Generation Initial Training Program

Introduction to the PJM Markets & Operational Reliability

PJM State & Member Training Dept.

Objectives

- Students will be able to:
  - Describe some of the basic functions of PJM

Growth of PJM

Joined in 1927

Joined in 1956

Joined in 1965

Joined in 1981

Joined in 2002

Joined in 2004

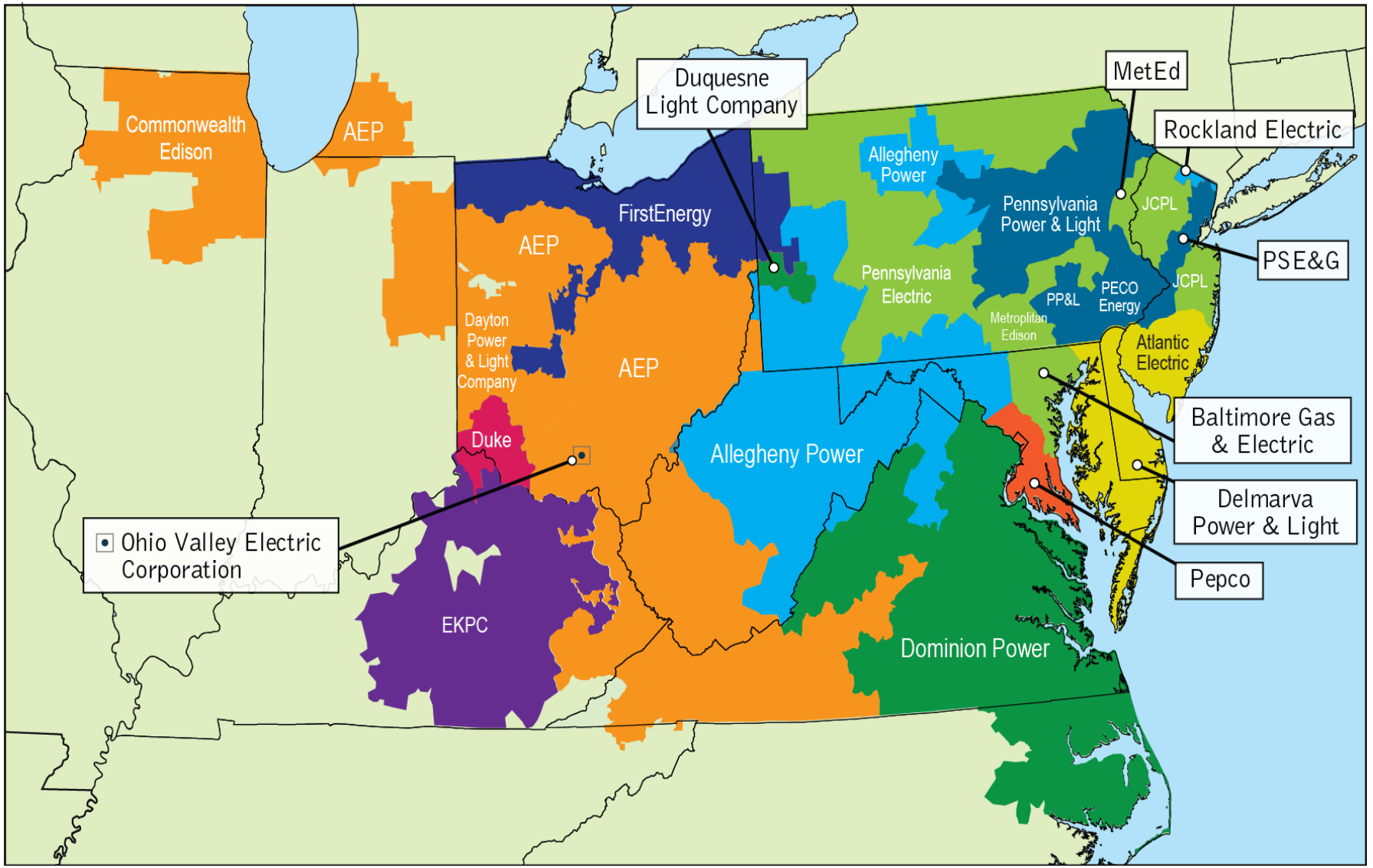
Joined in 2005

Joined in 2011

Joined in 2012

Joined in 2013

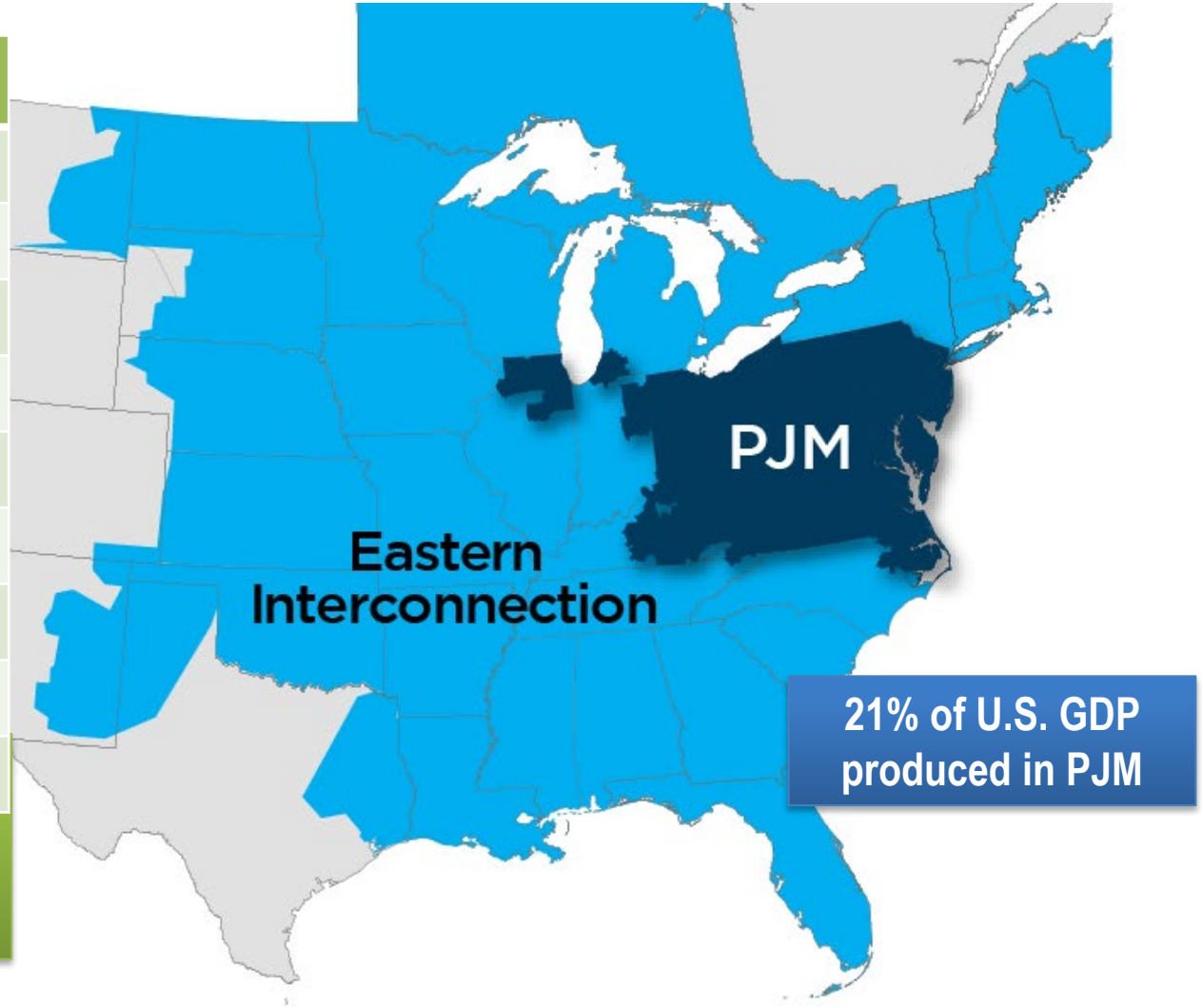
Joined in 2018



PJM as Part of the Eastern Interconnection

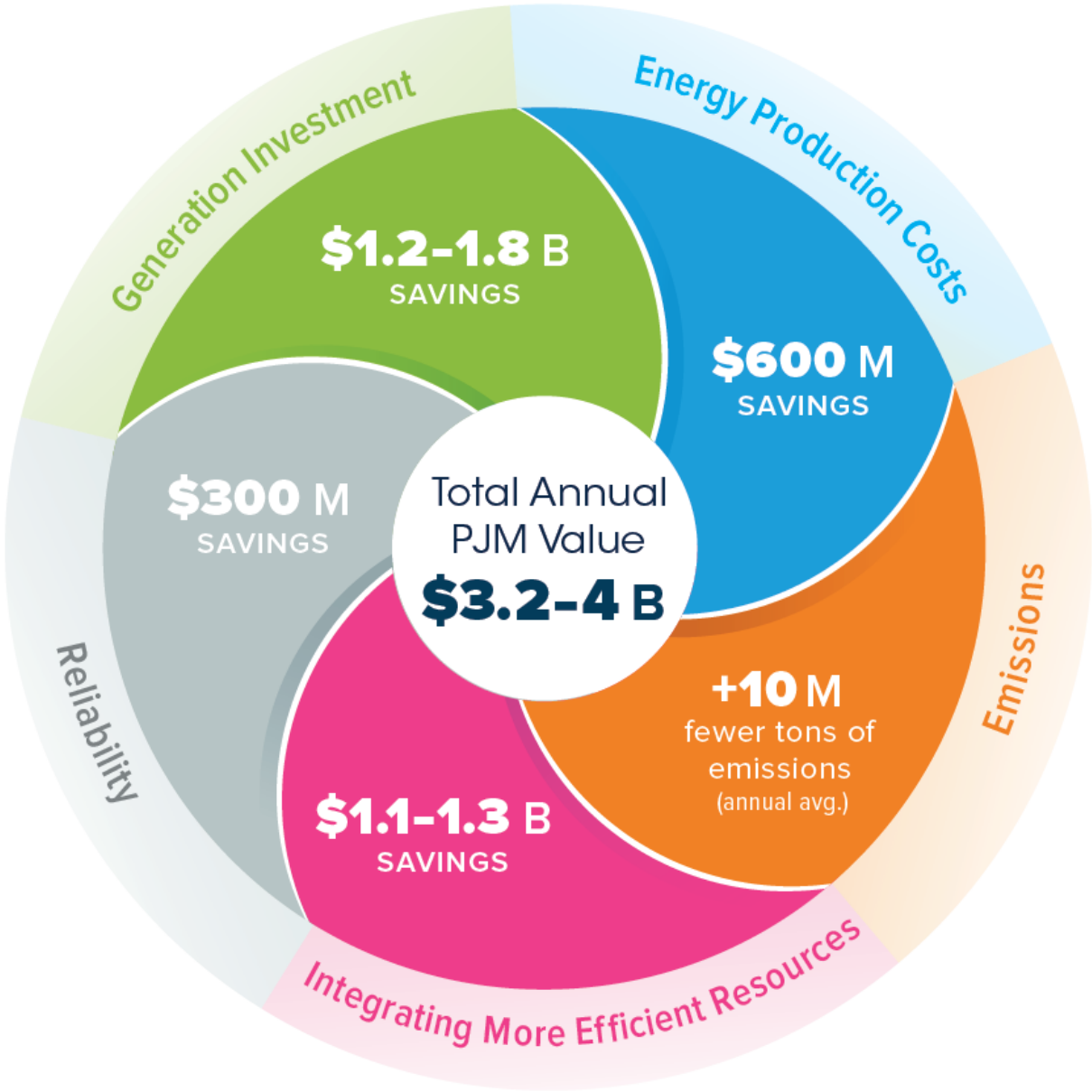
Key Statistics	
Member companies	1,060+
Millions of people served	65
Peak load in megawatts	165,563
MW of generating capacity	185,442
Miles of transmission lines	84,236
2021 GWh of annual energy	782,683
Generation sources	1,436
Square miles of territory	368,906
States served	13 + DC

- 25% of load in Eastern Interconnection
- 26% of generation in Eastern Interconnection

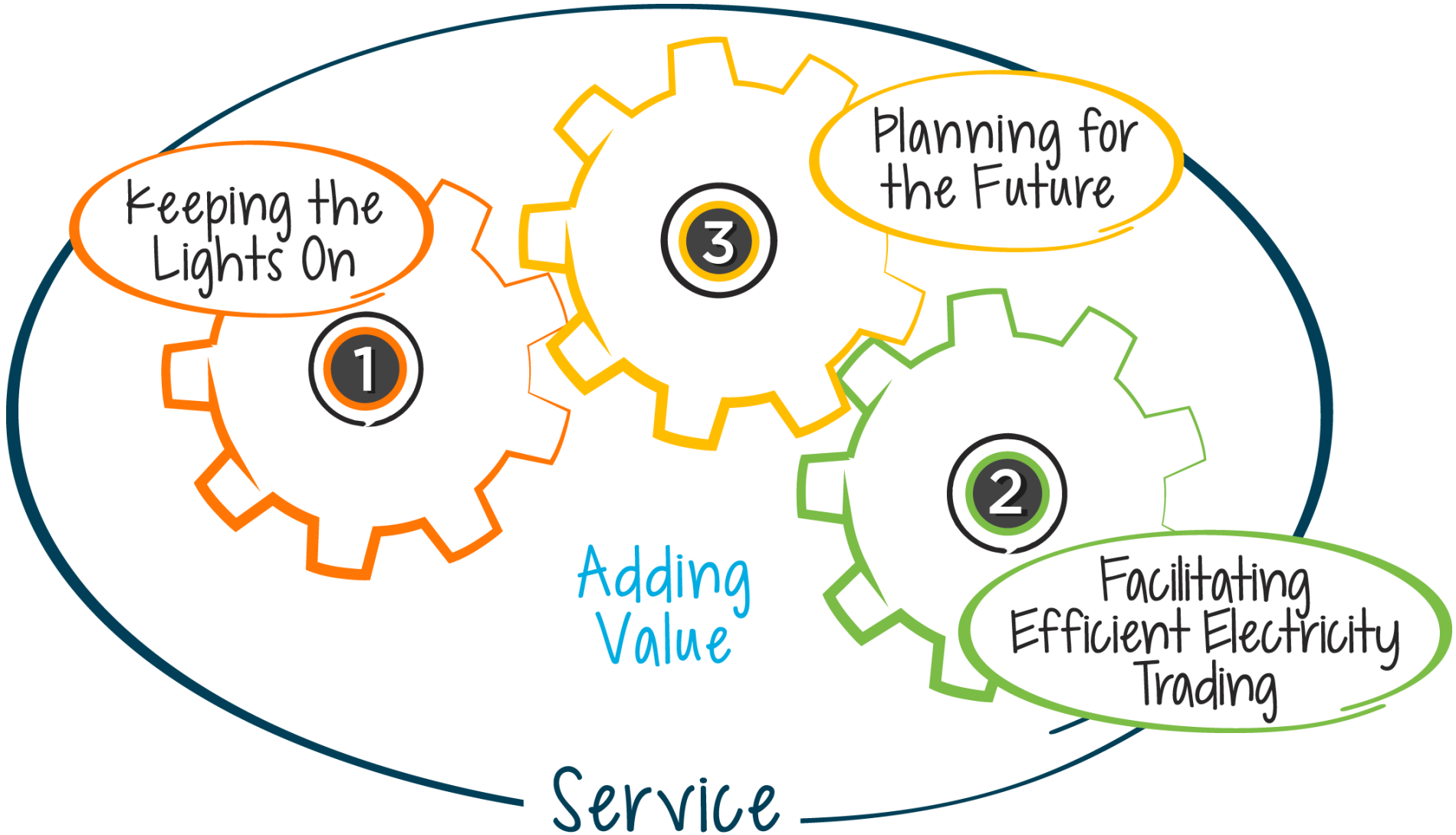


As of 2/2022

Value Proposition

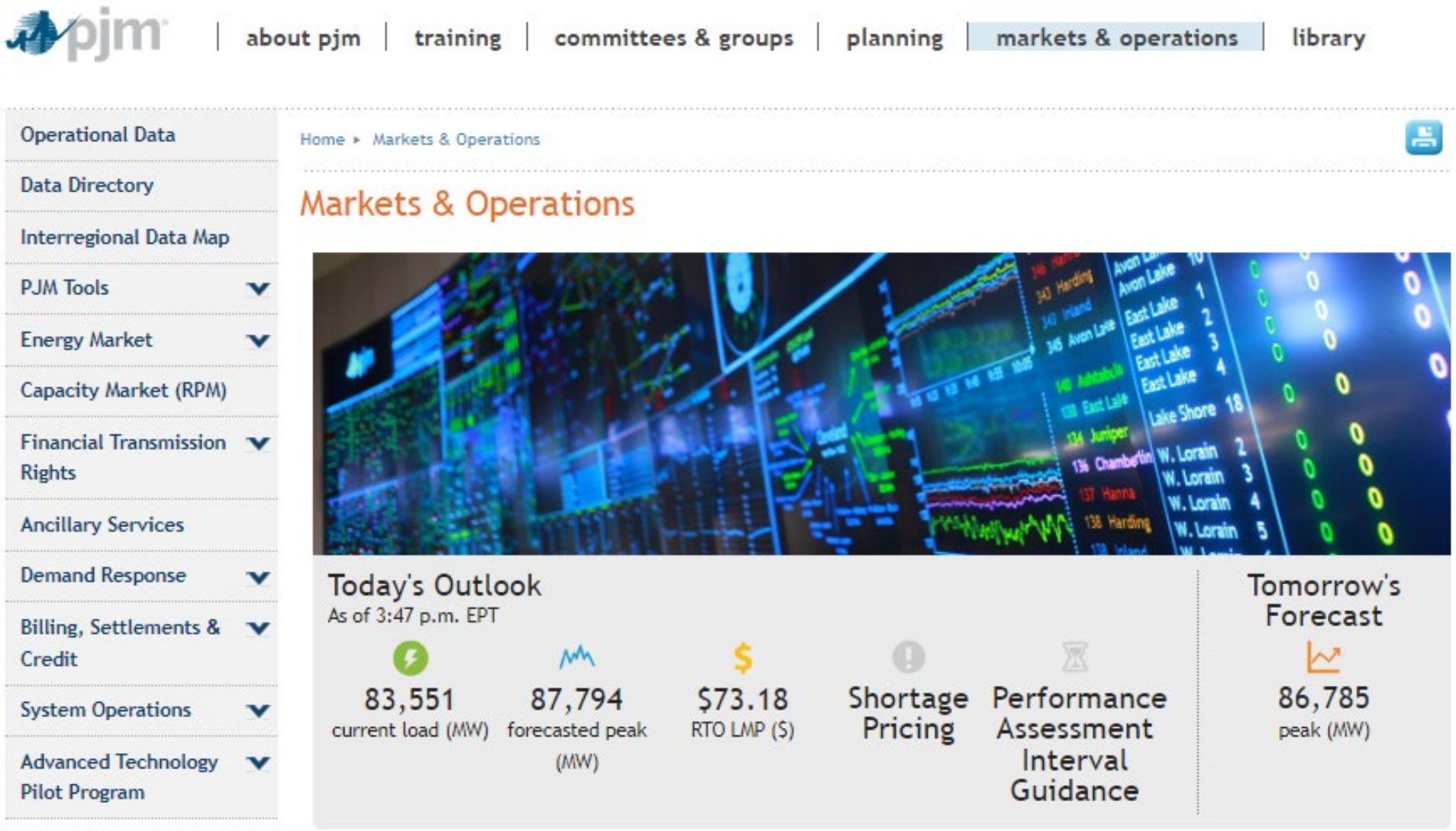


Focus on Just Three Things



How do the Energy Markets work?

PJM Markets

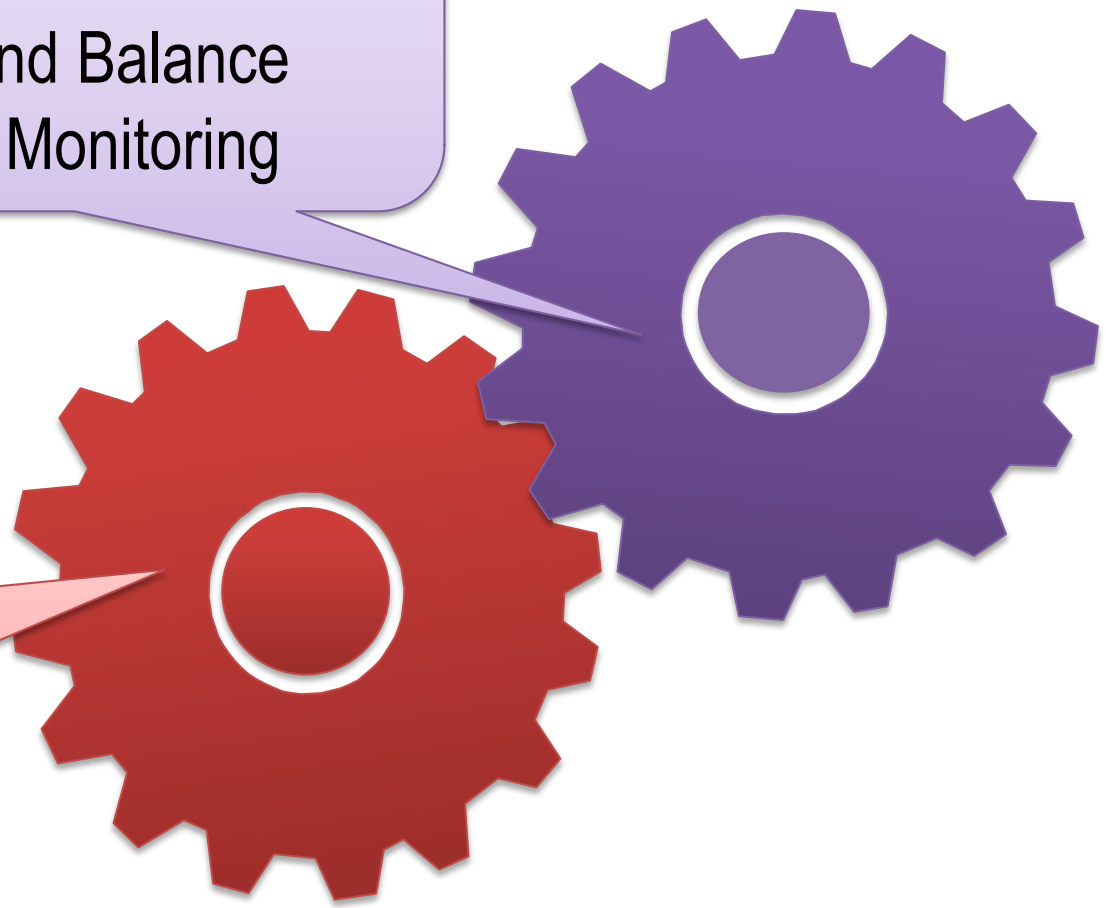

about pjm
training
committees & groups
planning
markets & operations
library
Operational Data
Data Directory
Interregional Data Map
PJM Tools
Energy Market
Capacity Market (RPM)
Financial Transmission Rights
Ancillary Services
Demand Response
Billing, Settlements & Credit
System Operations
Advanced Technology Pilot Program
Home ▸ Markets & Operations
Markets & Operations
Today's Outlook
As of 3:47 p.m. EPT
83,551
current load (MW)
87,794
forecasted peak (MW)
$73.18
RTO LMP ($)
Shortage Pricing
Performance Assessment Interval Guidance
Tomorrow's Forecast
86,785
peak (MW)

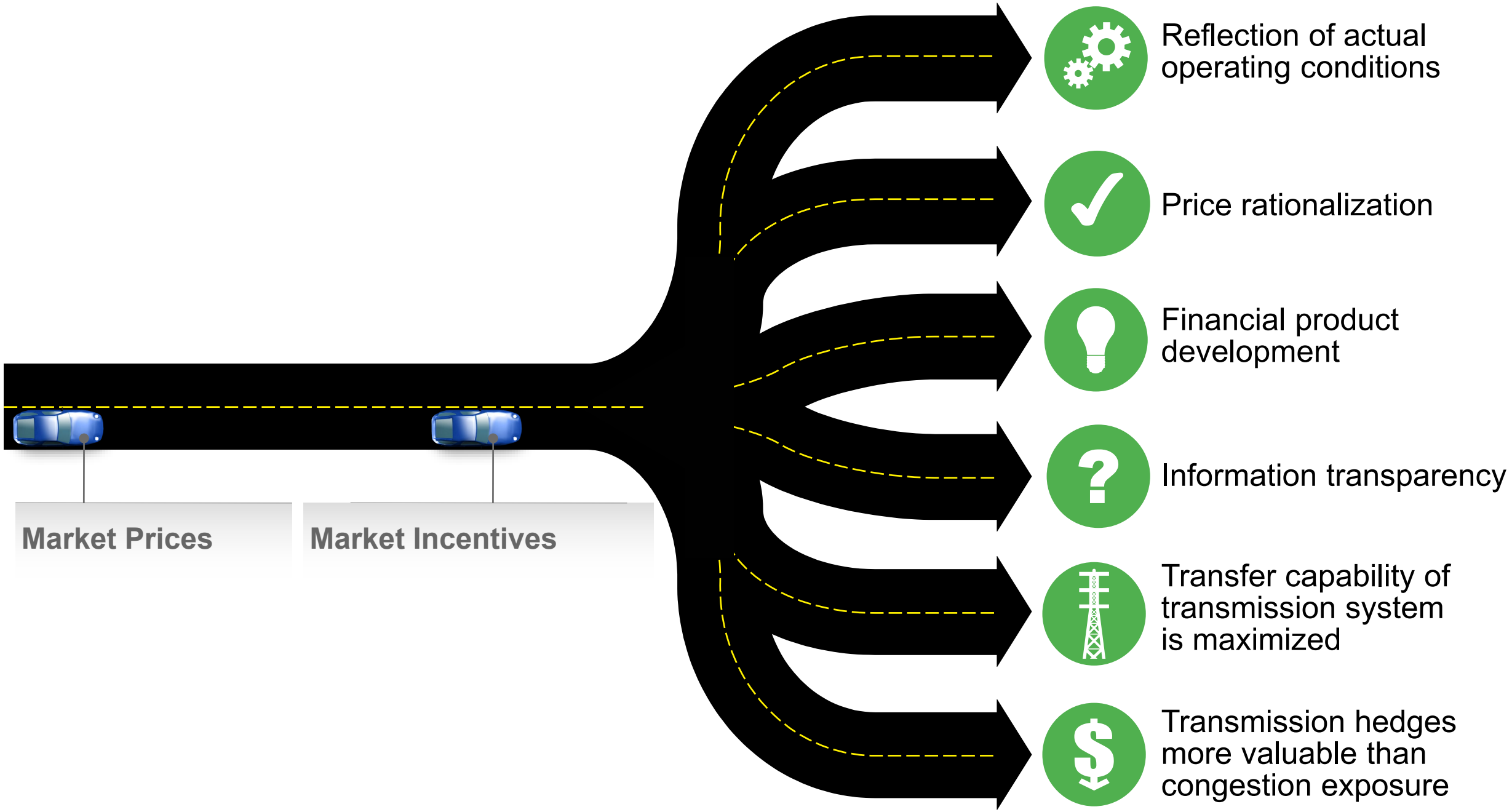
Reliability

- Grid Operations
- Supply/Demand Balance
- Transmission Monitoring

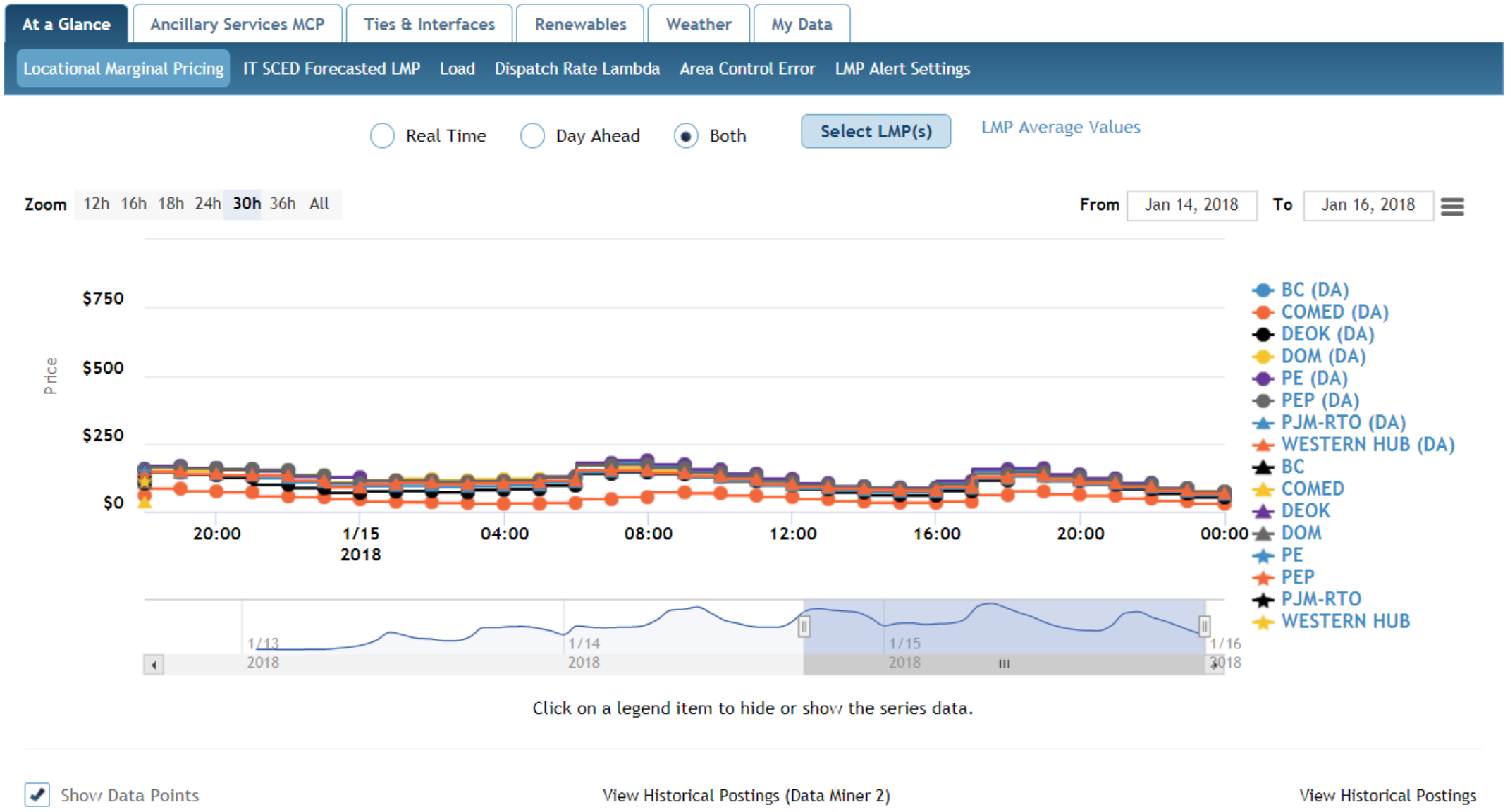
Market Operation

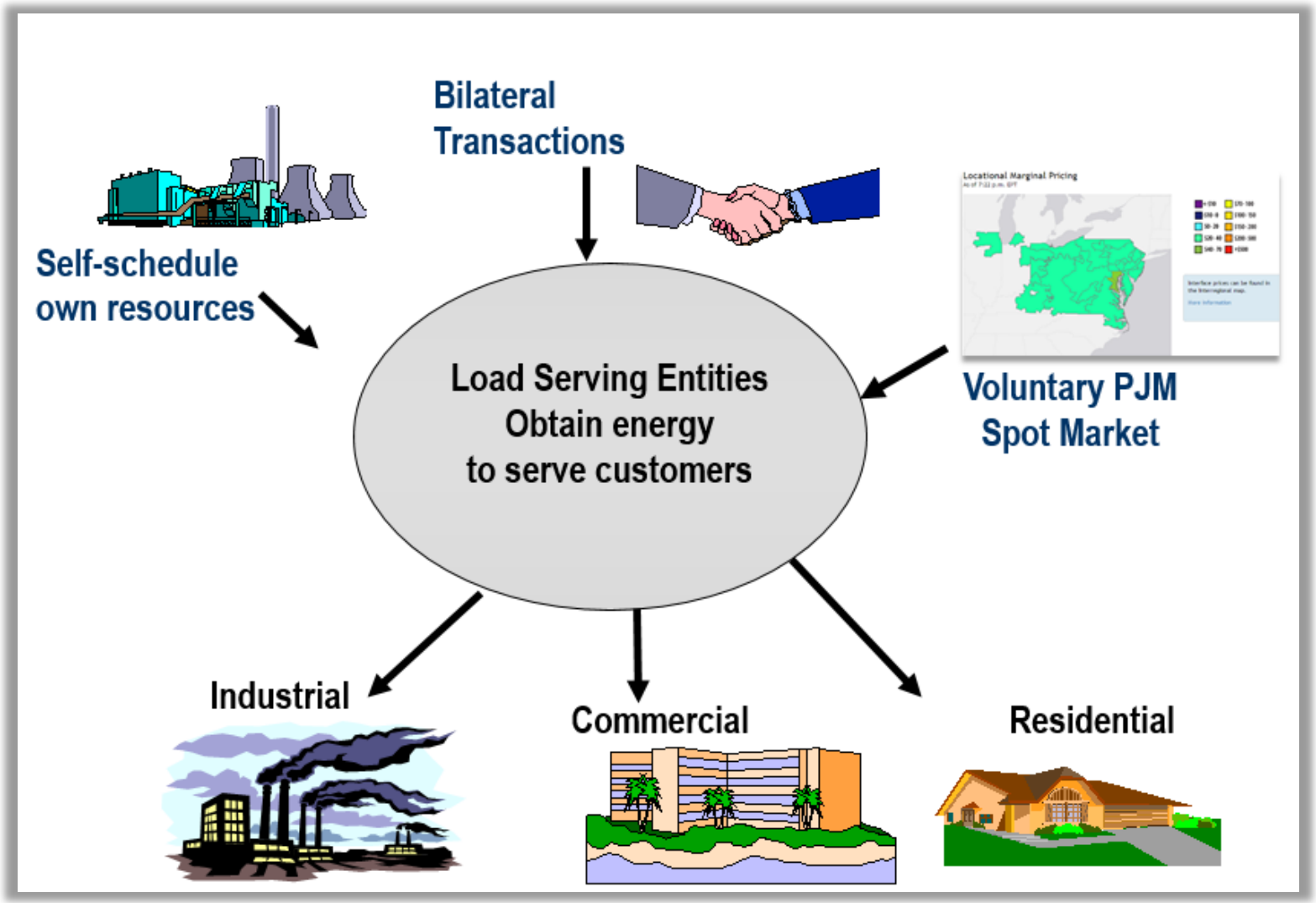
- Energy
- Capacity
- Ancillary Services

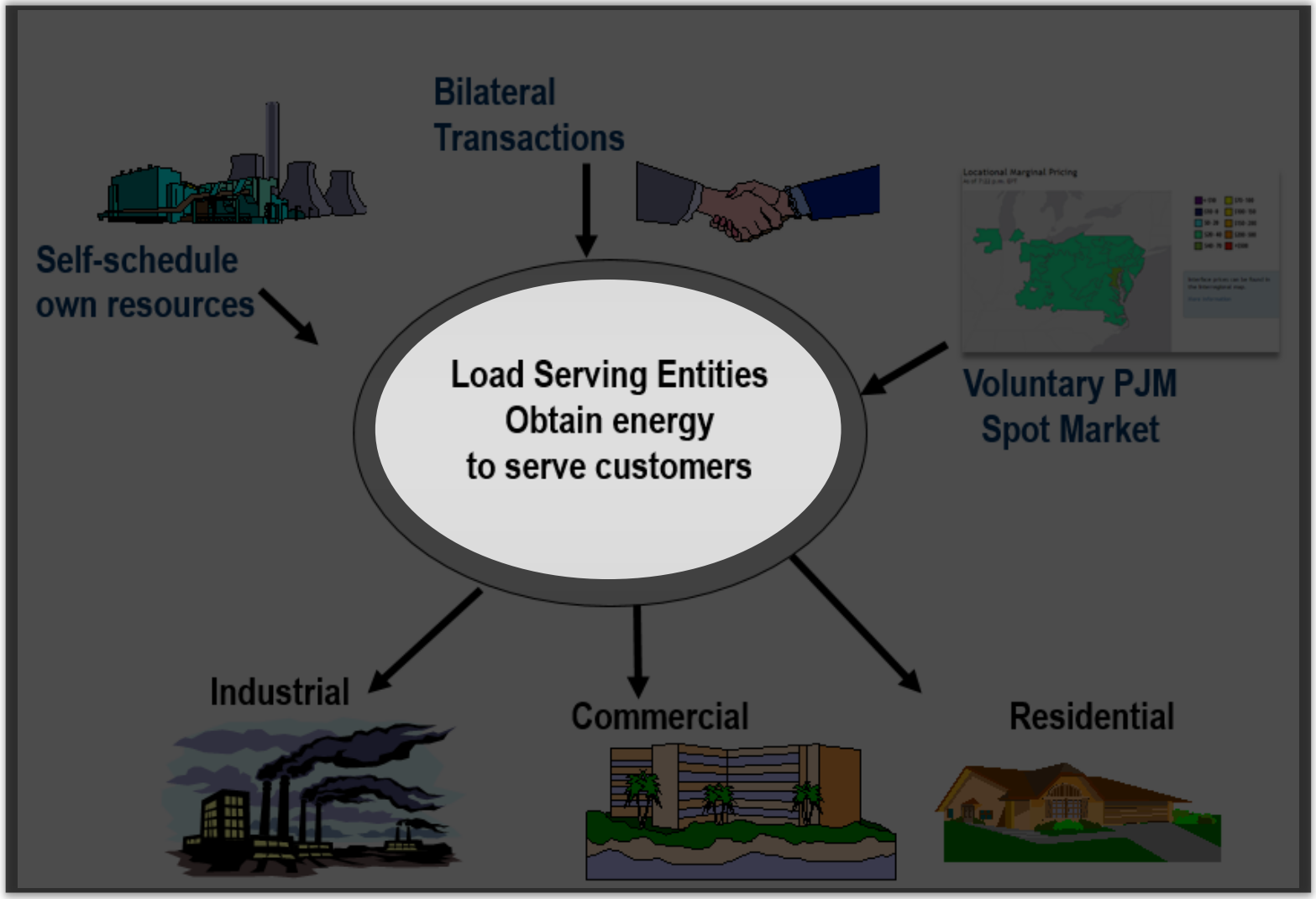



Market Prices
Market Incentives
Reflection of actual operating conditions
Price rationalization
Financial product development
Information transparency
Transfer capability of transmission system is maximized
Transmission hedges more valuable than congestion exposure

Transparency = TRUST




Bilateral
Transactions
Self-schedule
own resources
Load Serving Entities
Obtain energy
to serve customers
Voluntary PJM
Spot Market
Industrial
Commercial
Residential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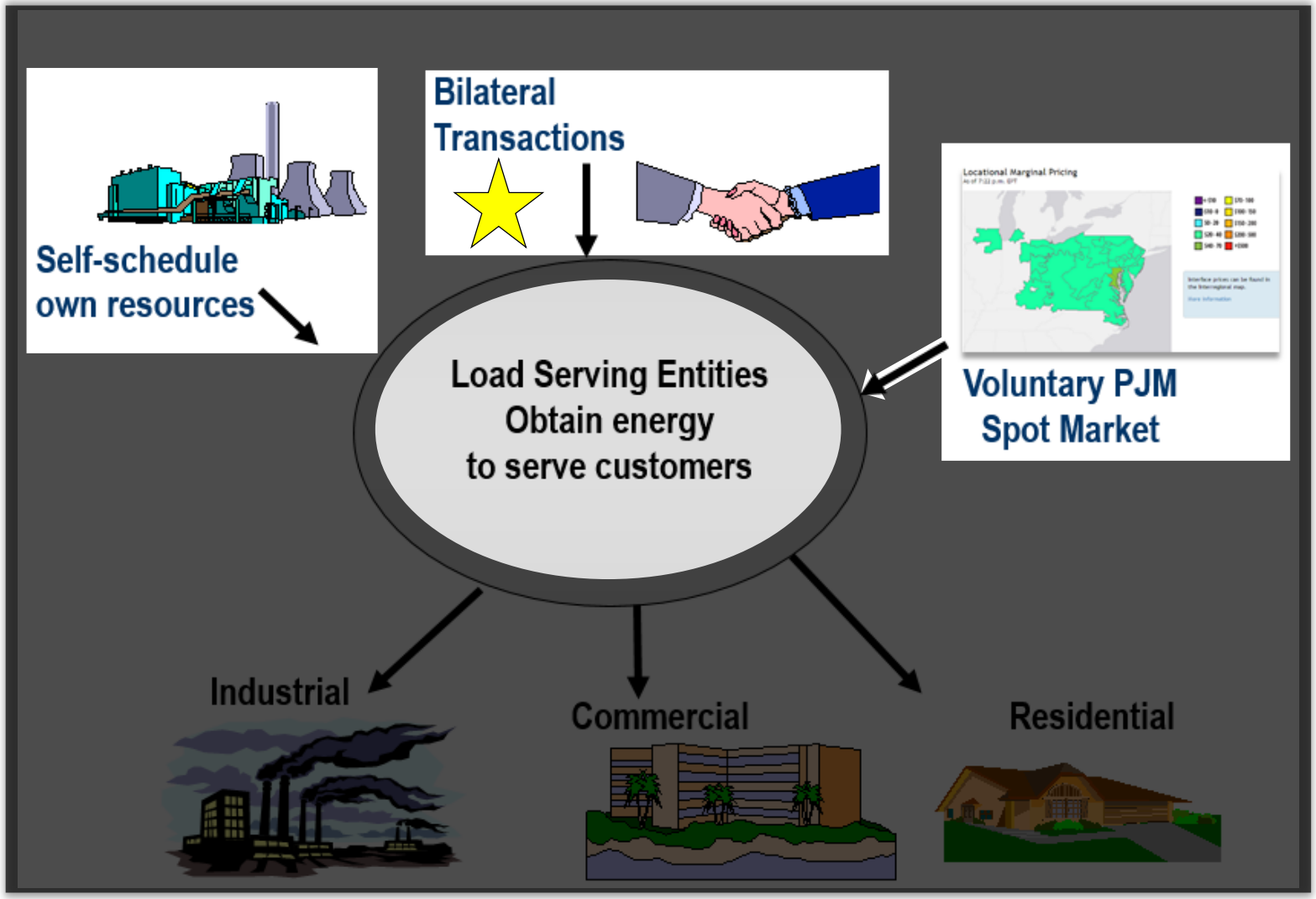
Self-schedule
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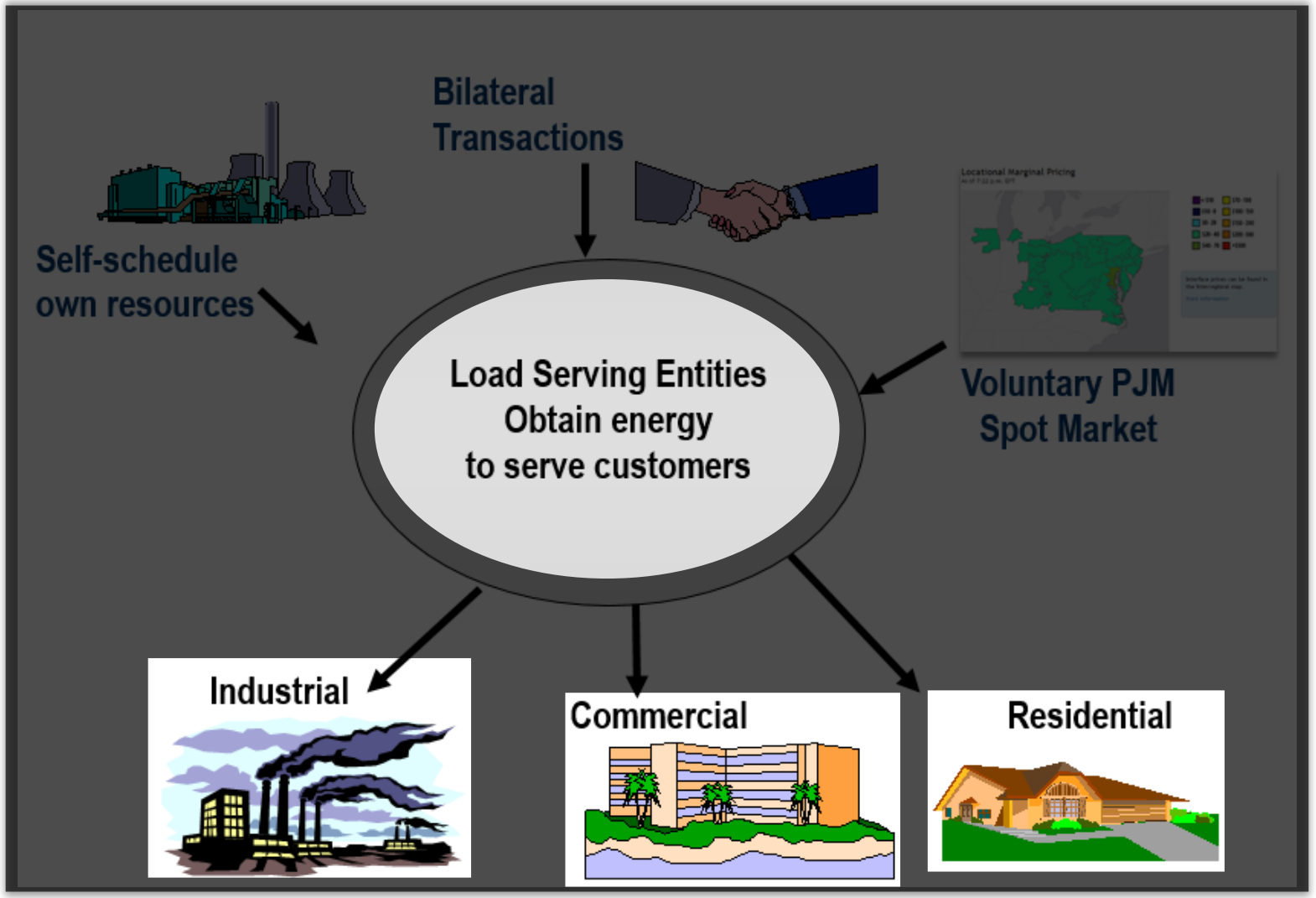
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to serve customers
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Spot Market
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Commercial
Residential

Dispatch Functions

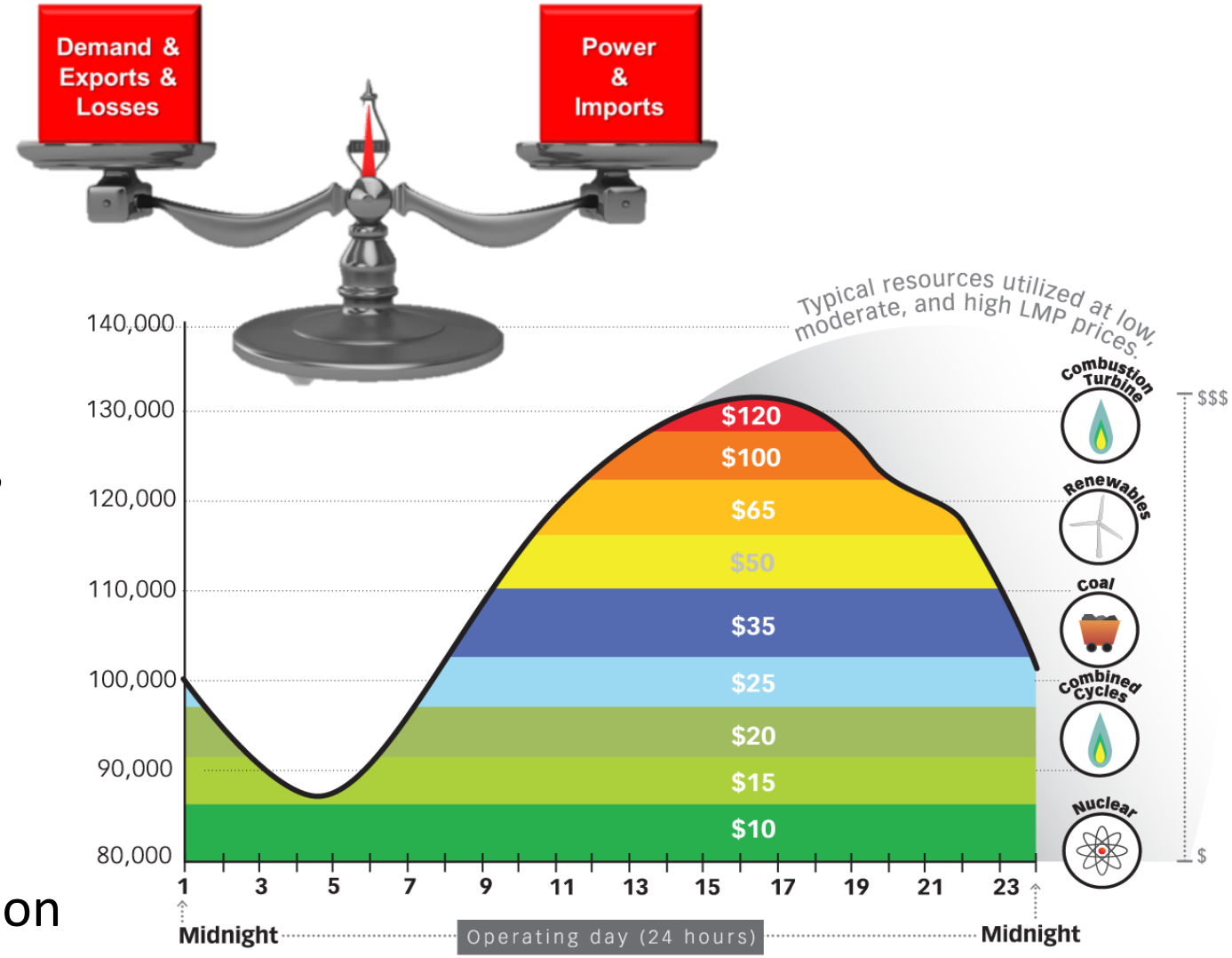
- Ensure sufficient generation is available or running to satisfy the demand at any hour of the day including maintaining adequate reserves
  - This is called ***Generation Control***
- Monitor, operate and control the high voltage transmission system in a reliable manner
  - This is called ***Transmission Control***

Generation Dispatch

Generation is economically dispatch to meet the demand across the entire RTO at the lowest cost

Generation Dispatch Operations

- Maintain System Control
  - Generation / Demand balance
- Maintain Adequate Reserves
  - Operate on contingency basis
- Implement Emergency Procedures
  - To keep the lights on!
- Synchronized Reserve/ Regulation Market
  - Clear Market
  - Administer real-time optimization



Economic Generation Control

- Purpose is to ensure that the least cost generation is used to satisfy 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

Offers Received from Resources

10MW @$30

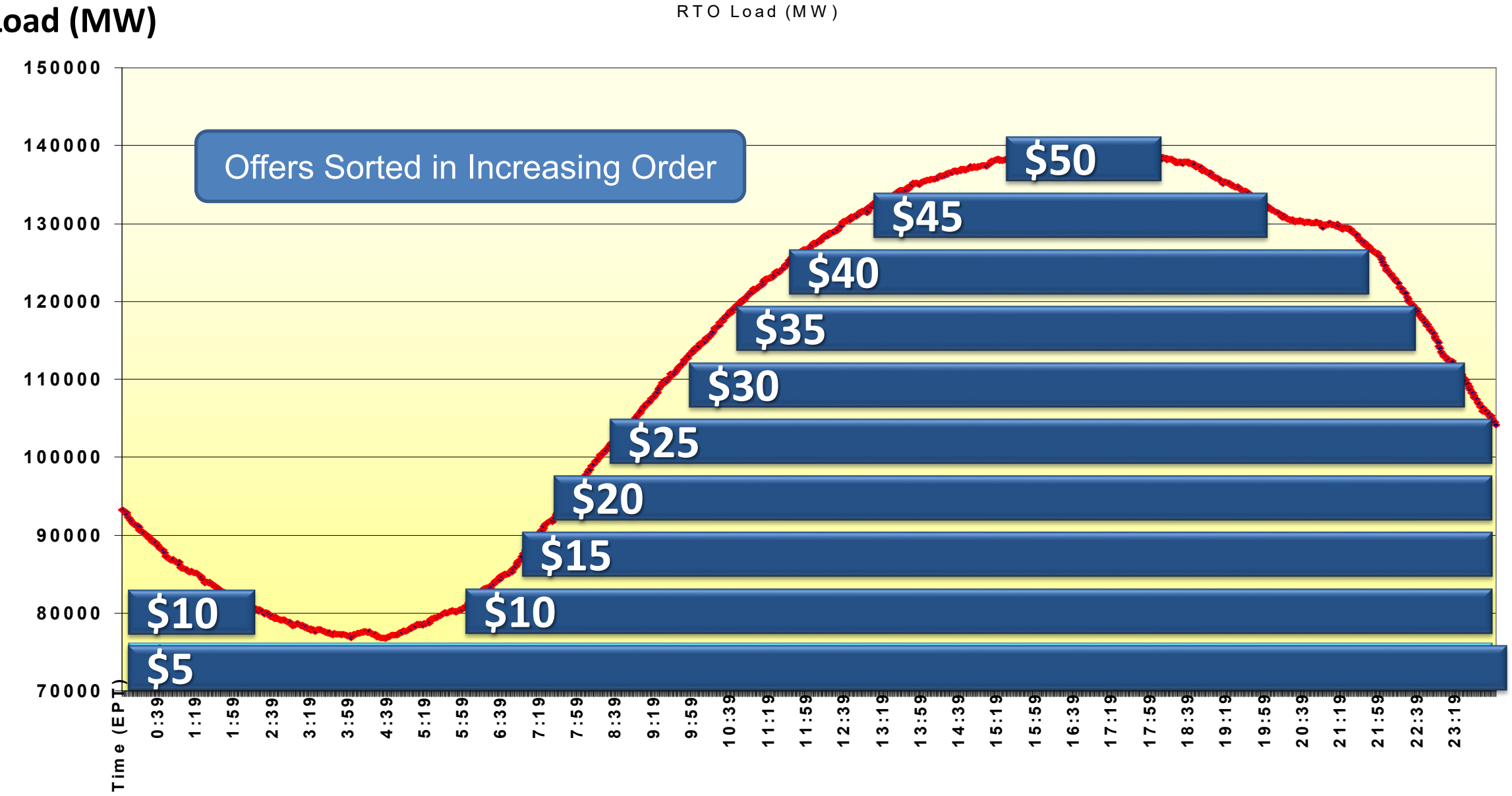
40MW @$5

20MW @$10

15MW @$25

25MW @ $15

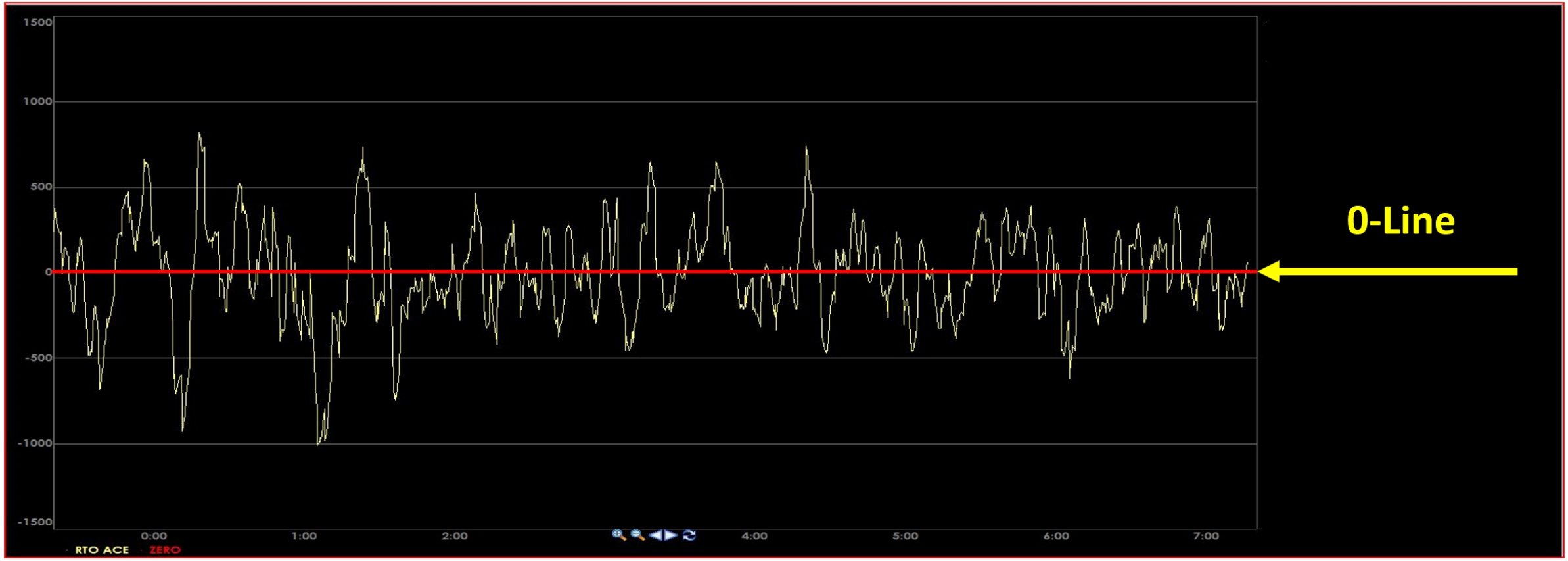
Resources Scheduled to Meet Demand



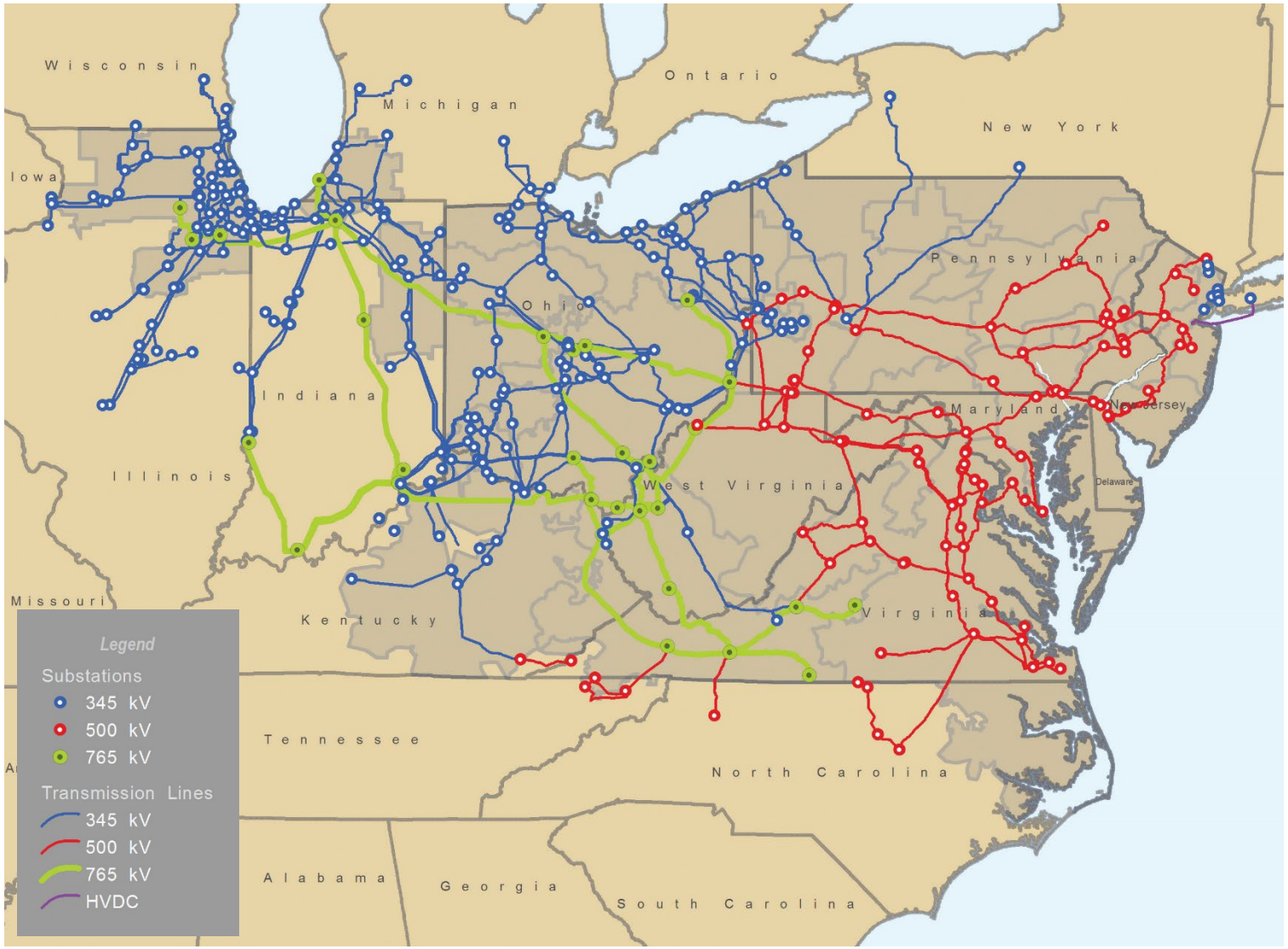
Events That Take Place

- Units trip – unexpected loss
- Units are delayed
- Contract curtailments
- Weather
- Emergency procedures

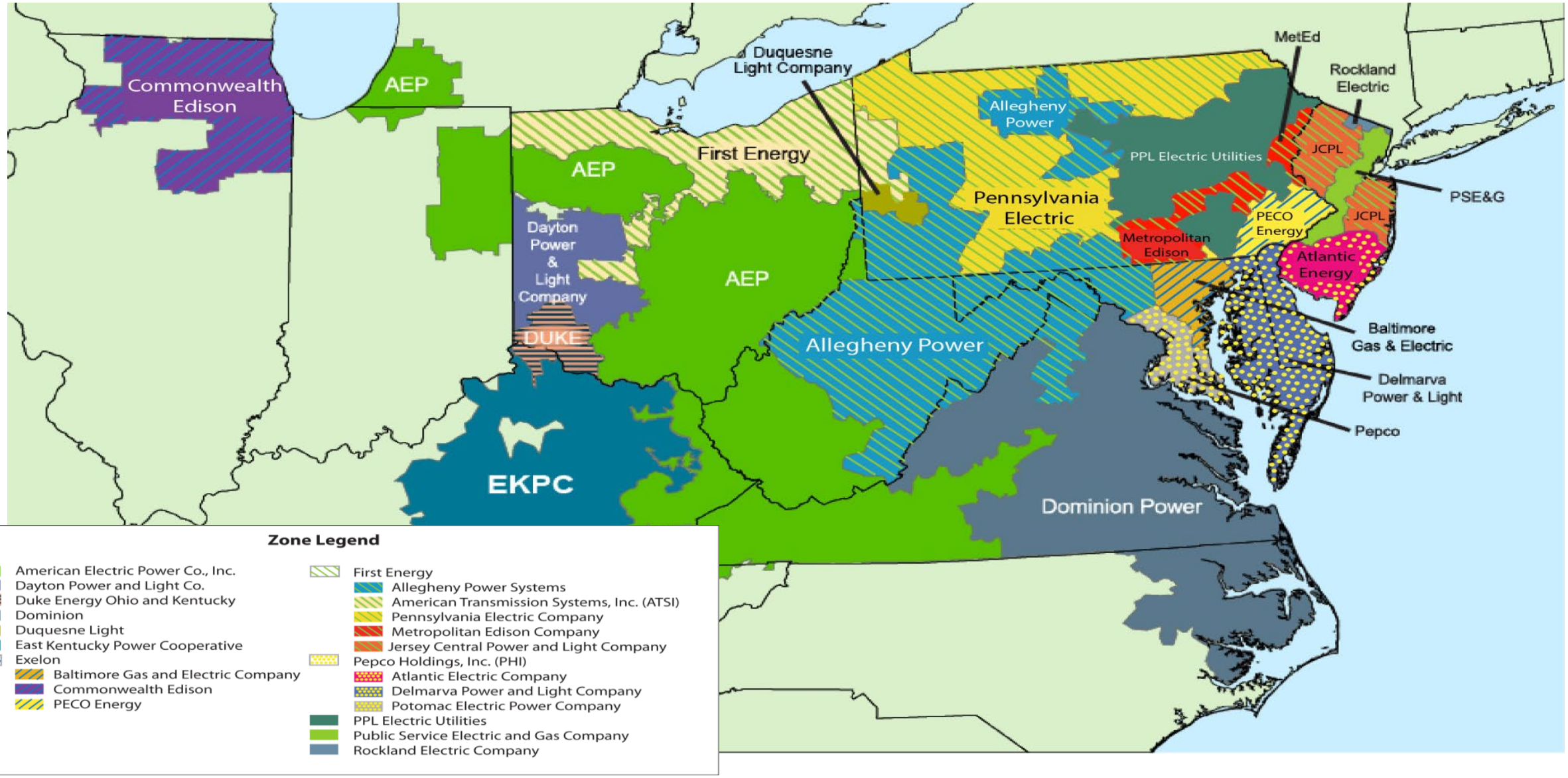
ACE Graph


1500
1000
500
0
-500
-1000
-1500
0:00
1:00
2:00
4:00
5:00
6:00
7:00
RTO ACE
ZERO
0-Line

PJM Backbone Transmission



PJM Territory by Transmission Zones

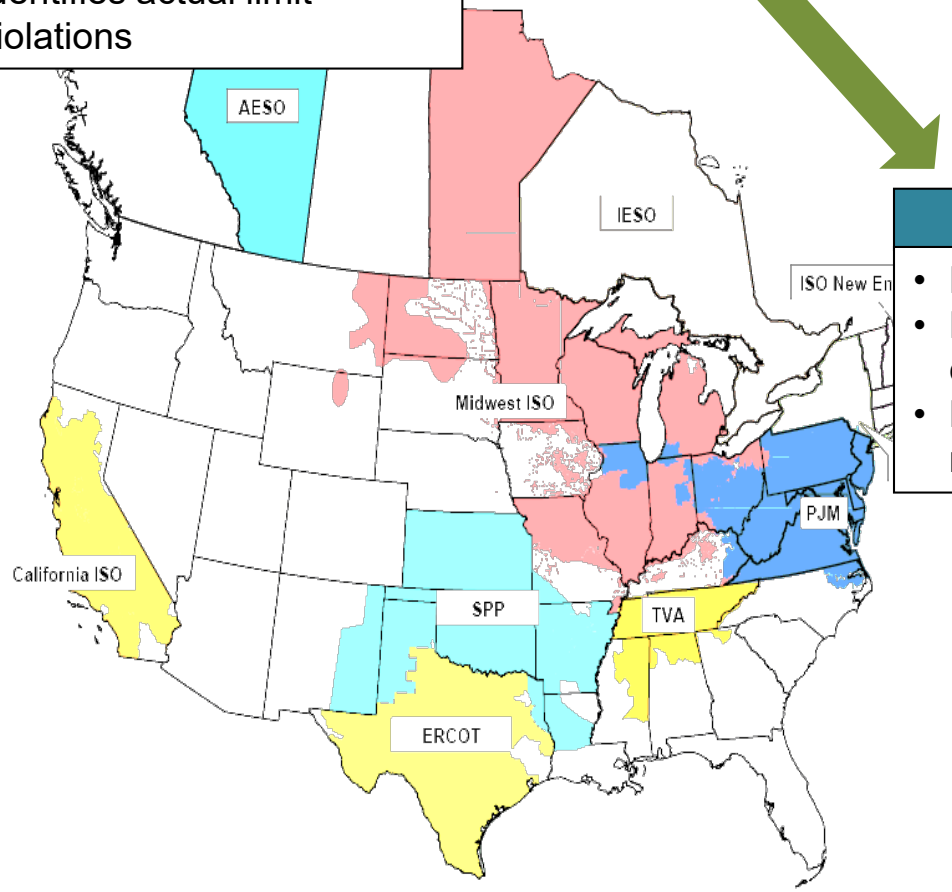


Transmission System Operations

- Ensure Security of the Transmission System
  - Monitor transfer limitations (IROL)
  - Monitor thermal constraints
- Contingency Analysis
- Direct Emergency Operations
- Direct Off-Cost Operations
  - Generation shifts
  - Contract curtailments
- Coordinate Switching

State Estimator – Computer

- Runs every minute
- Calculates flows, voltages
- Identifies actual limit violations



Security Analysis

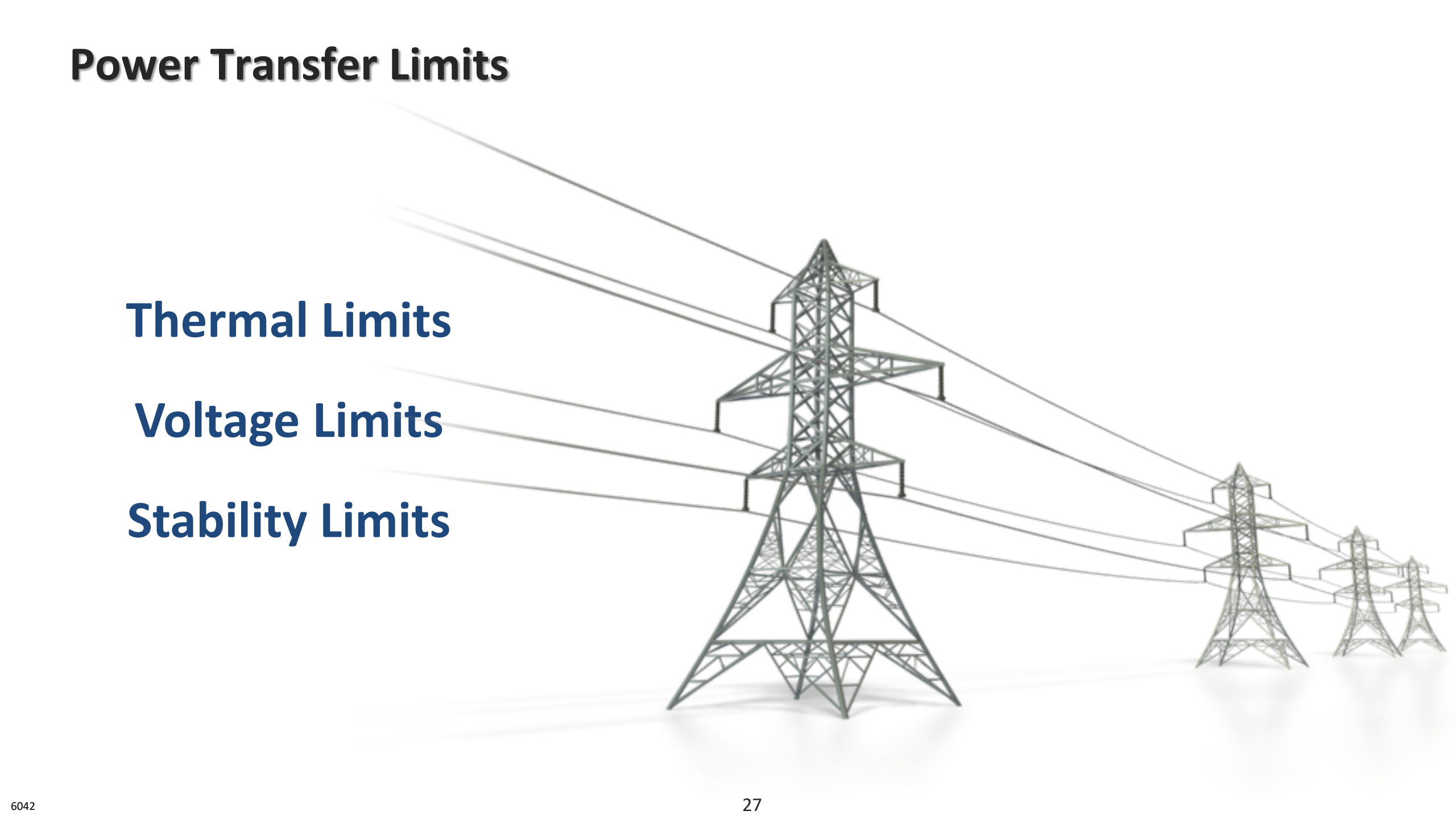
- Runs every minute
- Evaluates over 7,000 contingencies
- Provides "**what if**" results

Power Transfer Limits

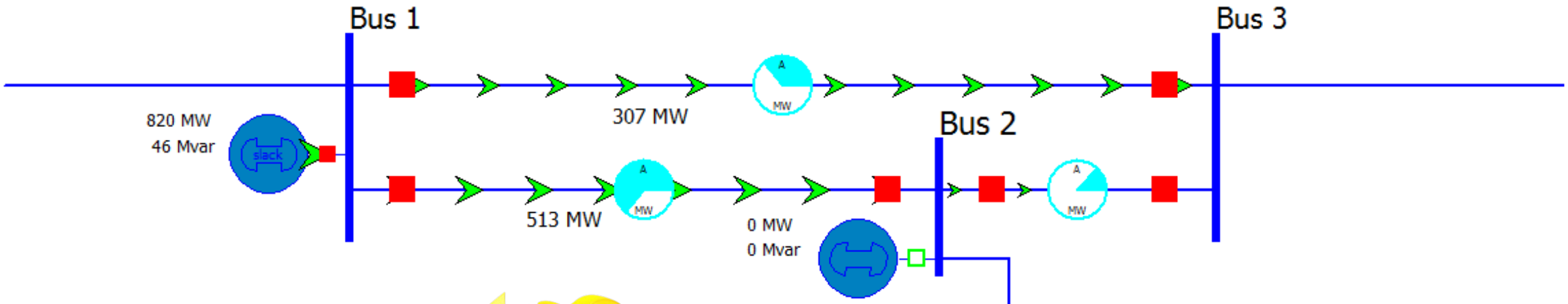
Thermal Limits

Voltage Limits

Stability Limits



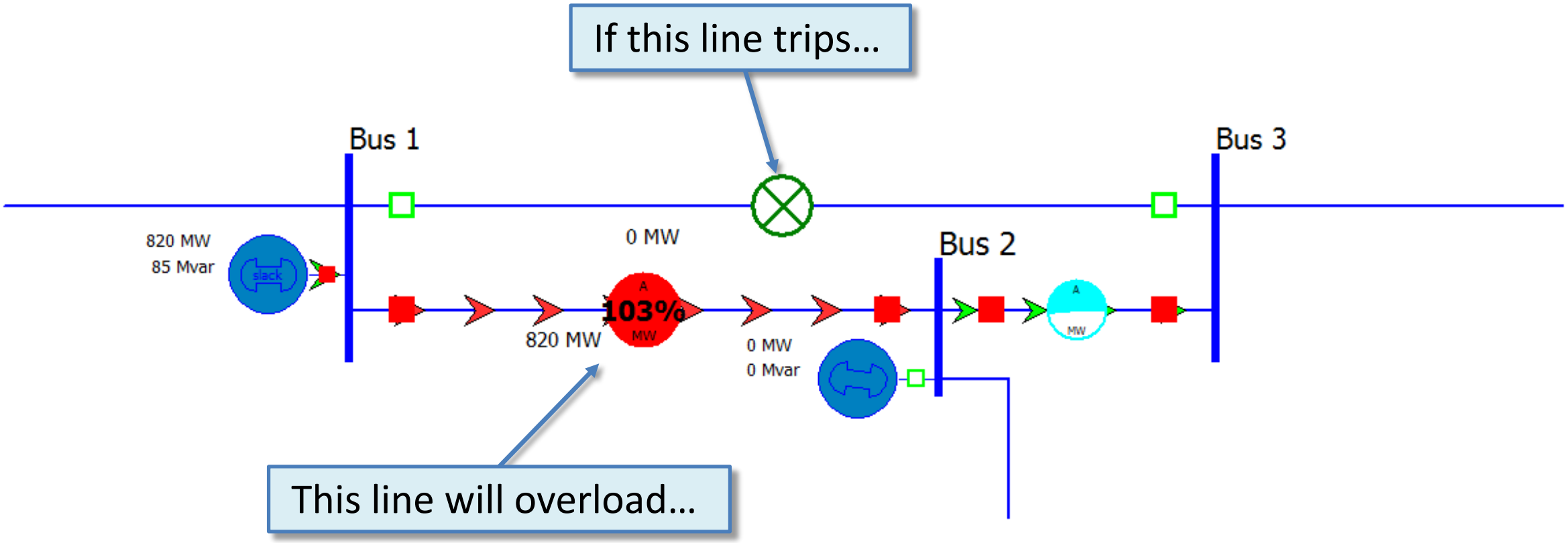
Control Actions for Contingencies



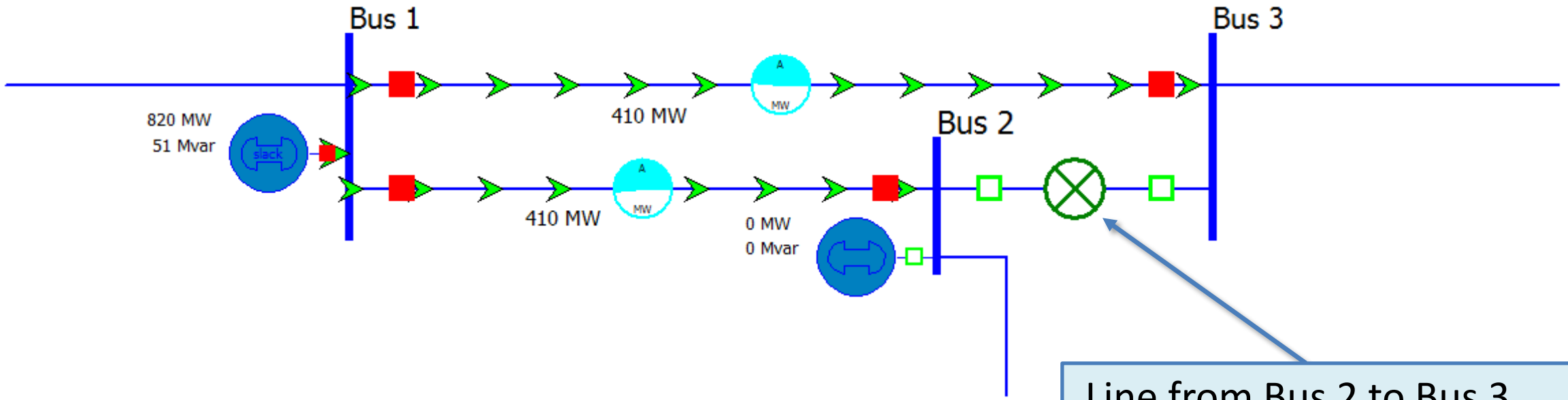
- System Reconfiguration
- Transaction Curtailments
- Generation Re-Dispatch

EMS Identifies a Potential Problem

PJM EMS does *"What If" analysis*



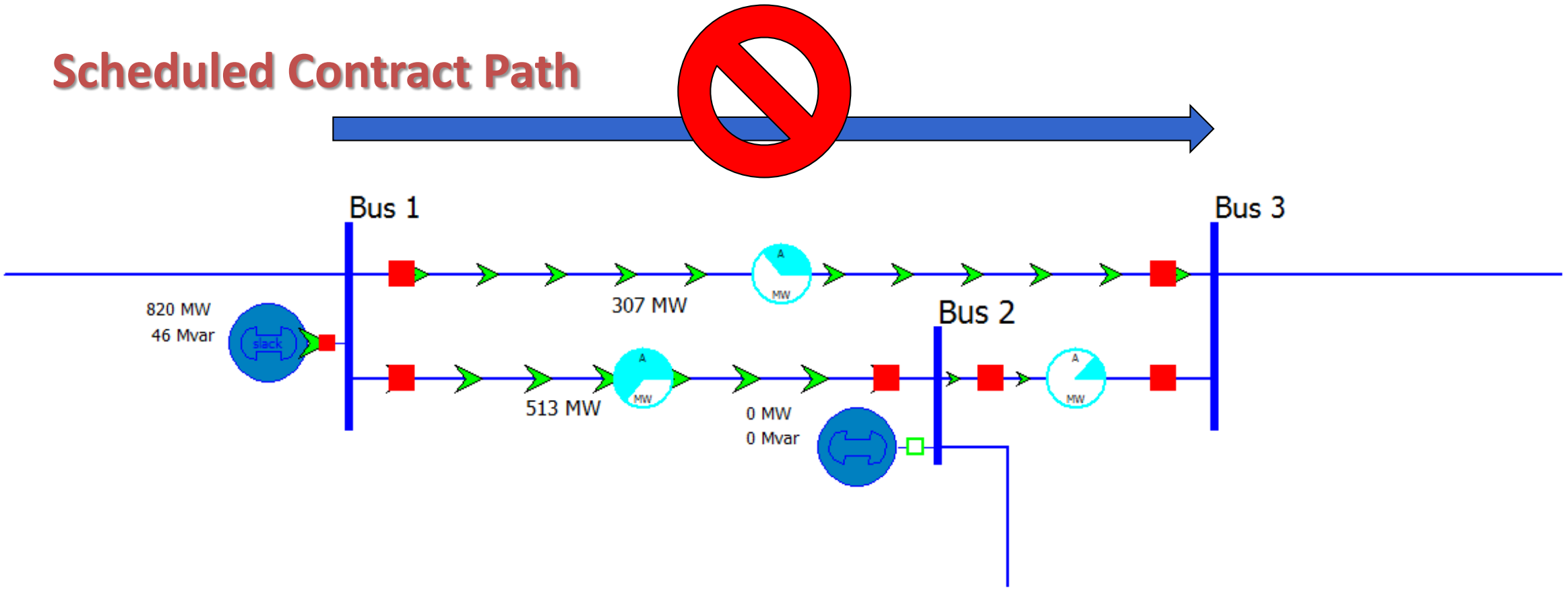
System Reconfiguration



Line from Bus 2 to Bus 3 switched out to prevent overload

Contract Curtailments

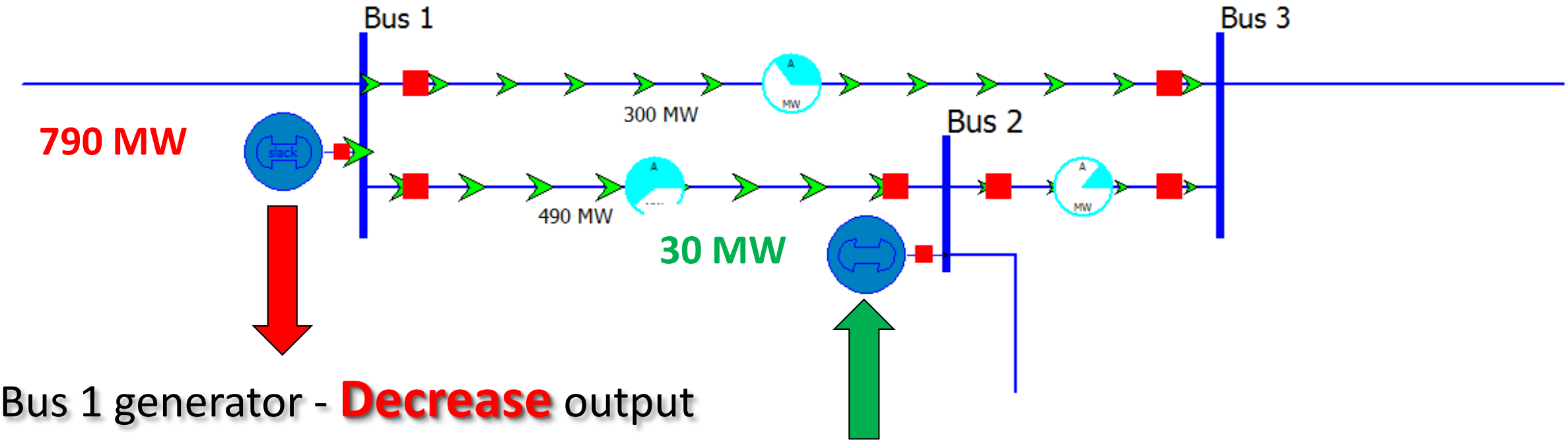
Scheduled Contract Path



Curtailing contract could fix problem……

Generation Re-Dispatch

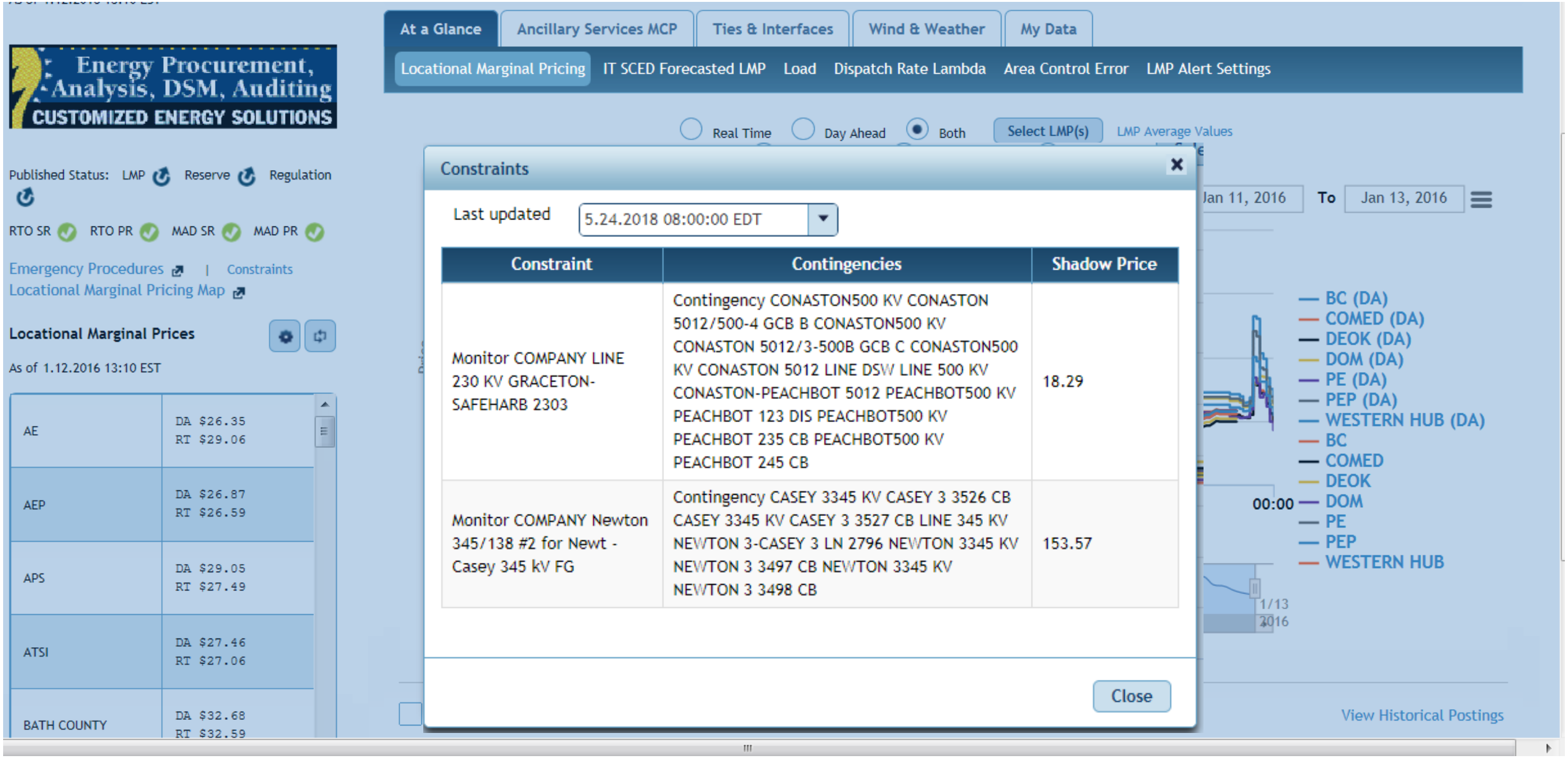
Total Supply = Demand = 820 MW



Bus 1 generator - **Decrease** output

Bus 2 generator - **Increase** output

Viewing Constraints – Data Viewer



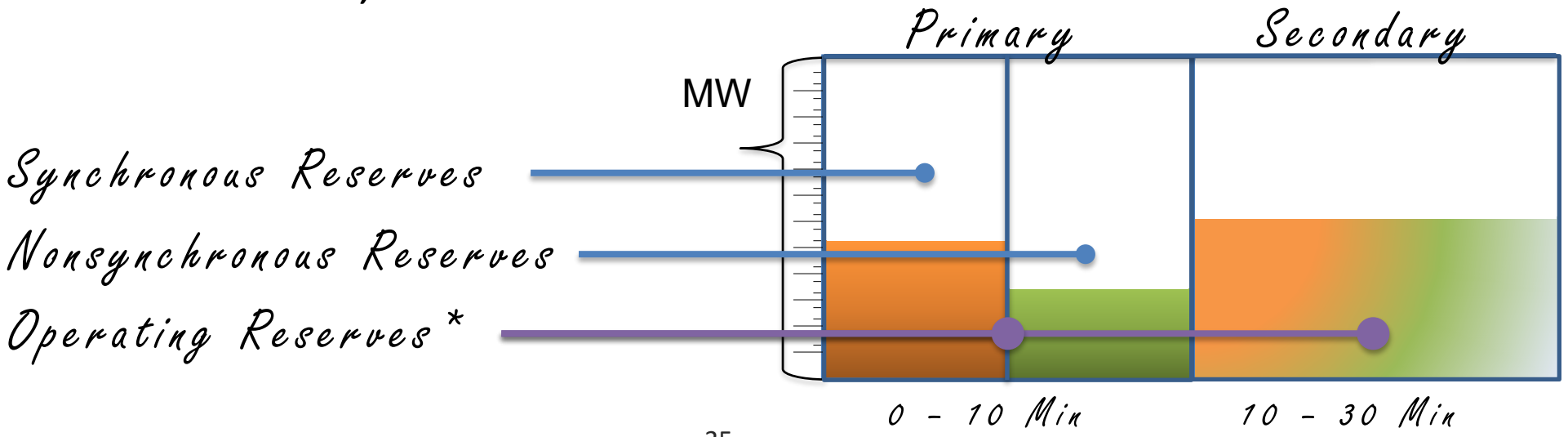
Reserves Overview

What are Reserves?

- Reserves are additional generation capacity above the expected load
  - Protects the power system against the uncertain occurrence of future operating events:
    - Loss of generation or load forecasting errors

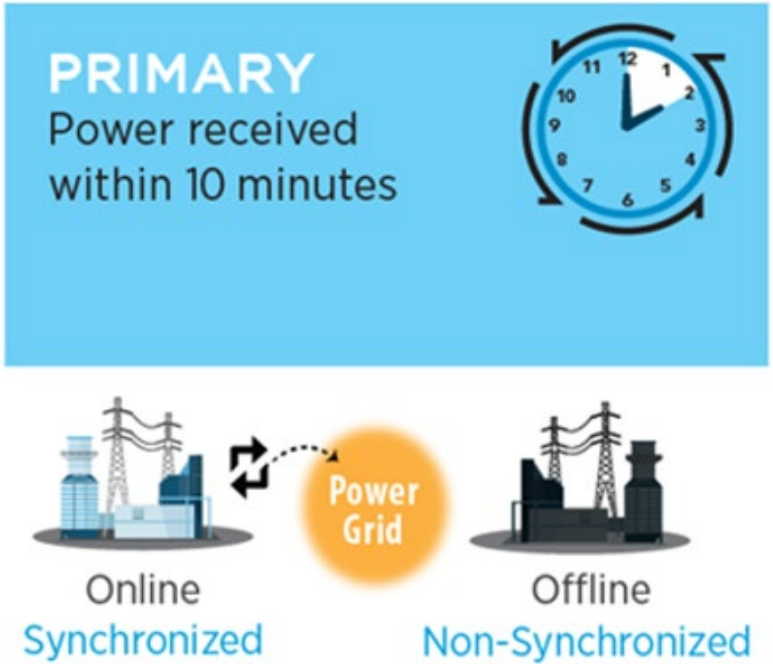
Reserve Monitoring

- Reserves are additional capacity above the expected load
- Used to protect the system against uncertain occurrences
  - Loss of capacity
  - Load forecasting errors
- Compliance with NERC, SERC and RF BAL standards



Primary Reserve

- NERC term is Contingency Reserves
  - On or off-line reserves available within 15 minutes
- **PJM Primary Reserves**
  - Reserves which can be converted fully into energy or;
  - Load that can be removed from the system within 10 minutes of the request from the PJM Dispatcher
- NERC and PJM terms are interchangeable
- Primary (Contingency) Reserves are subdivided two categories:
  - Synchronized Reserves
  - Non- Synchronized (Quick Start) Reserves



Synchronized Reserves

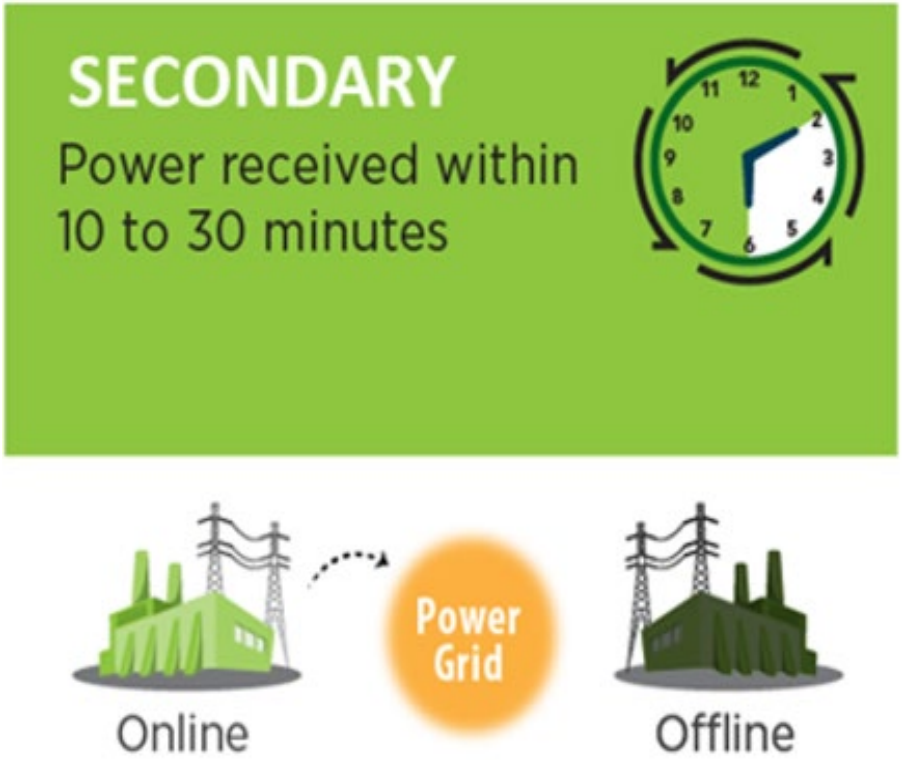
- Reserve converted fully into energy or load removed from the system within 10 minutes of the request
- Must be provided by equipment electrically synchronized to the system
- Includes:
  - increase in the output of a synchronized generator
  - reduction in load from a synchronized resource such as the load of a pumped hydro resource currently synchronized in the pumping mode and capable of being shut down
  - the maximum output energy level that could be attained on a resource operating as a synchronous condenser

Quick Start (non-synchronized) Reserves

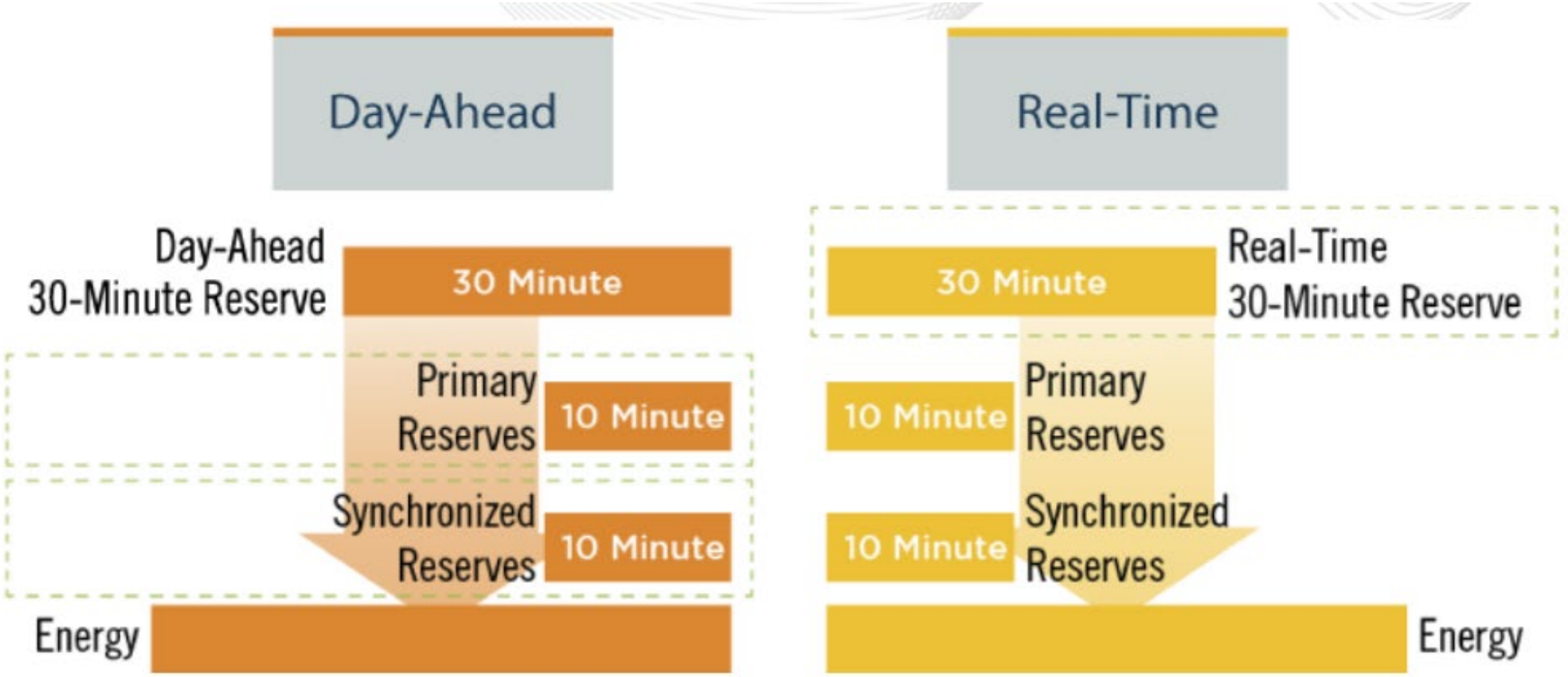
- Reserve fully converted into energy or load removed from the system within 10 minutes of the request
- Provided by equipment not electrically synchronized to the system
- Examples:
    - run-of-river hydro
    - pumped hydro
    - industrial combustion turbines, jet engine/expander turbines
    - Diesels

Secondary Reserve

- Reserve capability converted into energy or load removed from the system within a 10-to-30 minute timeframe
- These resources do not have to be electrically synchronized to the system



Day-Ahead and Real-Time Reserve Alignment



Solidify financial incentives to provide reserves when assigned due to day-ahead financial commitment.
Remove modeling differences between Day-Ahead and Real-Time Energy Markets.

Questions?

PJM Client Management & Services

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Toll Free Telephone: (866) 400-8980

Website: www.pjm.com

The Member Community is PJM's self-service portal for members to search for answers to their questions or to track and/or open cases with Client Management & Services