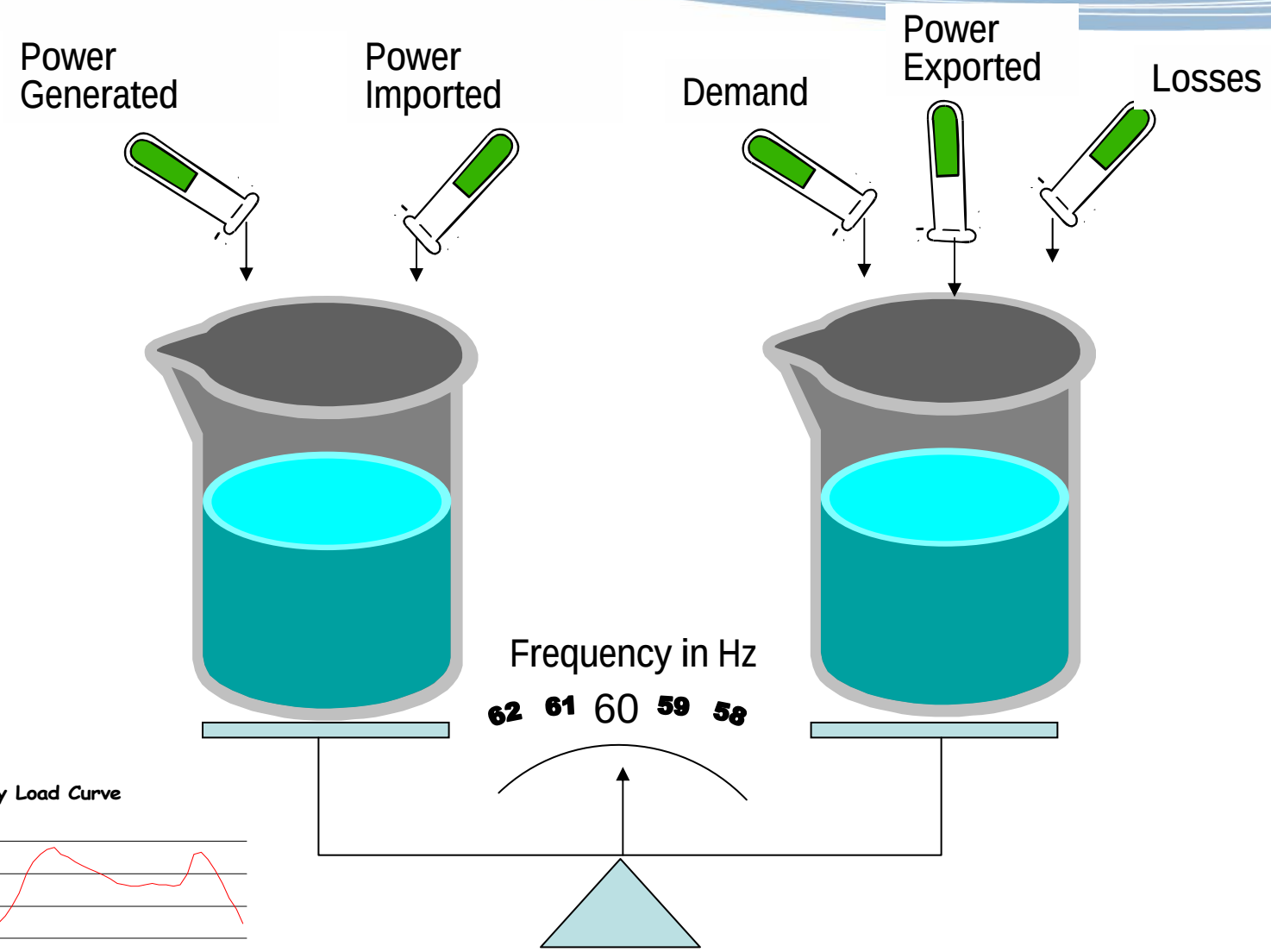
Load Curve – Summer profile (7/17/06)



Load Curve – Winter profile (2/6/06)

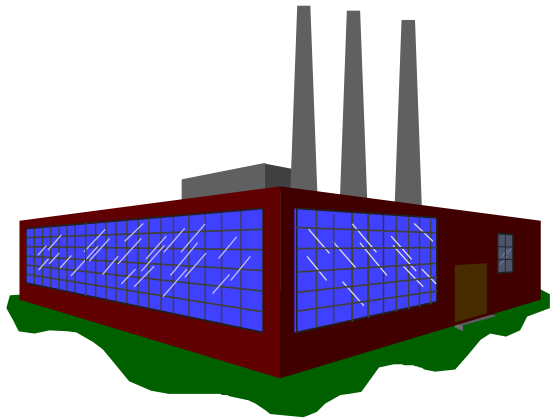


Achieving Energy Balance

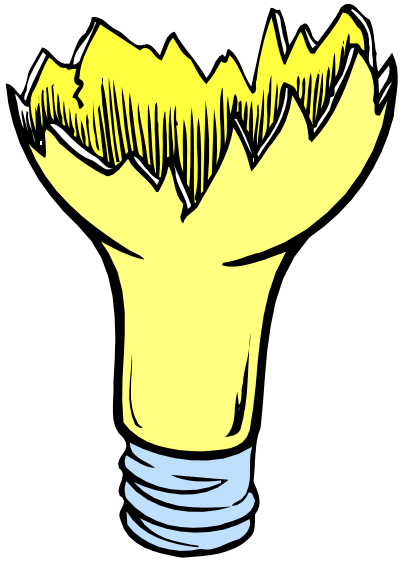


- Purpose is to ensure that the least cost generation is used to meet large changes in load demand.
- Enables power system to follow load as it moves from valley, to peak, to valley over a 24-hour period.
- Adjustments are allocated to generating units to optimize economy

- Capacity Resources must submit offers into the day-ahead market unless they are unavailable due to a forced, planned, or maintenance outage.
- Generation Offers may consist of startup, no-load and incremental energy offer.
- A generation offer may not exceed $1000/MWh.



- Units trip
- Units are delayed
- Changes in External Transactions
- Contract Curtailments
- Emergency Procedures

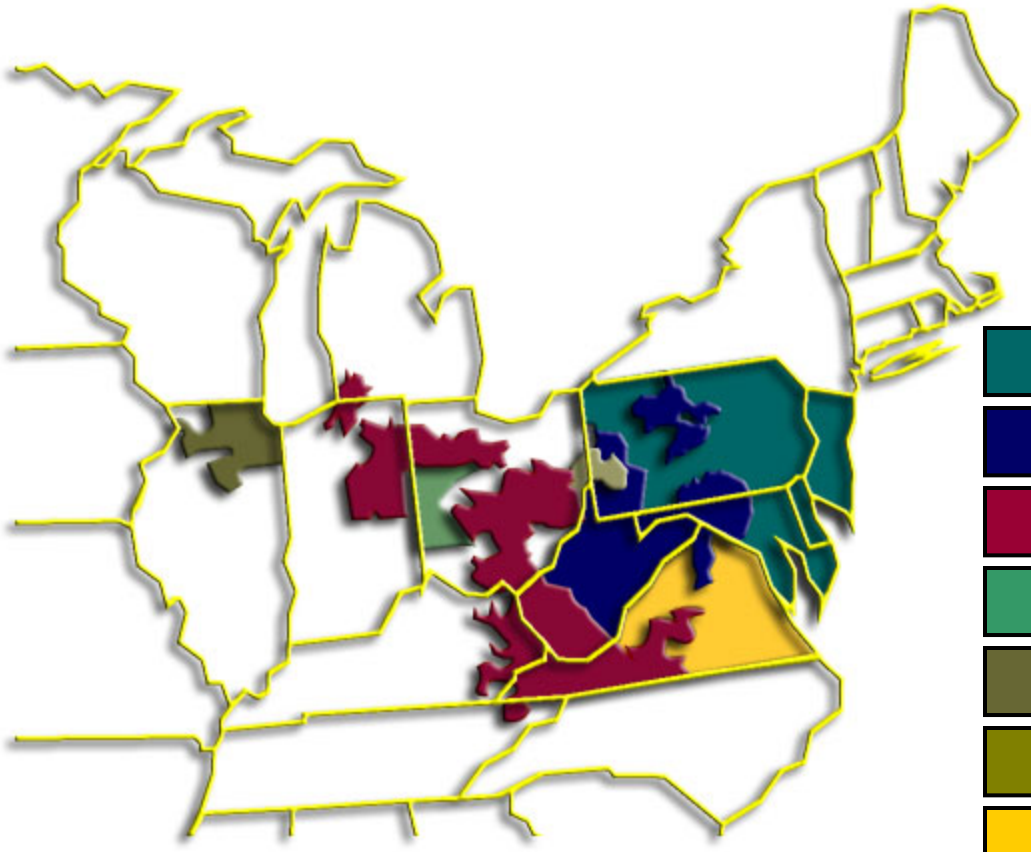


- Schedule PJM System to ensure that there is enough generation resources to cover projected load and required reserves.

<table>
<tr><td colspan="3">Operating Reserve
(T ≤ 30 Minutes)</td><td rowspan="3">Reserve
Beyond
30
Minutes</td></tr>
<tr><td colspan="2">Primary Reserve
(T ≤ 10 Minutes)</td><td rowspan="2">Secondary
Reserve
(10 Min. < T ≤ 30 Minutes)</td></tr>
<tr><td>Spinning
Reserve
(Synchronized)</td><td>Quick-Start
Reserve
(Off-Line)</td></tr>
</table>

- Dispatch Control Center operates, controls, and monitors both generation and transmission.
- Load (Customer Demand) is directly affected by weather, seasons and human behavior.
- Energy transactions (external tie flows between other control areas) have a direct impact on system control.
- Additional reserves are required to ensure there is enough generation resources to maintain a level of reliability.

Transmission Control

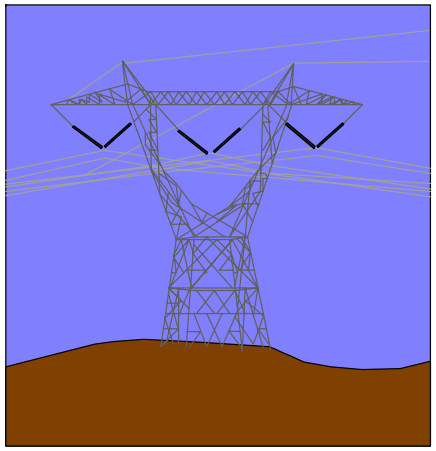


- PJM
- Allegheny Power
- AEP
- Dayton Power & Light
- ComEd
- Duquesne
- Dominion

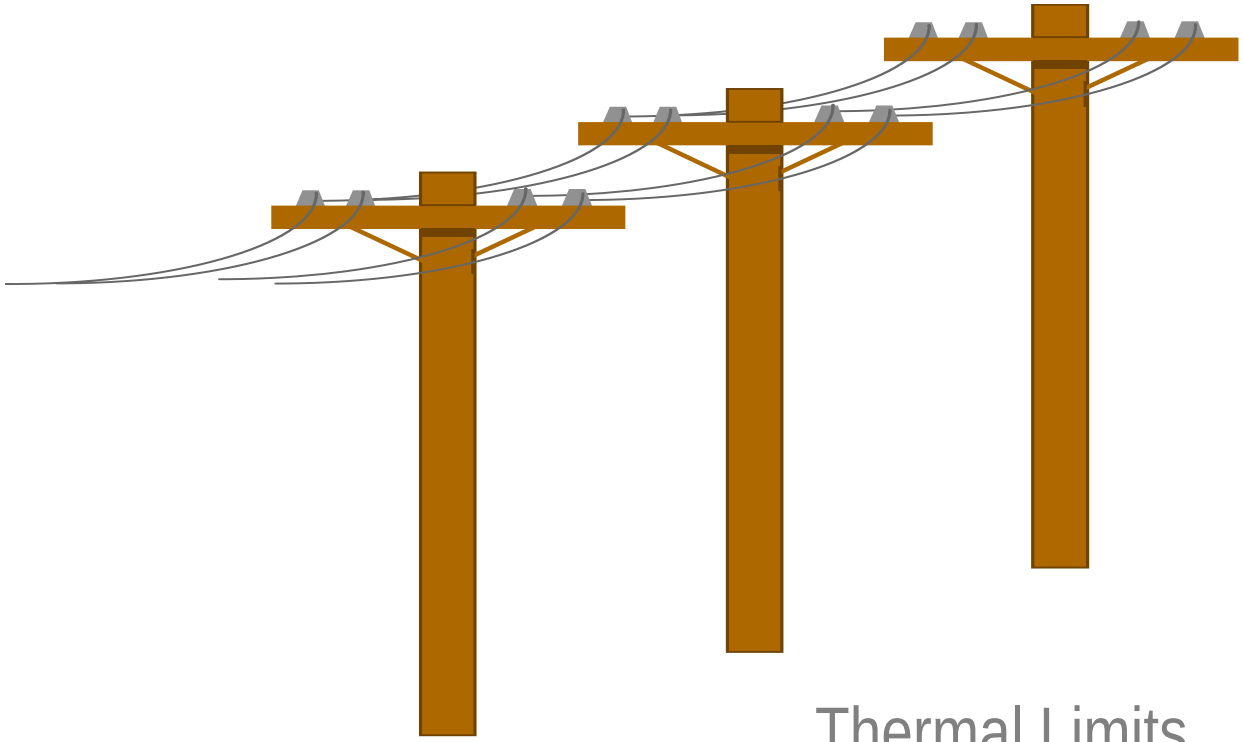
Transmission System Operations

- Ensure Security of the Transmission System
- Monitor Transfer Limitations
- Monitor Thermal Constraints
- Contingency Analysis

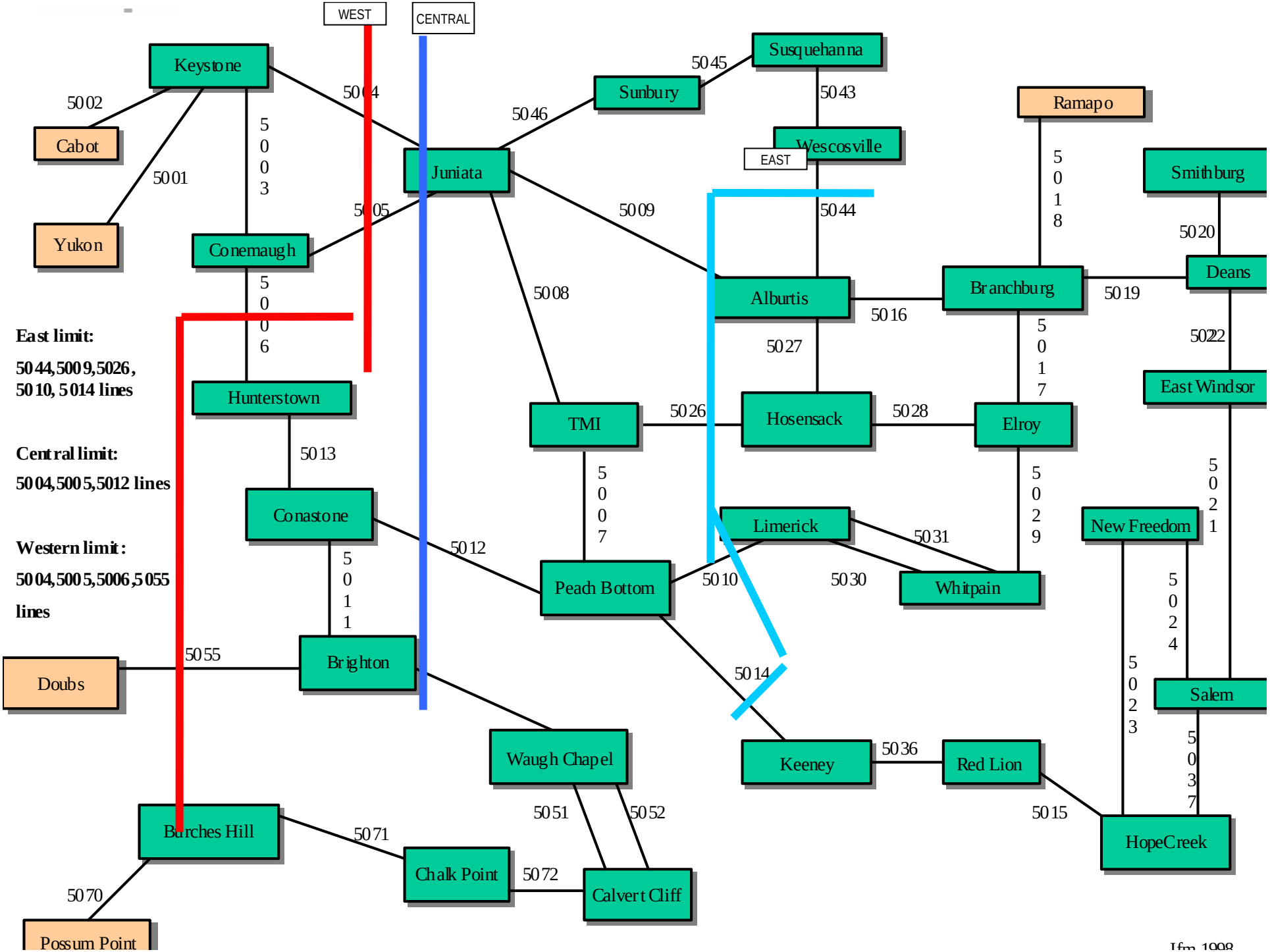
- Direct Emergency Operations
- Direct Off-Cost Operations
  - Generation Shifts
  - Contract Curtailments
- Coordinate Switching



Power Transfer Limits



Thermal Limits
Voltage Limits
Stability Limits


WEST
CENTRAL
EAST
Keystone
Cabot
Yukon
Conemaugh
Juniata
Sunbury
Susquehanna
Wescosville
Ramapo
Smithburg
Deans
Branchburg
Alburtis
Hunterstown
TMI
Hosensack
Elroy
East Windsor
Conastone
Limerick
New Freedom
Peach Bottom
Whitpain
Salem
Doubs
Brighton
Waugh Chapel
Keeney
Red Lion
Burches Hill
Chalk Point
Calvert Cliff
HopeCreek
Possum Point
5002
5001
5003
5004
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5043
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5018
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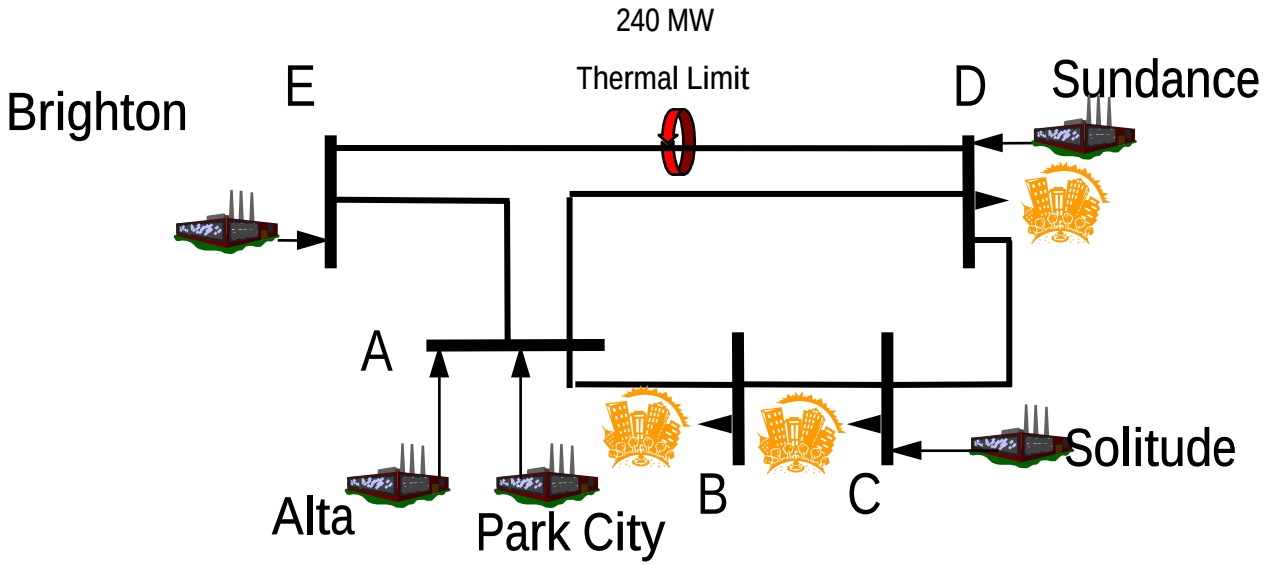
5071
5072
5070
East limit:
5044,5009,5026,
5010, 5014 lines
Central limit:
5004,5005,5012 lines
Western limit:
5004,5005,5006,5055
lines
Ifm 1998



System Reconfiguration

Re-dispatch Generation

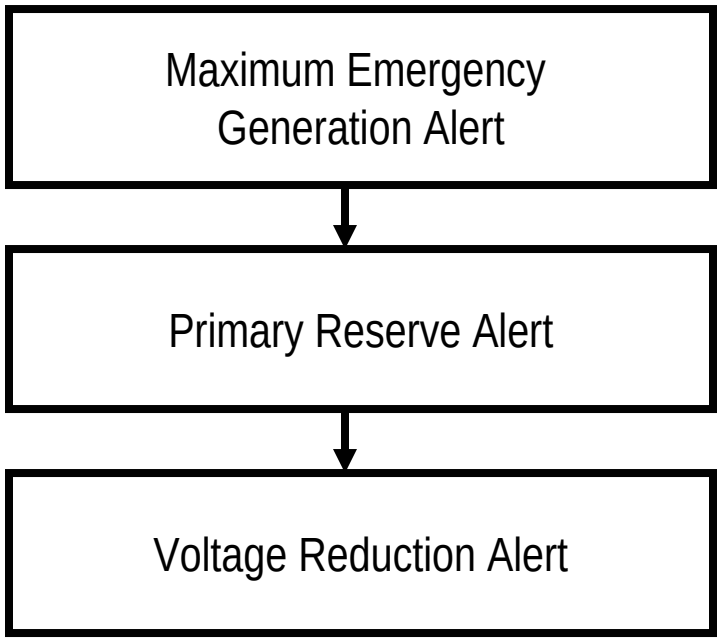
Transaction Curtailments

Summary: Transmission Control

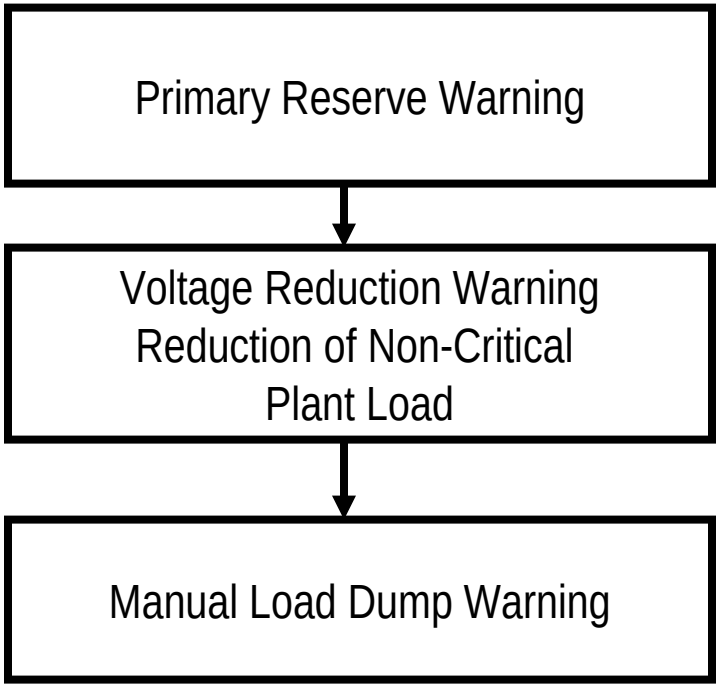
- Transmission System Operations ensures the security of the transmission system by monitoring limitations, constraints and performing contingency analysis.

- Dispatchers control the power flow by monitoring three types of limits:
  - Thermal
  - Voltage
  - Stability

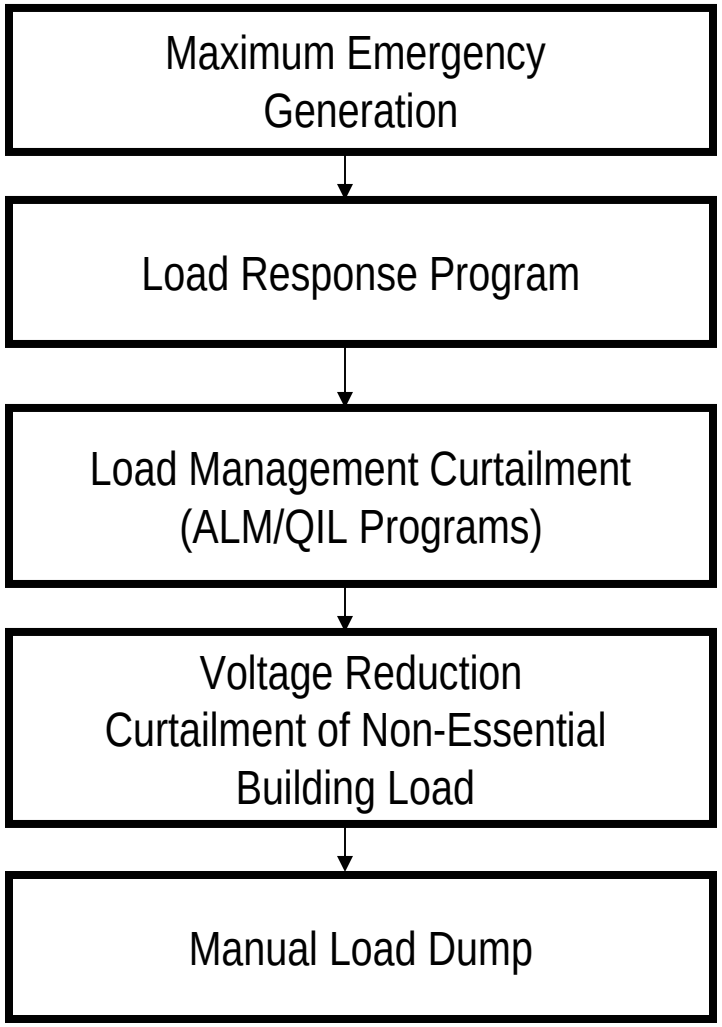
Emergency Procedures



The purpose of alerts is to keep all affected system personnel aware of the expected conditions prior to actual period of operation.



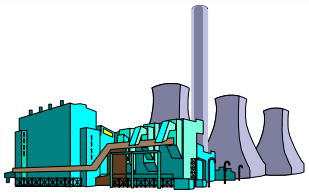
Warnings are issued during present operations to inform members of actual capacity shortages or contingencies that may jeopardize reliable operation.



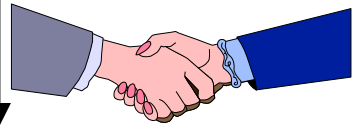
The PJM control area is normally loaded according to offer prices. During periods of reserve deficiencies, other measures are taken to maintain reliability.

Energy Market

Options for Energy Supply



Bilateral Transactions



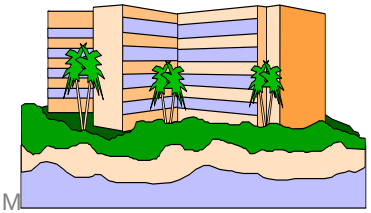
Self-schedule own resources

PJM Spot Market

Load Serving Entities
Obtain energy
to serve customers

Industrial

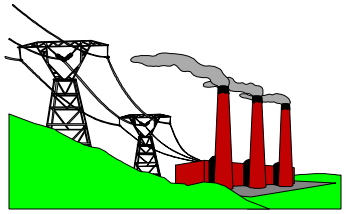
Commercial



Residential

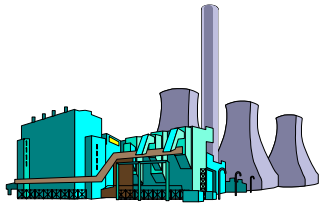
- PJM Dispatcher calls on units in “merit order” to meet load.
- Price is set by the eligible unit with the highest offer price running to meet load
- If load is 199 MW, price is $10
- If load is 200 MW, price is $15
- All generators are paid LMP at their generation bus.

A
Offer Price $20/MW
Capacity 200 MW



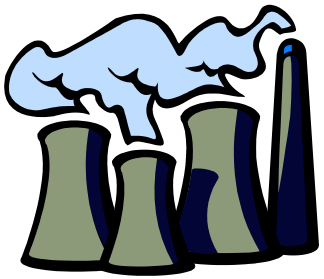
LMP = $15

Offer Price $15/MW
Capacity 200 MW

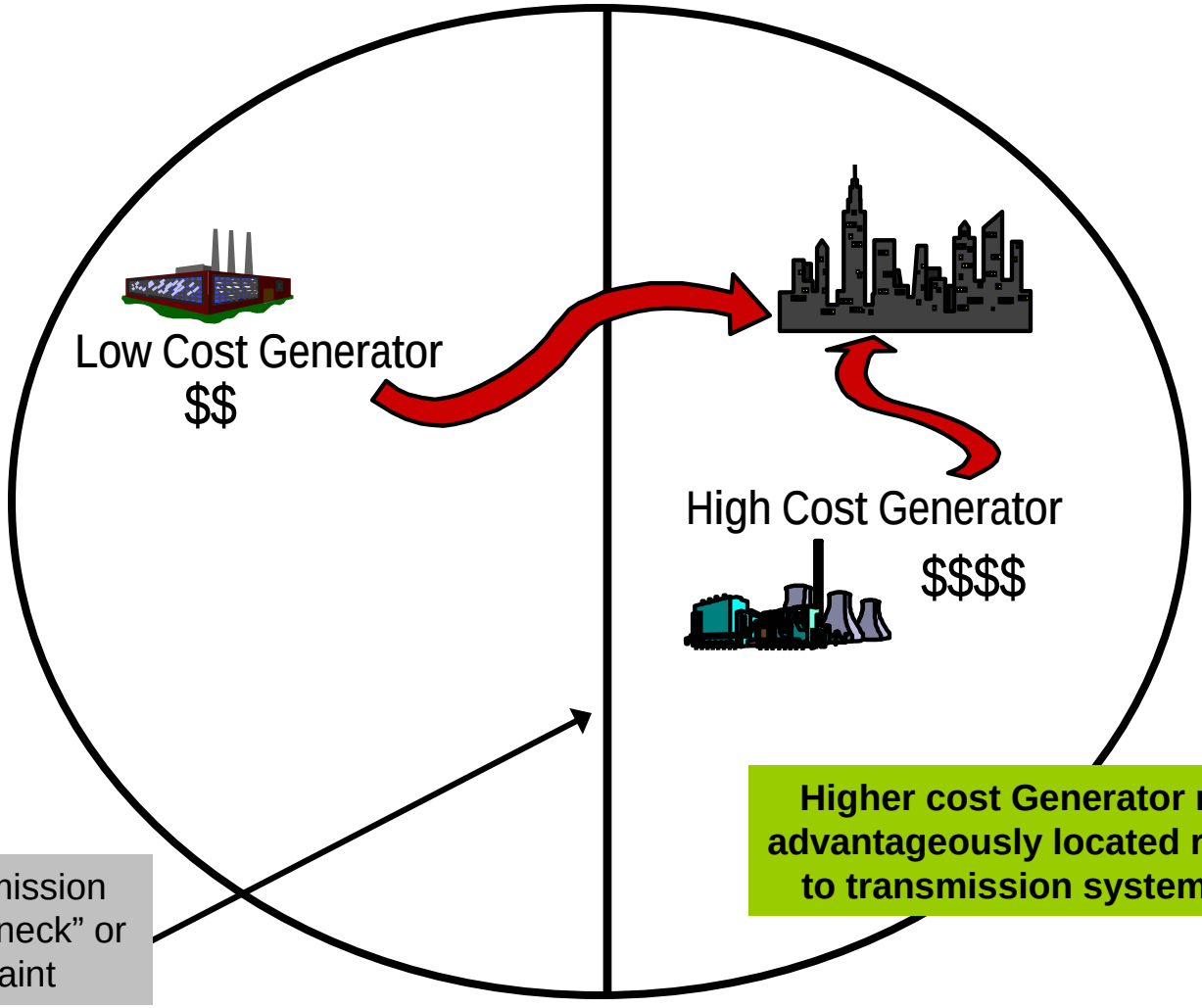


LMP = $10

C
Offer Price $10/MW
Capacity 200 MW

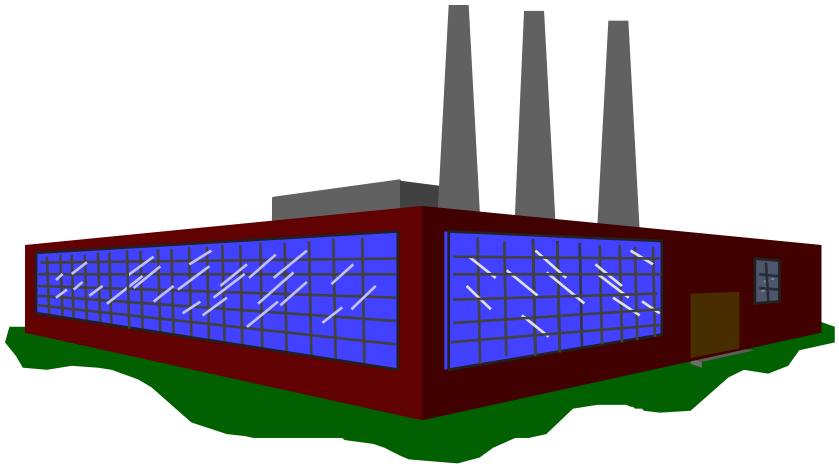


Security Constrained Re-Dispatch

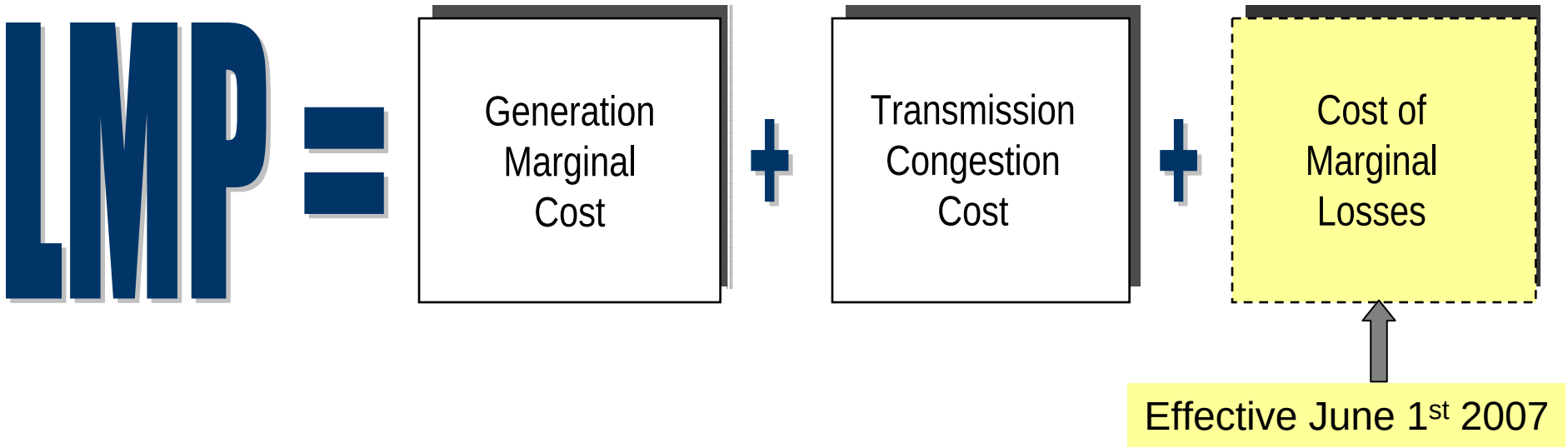


There are three basic types of actions that can be performed to control the flow of power on the electric system:

1. System Reconfiguration
2. Redispatch Generation
3. Transaction Curtailments

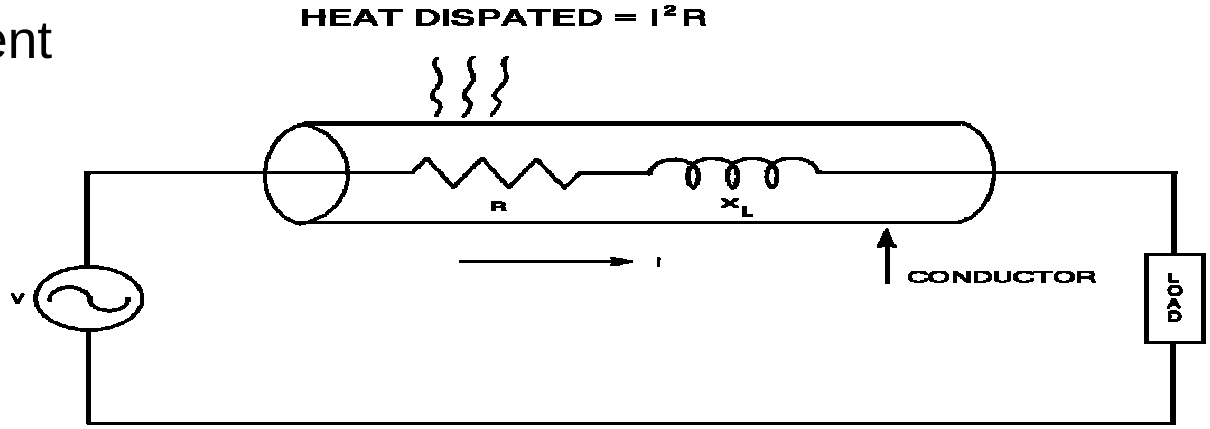


- Pricing method PJM uses to:
  - price energy purchases and sales in PJM Market
  - price transmission congestion costs to move energy within PJM RTO
- Physical, flow-based pricing system:
  - how energy actually flows, NOT contract paths



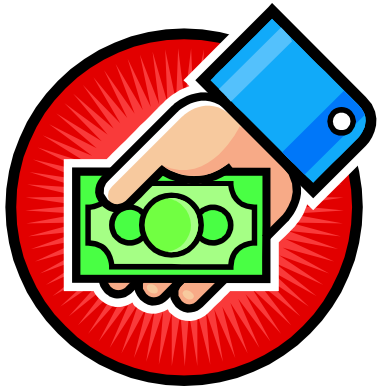
Cost to serve the next MW of load at a specific location, using the lowest production cost of all available generation, while observing all transmission limits

- Real Power (MW) Losses
  - Power flow converted to heat in transmission equipment
  - Heat produced by current (I) flowing through resistance (R)
  - Losses equal to I^2R
  - Heat loss sets the “thermal rating” of equipment
- Losses increase with:
  - Lower voltage
  - Longer lines
  - Higher current



How does PJM use LMP

- ☑ Generators get paid at generation bus LMP
- ☑ Loads pay at load bus LMP
- ☑ Transactions pay differential in source and sink LMP
- ☑ PJM LMPs are the result of the physical flow of energy, not a contract path



Summary: Markets and LMP

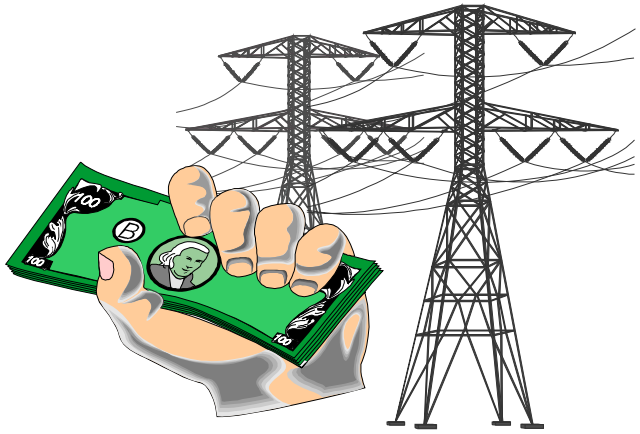
- PJM Dispatchers are responsible to dispatch and re-dispatch units in order to meet the load and alleviate any transmission constraints.
- Locational Marginal Price is the price to serve the next increment of load at the lowest cost, while observing transmission limits.
- Factors affecting LMP include: demand, congestion, economic dispatch, interchange and price of generation.
- PJM credits generators for MW produced at generator bus LMP and charges load servers for MW consumed at load bus LMP. Transactions pay the difference in LMP between source and sink

Hedging Transmission Congestion

- Transmission congestion — hedging mechanisms
  - transactions may specify not willing to pay congestion (PJM curtails)
  - transactions may self-curtail (with notification)
  - Financial Transmission Rights
  - PJM trading hubs

Financial Transmission Rights are …

A financial contract that entitles holder to a stream of revenues (or charges) based on the Day-ahead hourly energy price differences across the path

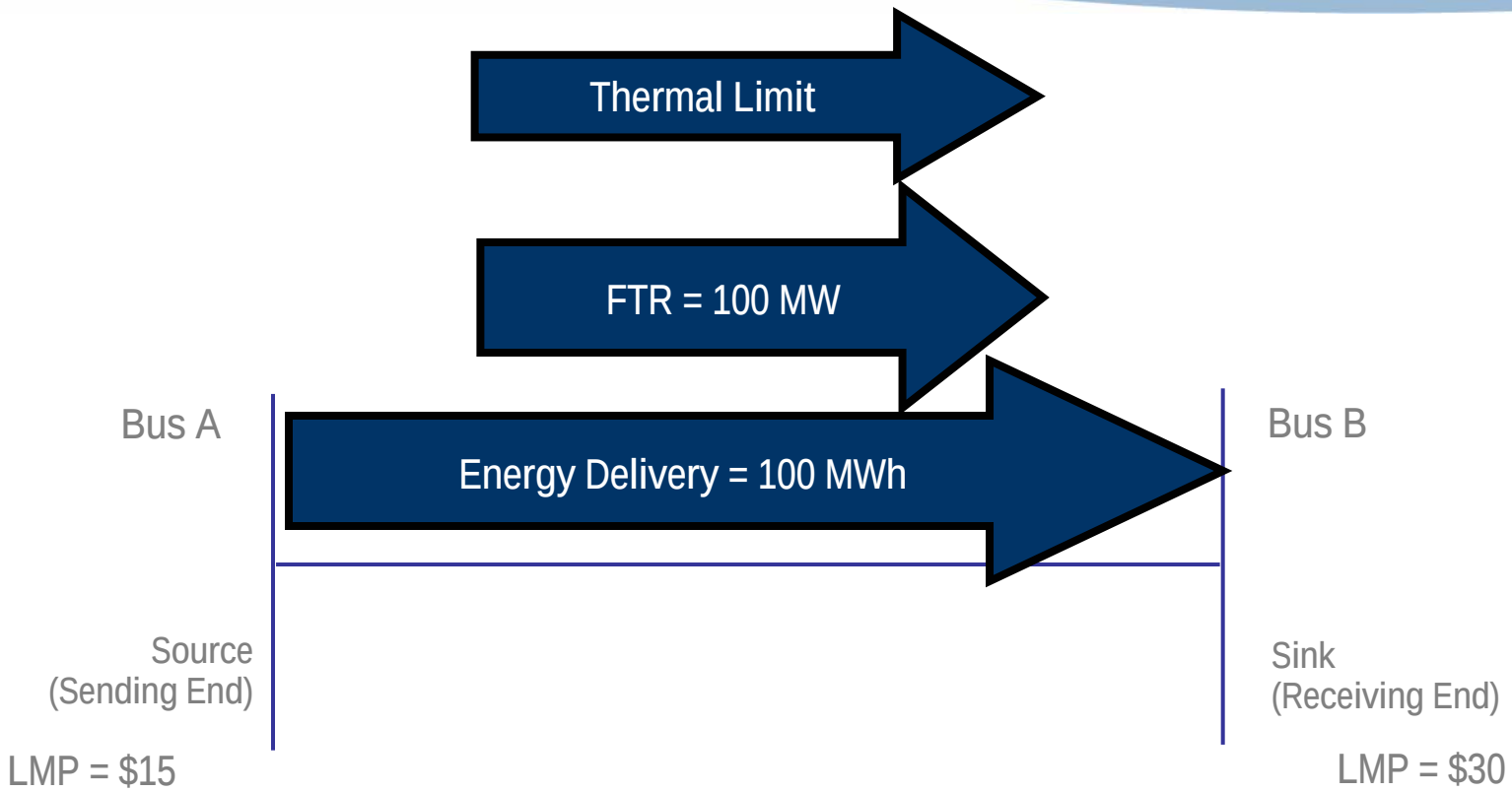


Why do we Need FTRs?

- Challenge:
  - Protect Load Servers from price uncertainty for congestion charges
  - Redistribute excess congestion charges collected during constrained conditions.

- Solution:
  - FTR credits equal congestion charges on same path
  - FTRs provide hedging mechanism that can be traded separately from transmission service

Energy Delivery Consistent With FTR

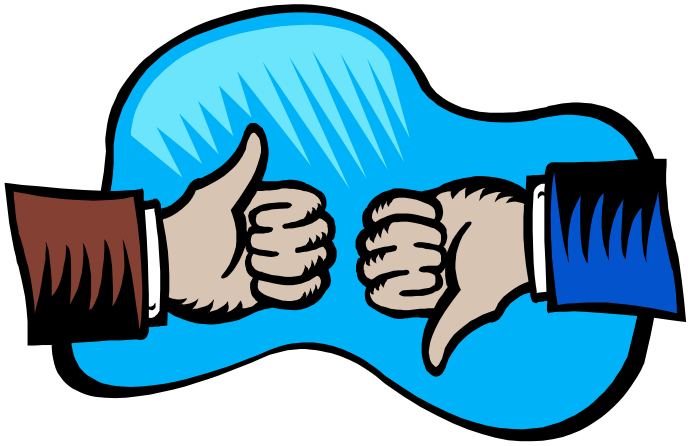


Congestion Charge = 100 MWh * ($30-$15) = $1500

FTR Credit = 100 MW * ($30-$15) = $1500

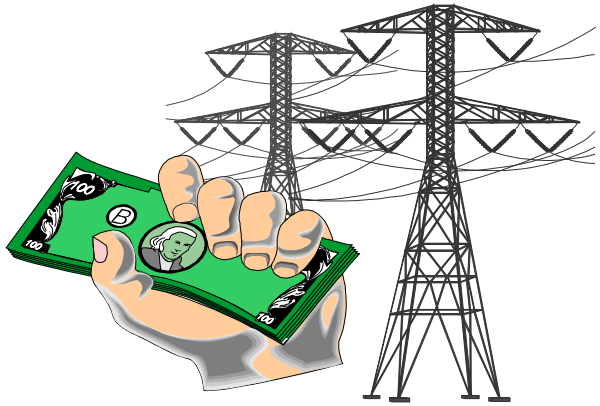
- Annual Auction
  - Multi-round
  - Multi-period
  - Multi-product
  - Entire System Capability
- Secondary market -- bilateral trading
  - FTRs that exist are bought or sold
- Monthly & Balance of Planning Period FTR Auction -- centralized market
  - purchase “left over” capability

- Economic value determined by Day ahead hourly LMPs
- Benefit (Credit)
  - same direction as congested flow
- Liability (Charge)
  - opposite direction as congested flow
- FTR Options available
  - always benefit

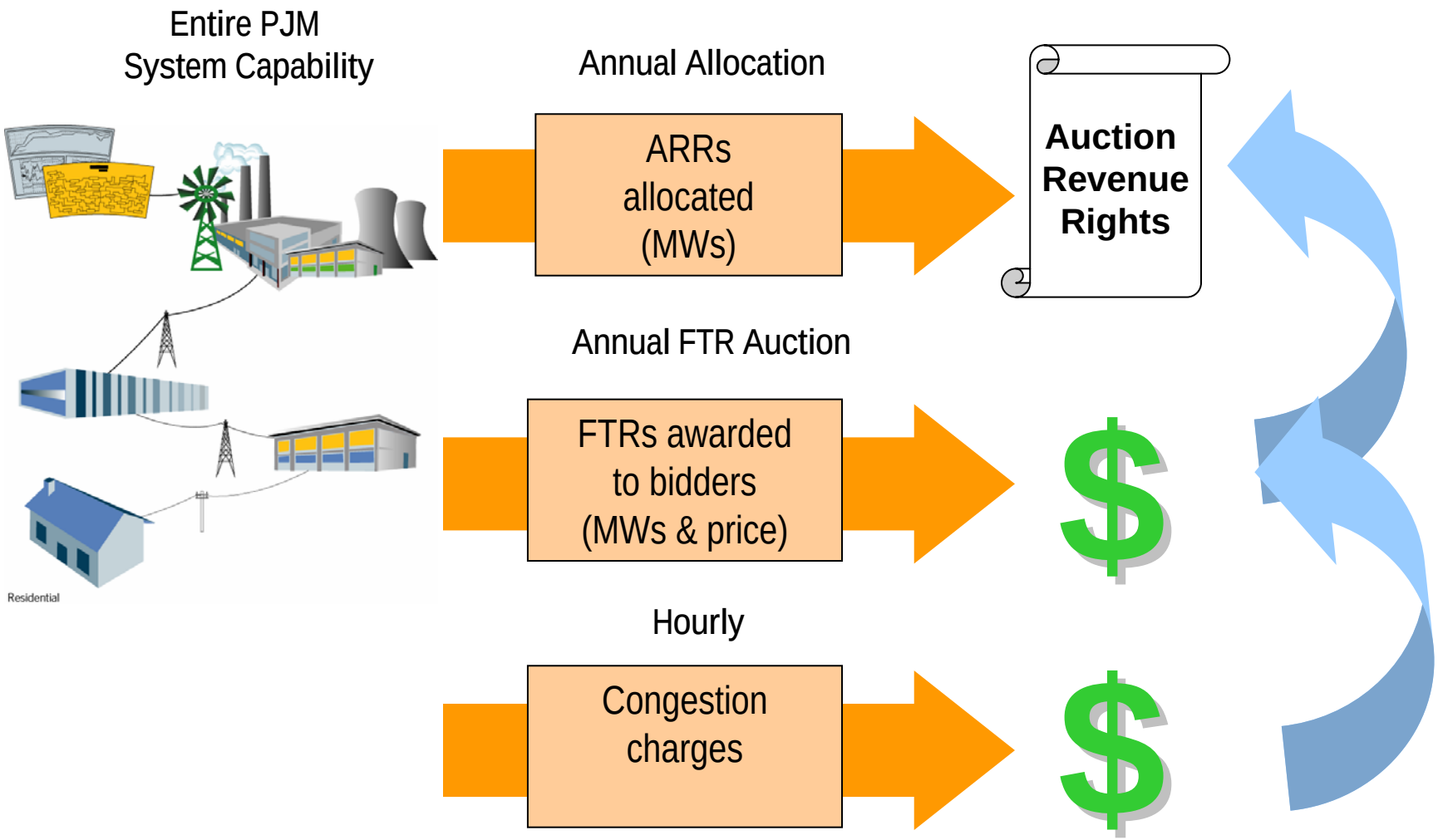


Auction Revenue Rights …

are entitlements allocated annually to Firm Transmission Service Customers that entitle the holder to receive an allocation of the revenues from the Annual FTR Auction



ARRs provide a revenue stream to the firm transmission customer to offset purchase price of FTRs



- Convert ARR into FTR by “self-scheduling” FTR into Annual Auction on exact same path as ARR
- Reconfigure ARR by bidding into Annual Auction to acquire FTR on alternative path or for alternative product
- May retain allocated ARR and receive associated allocation of revenues from the auction

Summary: Congestion Hedging

- Financial Transmission Rights (FTRs) are a financial contract protecting the holder from an increase in cost due to transmission congestion.
- FTRs protect load servers from price uncertainty while redistributing excess congestion charges due to constrained conditions.
- FTRs only have value when the system is constrained. Their value is determined by the value of the day-ahead hourly LMPs.
- Hubs provide buyers and sellers with a more stable trading pricing reference.

Two-Settlement System

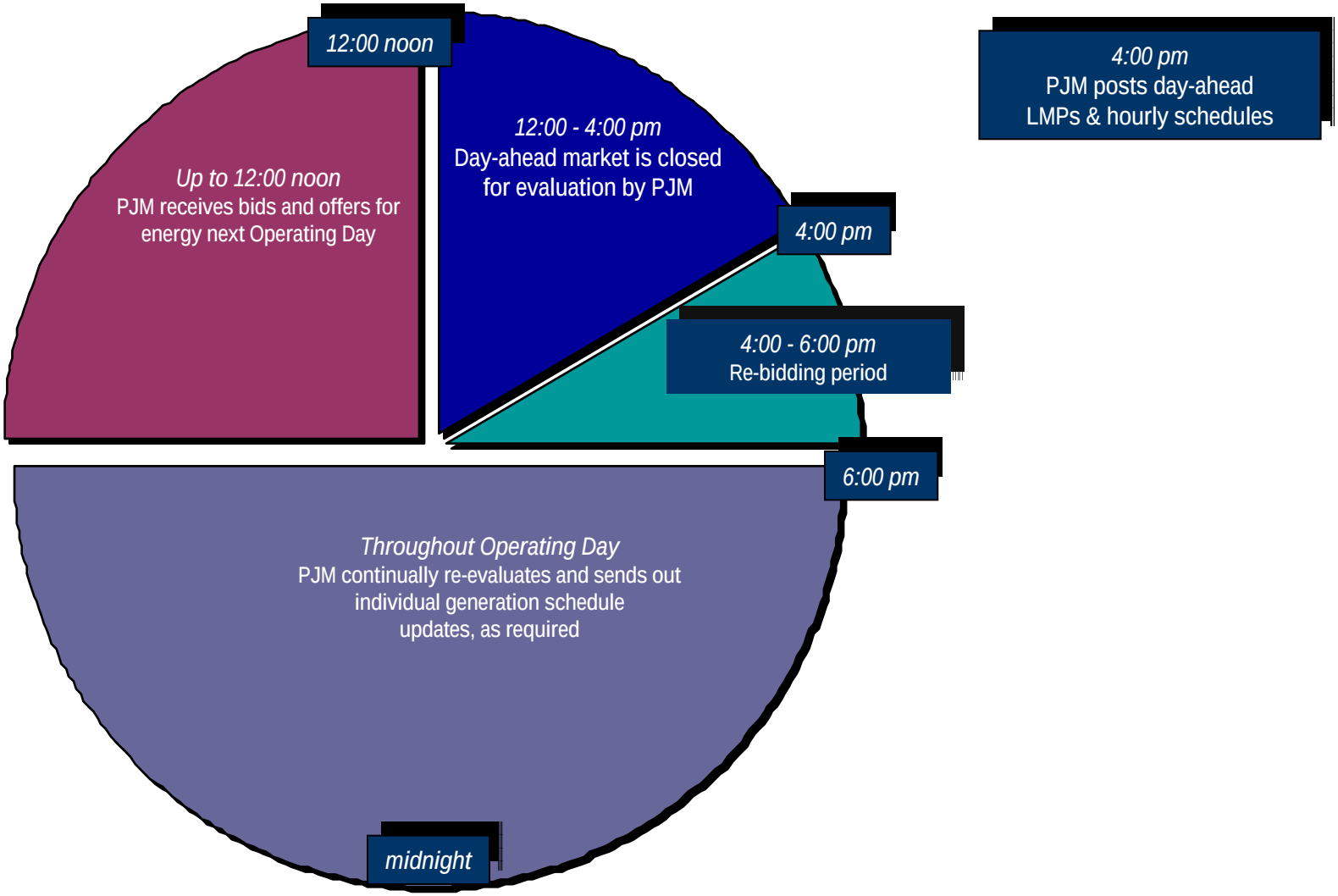
- It provides PJM Market Participants with the option to participate in a forward market for electric energy in PJM
  - Consists of two markets
  - Separate settlements performed for each market

- Day-ahead Market
  - Day-ahead schedule uses least-cost unit commitment and economic dispatch programs
  - Hourly LMPs for next Operating Day calculated using generation offers, demand bids, and bilateral transaction schedules

- Real-time Energy Market
  - calculate hourly LMPs based on actual operating conditions

- Day-ahead Market Settlement
  - based on scheduled hourly quantities and day-ahead hourly prices
- Real-time Market Settlement
  - based on actual hourly quantity deviations from day-ahead schedule hourly quantities and on real-time prices

Day-Ahead Market Timeline



- In a Two Settlement Market, market participants have the opportunity to participate in a forward market for electric energy in PJM.
- Day-ahead Market is a financial market which calculates hourly LMPs for the next Operating Day based on submitted demand bids and generation offers.
- In the Real-time or Balancing Energy Market, deviations from day-ahead schedules are priced at hourly LMPs based on actual operating conditions.