Power Systems Fundamentals

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New York Market Orientation Course (NYMOC)

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Rensselaer, NY

Session Objectives

- At the end of this session attendees will be able to
  - Understand the Fundamentals of the New York Control Area (NYCA) Power System
  - Identify the Physical Components of the New York Control Area (NYCA) Power System
  - Explain the Purpose behind Operational Ancillary Services

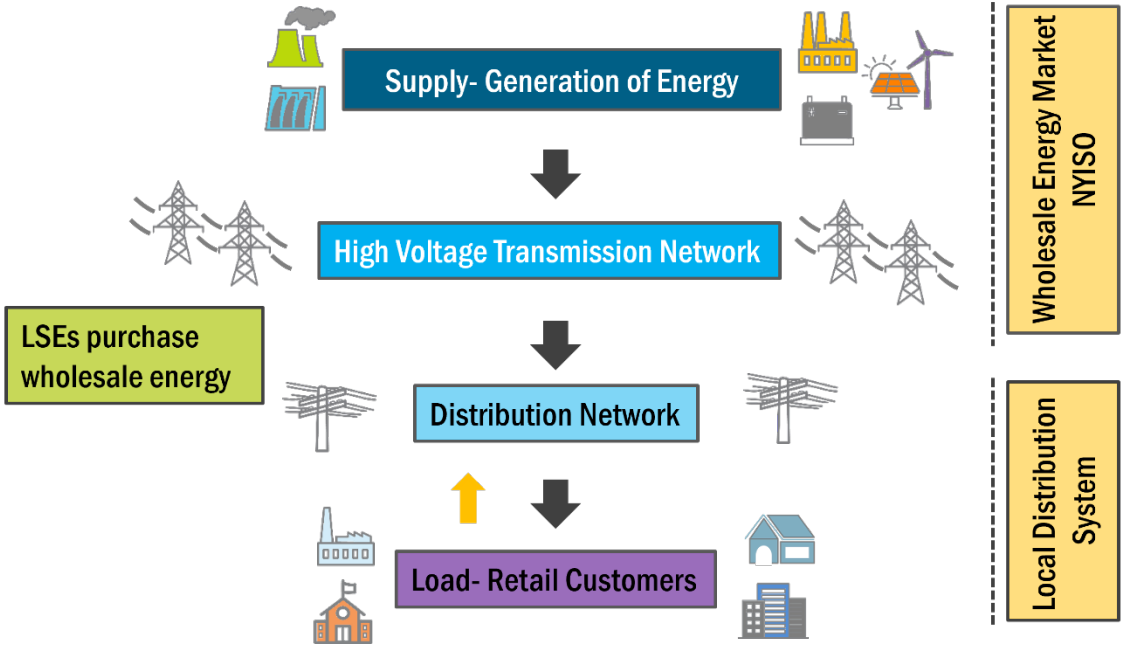
Fundamentals

NYCA Power System

- Fundamentals
  - Bulk Power vs. Retail Load Distribution
  - NYCA Zones
  - Neighboring Control Areas

Bulk Power vs. Load Distribution

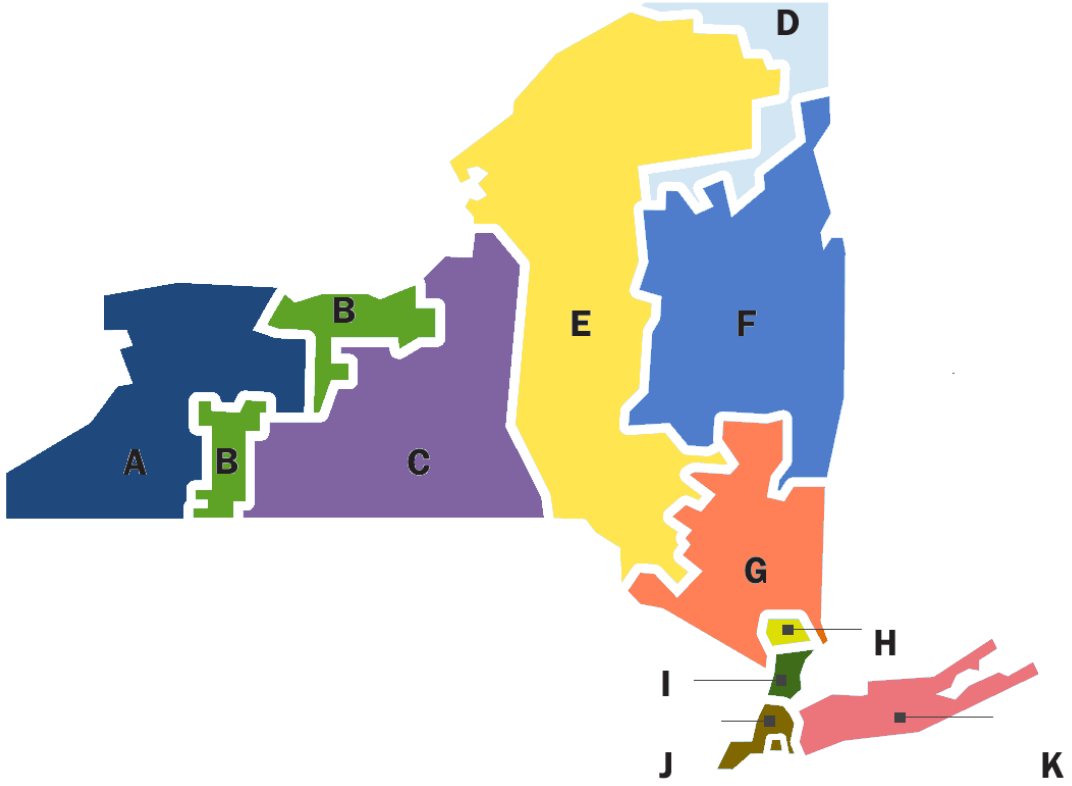
- **Bulk Power Transmission**
  - NYISO is responsible for controlling the transmission of power across the high-voltage transmission network, which is maintained by the Transmission Owners
- **Distribution System**
  - Transmission Owners are responsible for distributing power across the lower voltage transmission network to consumers
- **Management of Retail Load Consumption**
  - Load Serving Entities (LSEs) buy power at the wholesale level to sell to consumers at the retail level



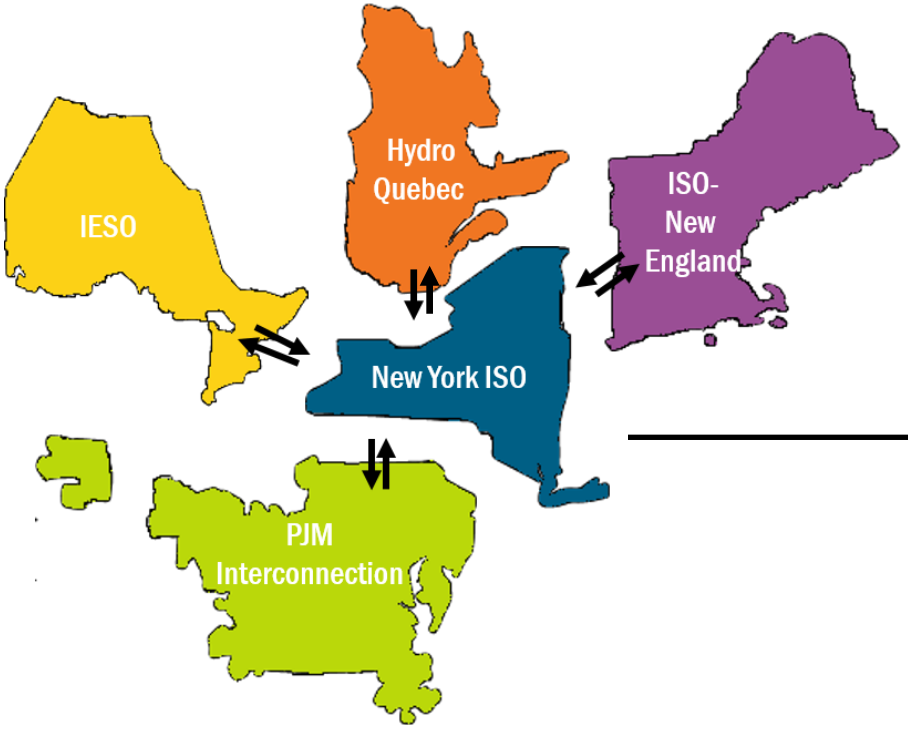
New York Control Area Load Zones

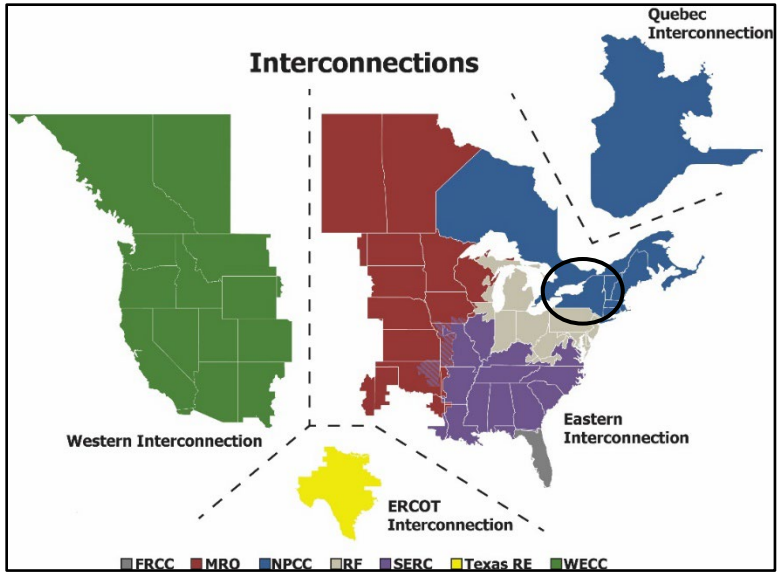
NY Load Zones

A- West
B- Genesee
C- Central
D- North
E- Mohawk Valley
F- Capital
G- Hudson Valley
H- Millwood
I- Dunwoodie
J- NYC
K- Long Island



Neighboring Control Areas

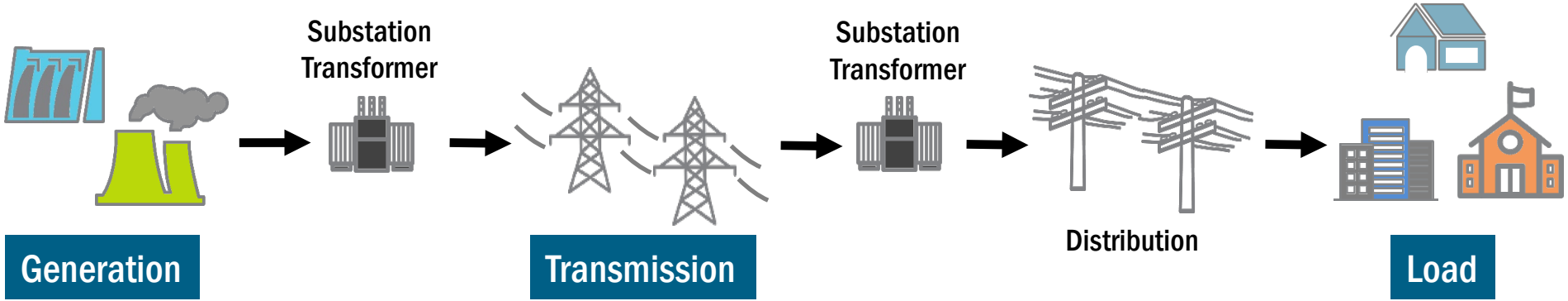




Physical Components of the NYCA Power System

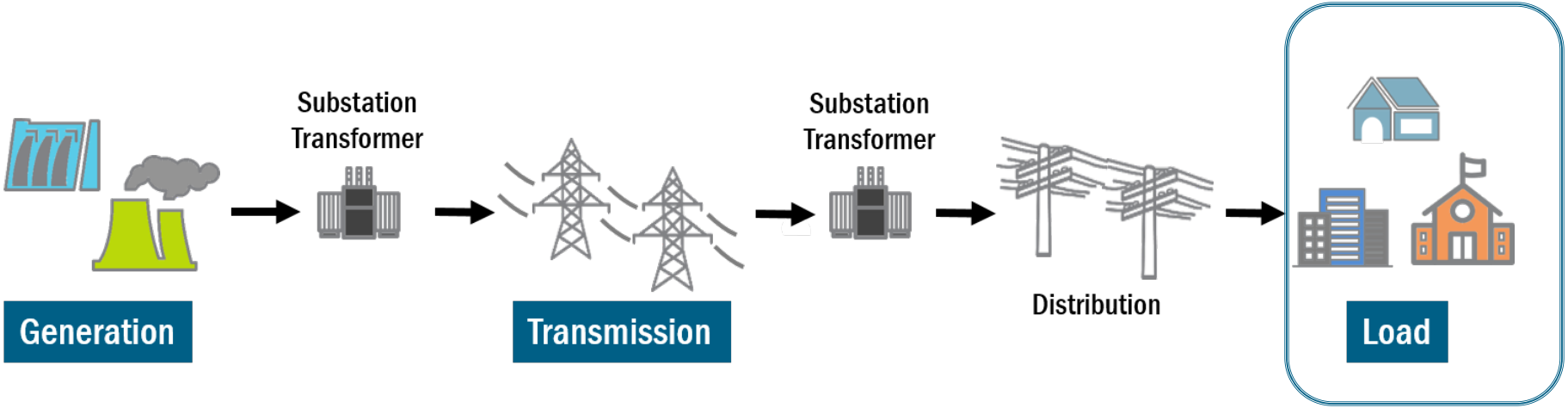
Physical Components of NYCA Power System

- Load
- Generation
- Transmission

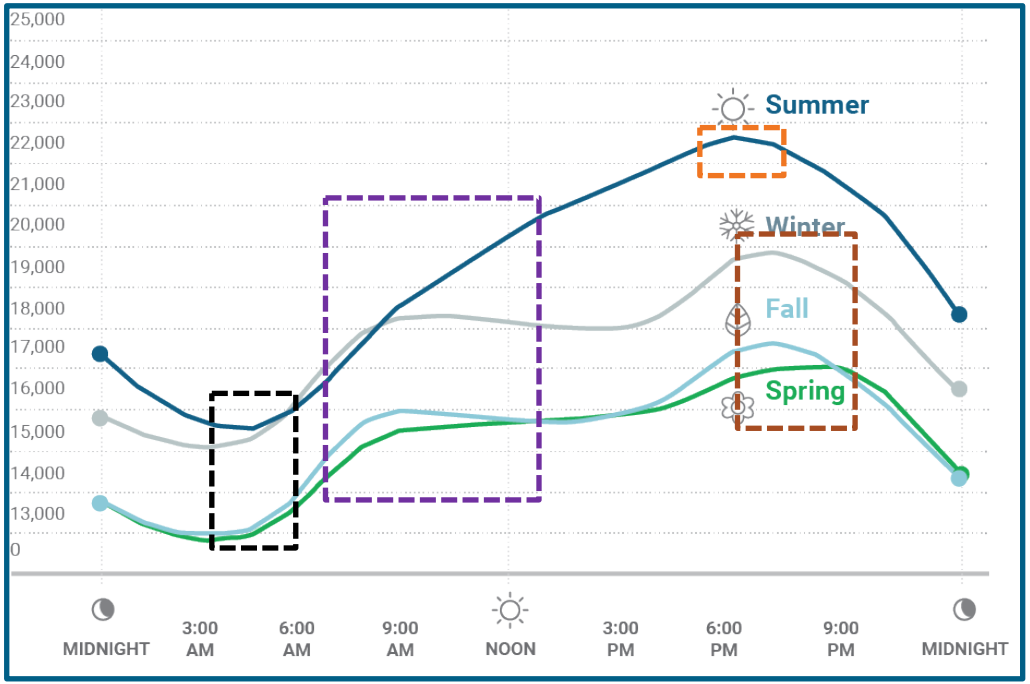


Load

- Power Consumed off NYCA Grid



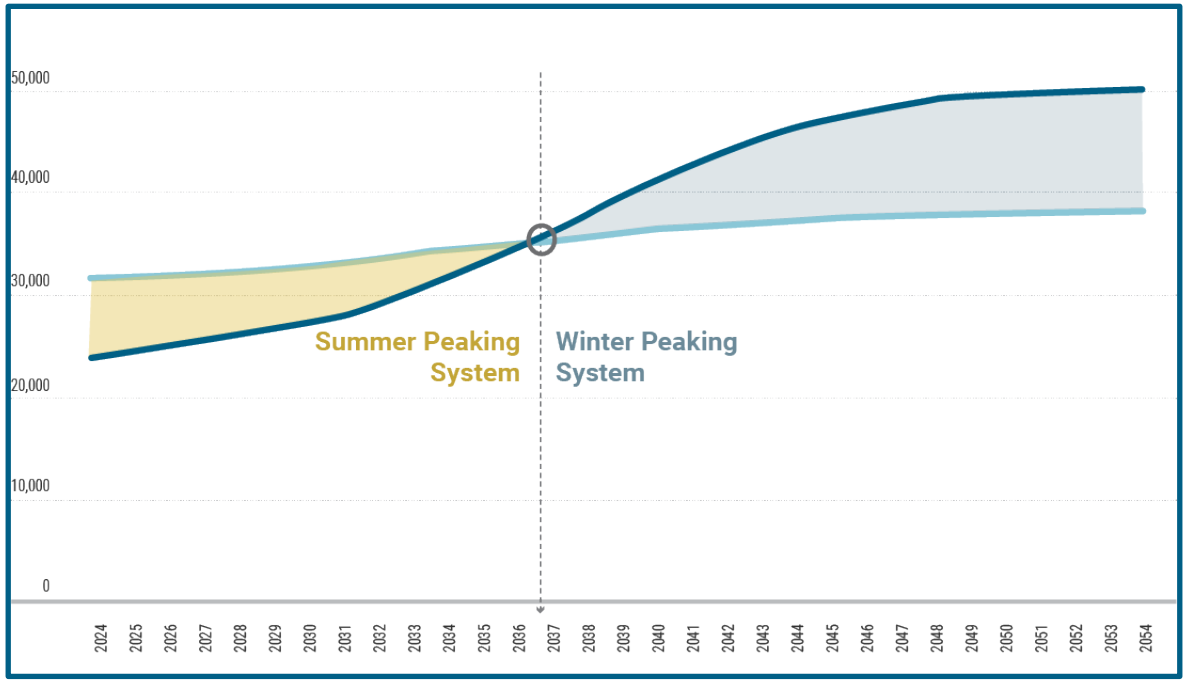
Illustrative NYCA Load Profile – Seasonal and Hourly



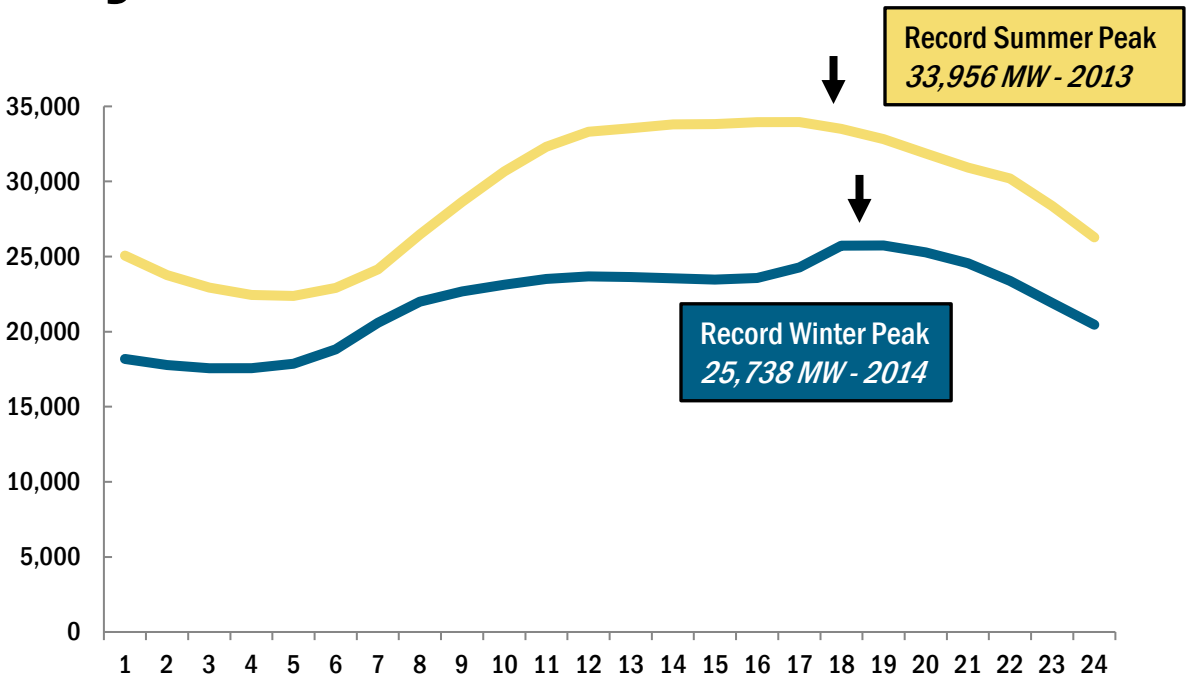
- Low Points
- Morning Pickup
- Summer Peak
- Fall/Winter /Spring Peak

***Seasonal Hourly Demand Patterns, Power Trends 2022

NYCA Load Profile: Projections

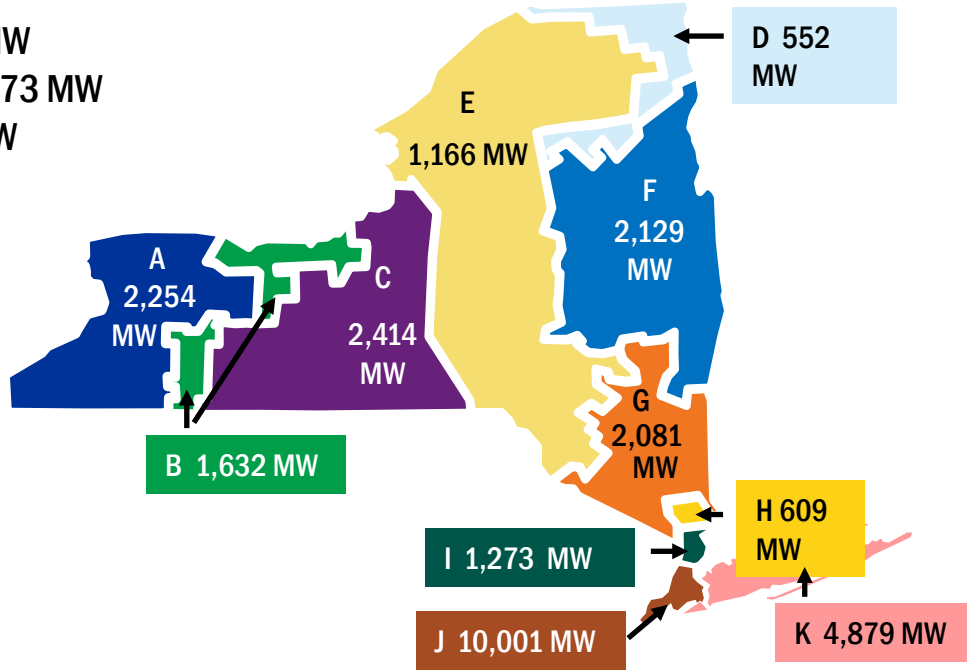


NYCA Load Profile – Historical Record Peak Days



Load Profile by NYCA Zones

Total Load = 28,990 MW
Upstate Zones (A-E) = 8017 MW
Downstate Zones (F-K) = 20,973 MW
NYC and LI (J+K) = 14,881 MW



Example Hour:
July 8, 2024
HB 17:00

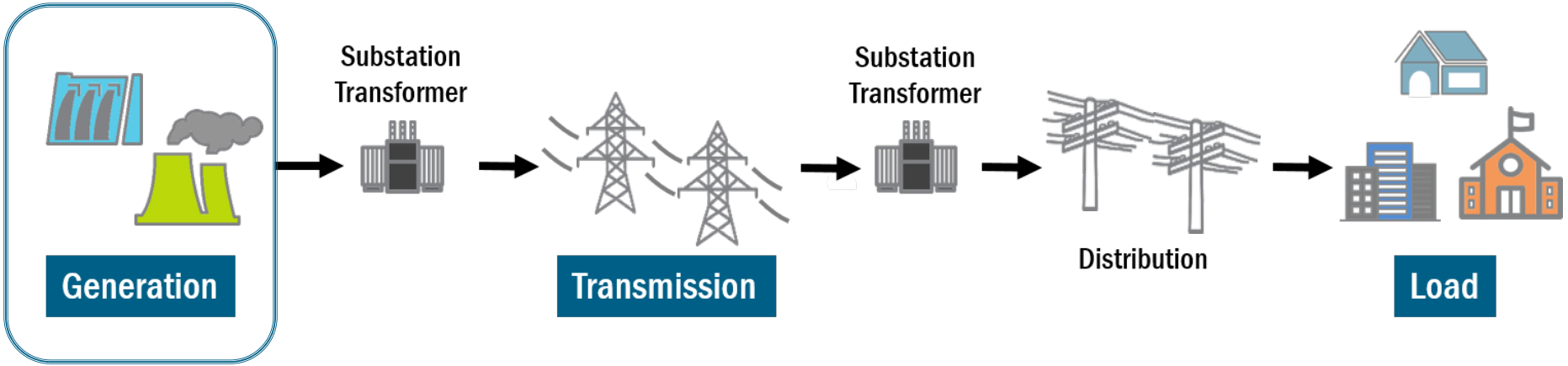
Important Facts

- ~70% of the Load was in Downstate Zones (F-K)
- ~50% of the load located in NYC & LI

* Data from the Actual Load Report from the NYISO website

Generation

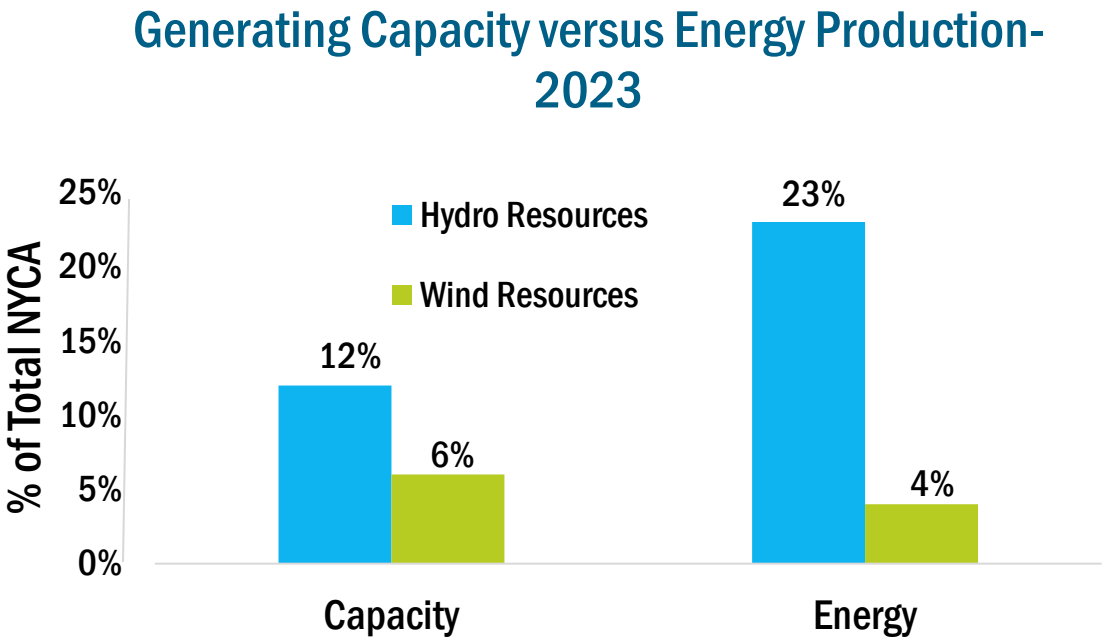
- Electrical energy for load consumption



Capacity vs. Energy

- Two very different commodities
- Capacity – *measured in MW*
  - Refers to the electric power output for which a generating system, plant, or unit is rated
- Energy – *measured in MWh*
  - Is the amount of energy produced (from capacity) over time

Generating Capacity versus Energy

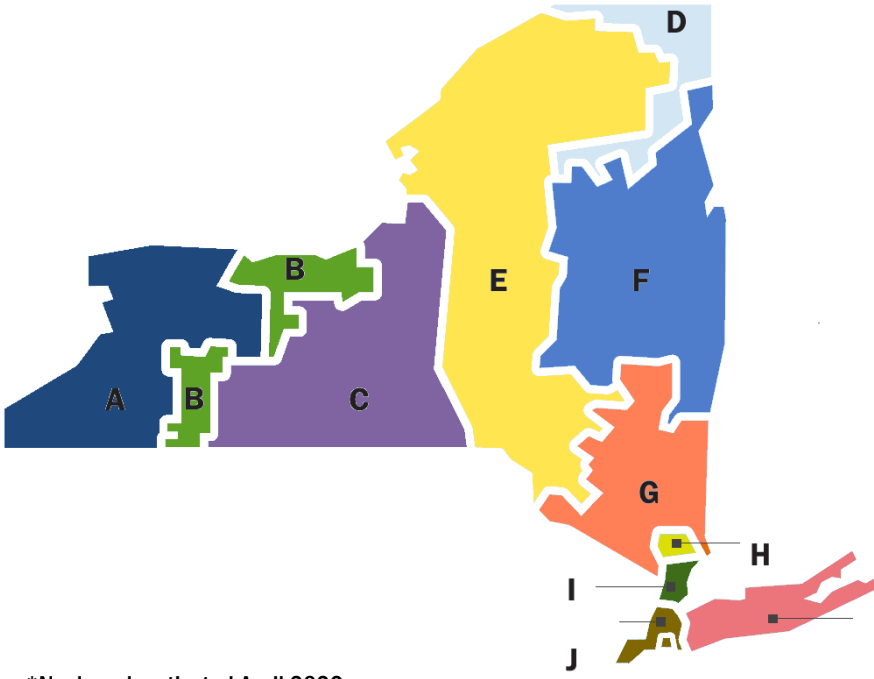


The conversion of maximum generation potential (Capacity) to actual generation (Energy) differs from one Resource type to another

NYS Major Generation

Nameplate Capacity for Summer, 2022 Load and Capacity Data Report

Zones	Major Generation Capacity Examples
Zone A - West	Dual Fuel, Hydro, Wind
Zone B - Genesee	Nuclear
Zone C - Central	Dual Fuel, Nuclear, Wind
Zone D - North	Hydro, Wind
Zone E – Mohawk Valley	Hydro, Wind
Zone F – Capital	Dual Fuel, Pumped Storage, Hydro
Zone G – Hudson Valley	Dual Fuel, Gas
Zone H – Millwood Valley*	Steam Turbine
Zone I - Dunwoodie	No generation
Zone J - NYC	Dual Fuel, Gas, Oil
Zone K – Long Island	Dual Fuel, Oil



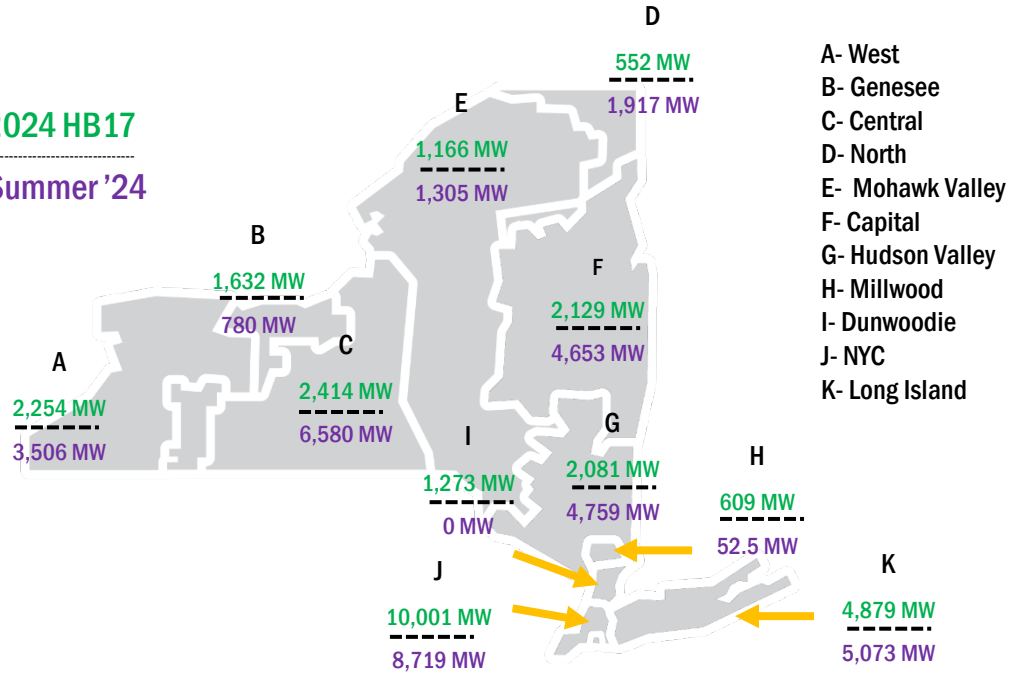
*Nuclear deactivated April 2022

NYCA Load vs. Generation

Representative day

LOAD 07/08/2024 HB17

GEN CAPACITY Summer '24



A- West
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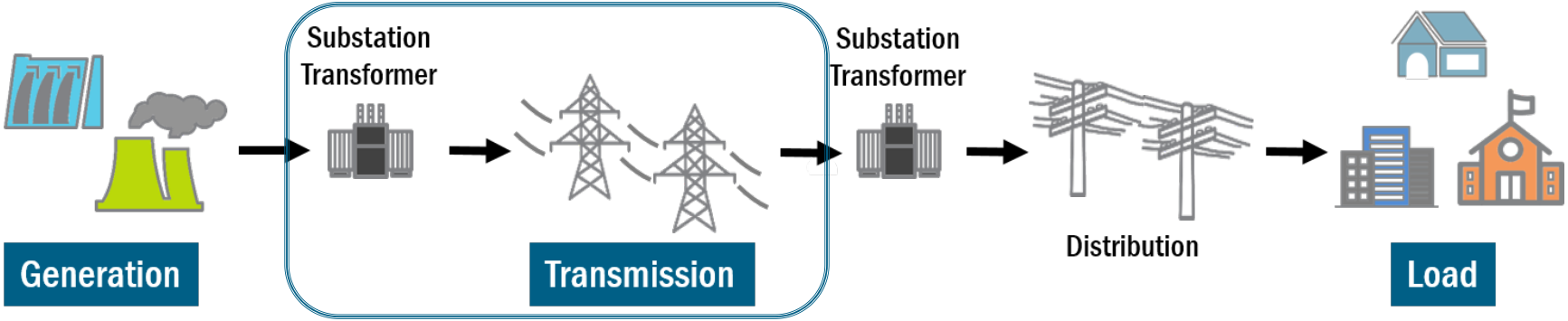
Total Generation Capacity for Summer 2024: 37,375 MW

*Load data from the Actual Load Report from the NYISO website
Gen Capacity data from the Load and Capacity data Report 2024

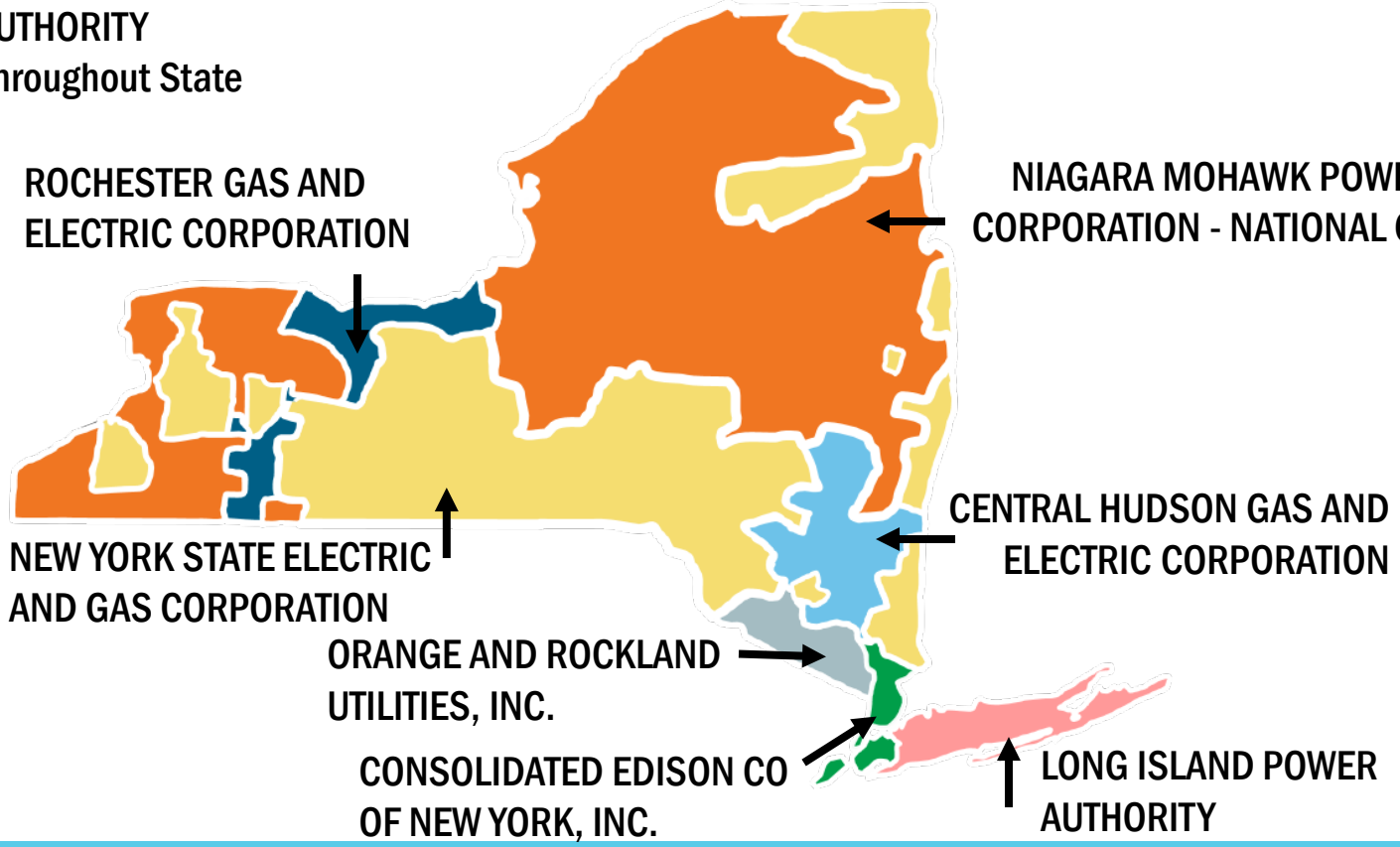
Transmission

- Bulk transfer of electrical energy



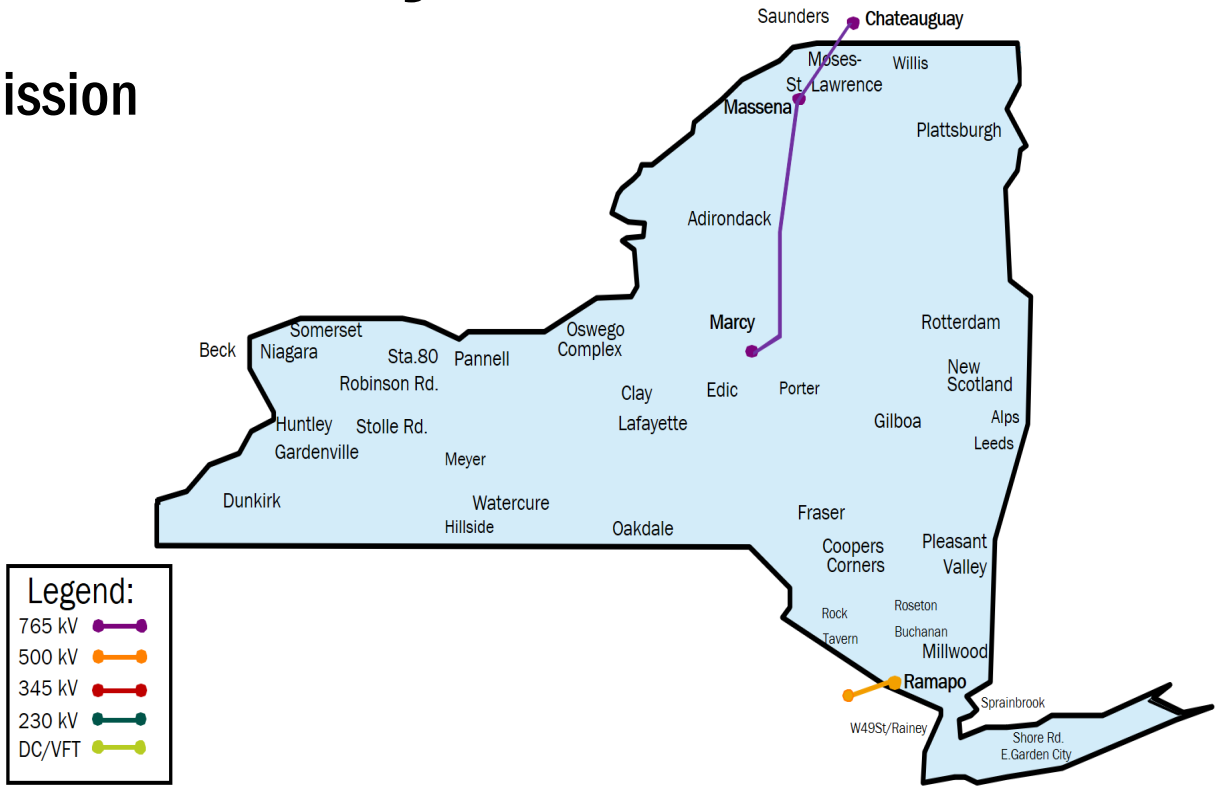
NYCA Transmission Owners

NEW YORK POWER AUTHORITY
Transmission Lines Throughout State



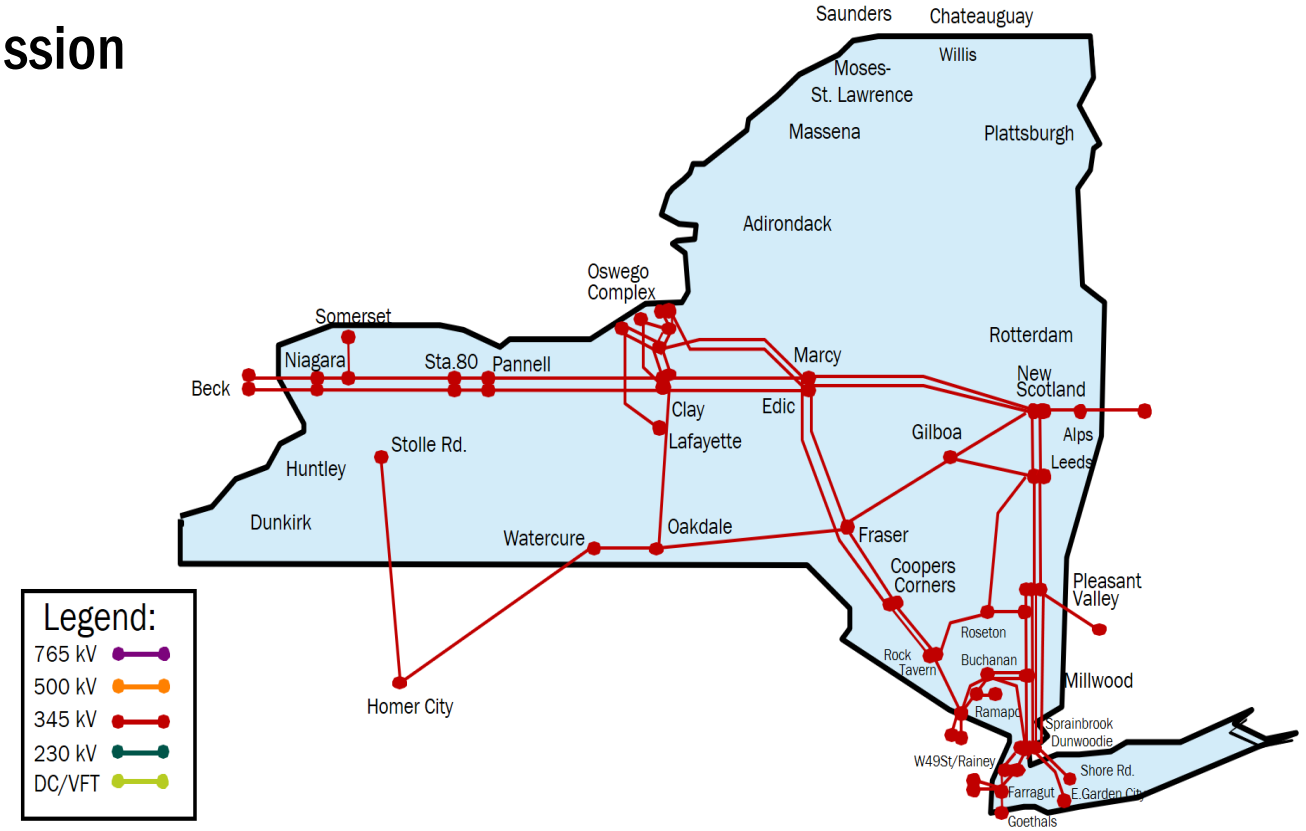
NYCA Transmission System

765/500 kV Transmission



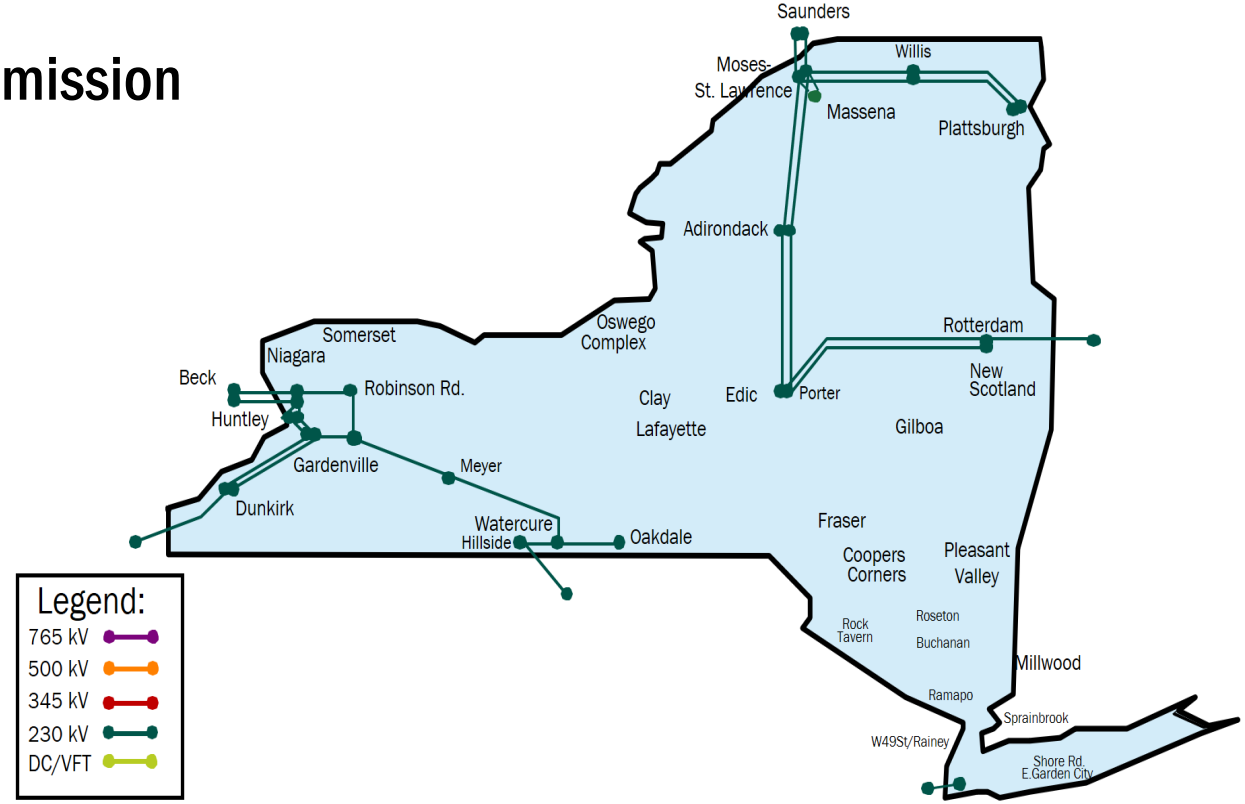
NYCA Transmission System

345 kV Transmission

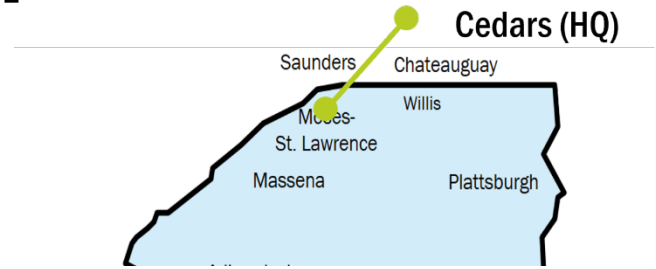


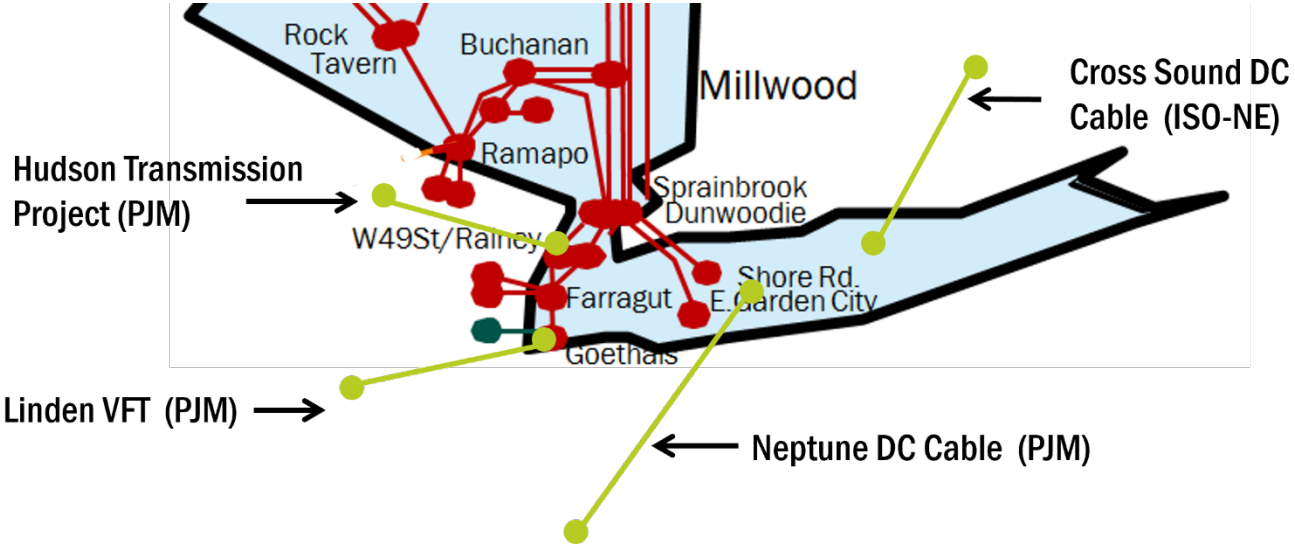
NYCA Transmission System

230 kV Transmission



DC/VFT Transmission

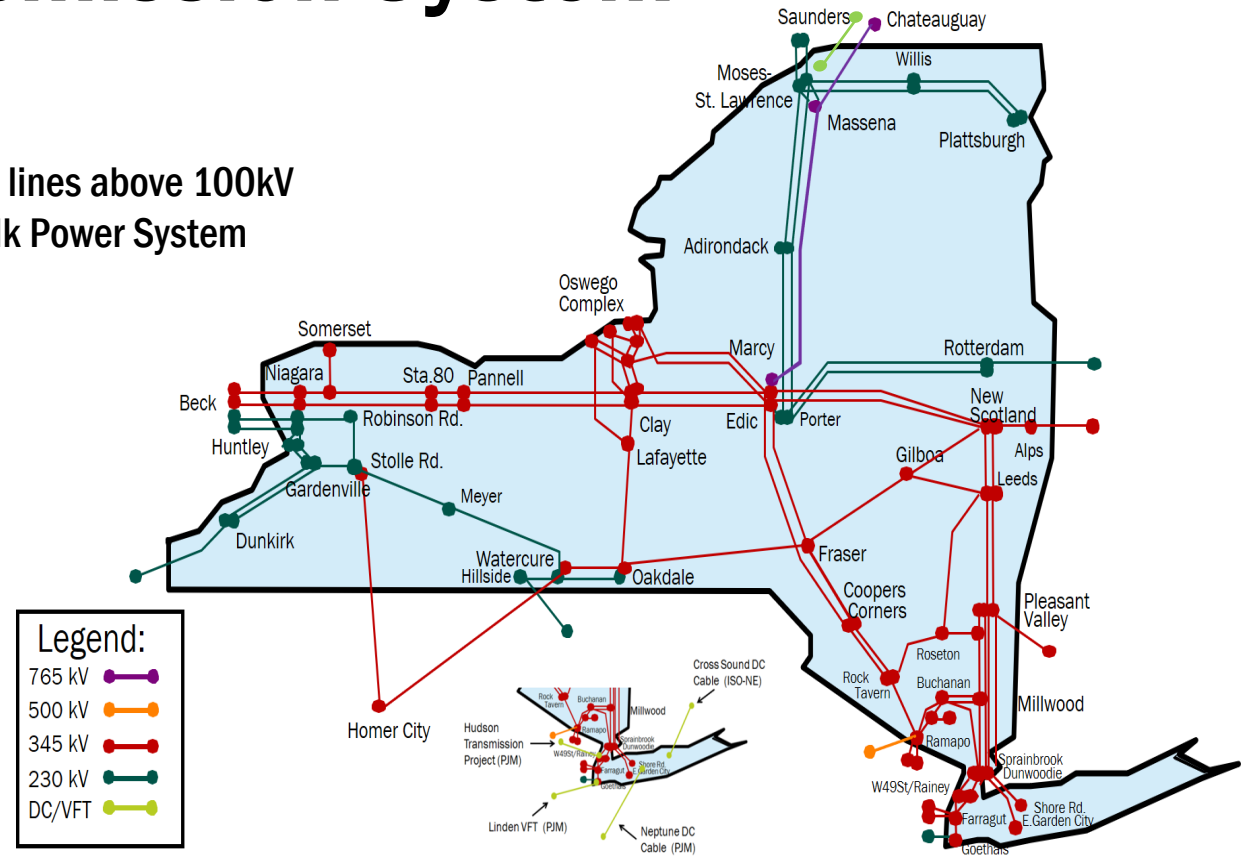




NYCA Transmission System

Bulk Transmission

Note: Generally, transmission lines above 100kV are considered part of the Bulk Power System

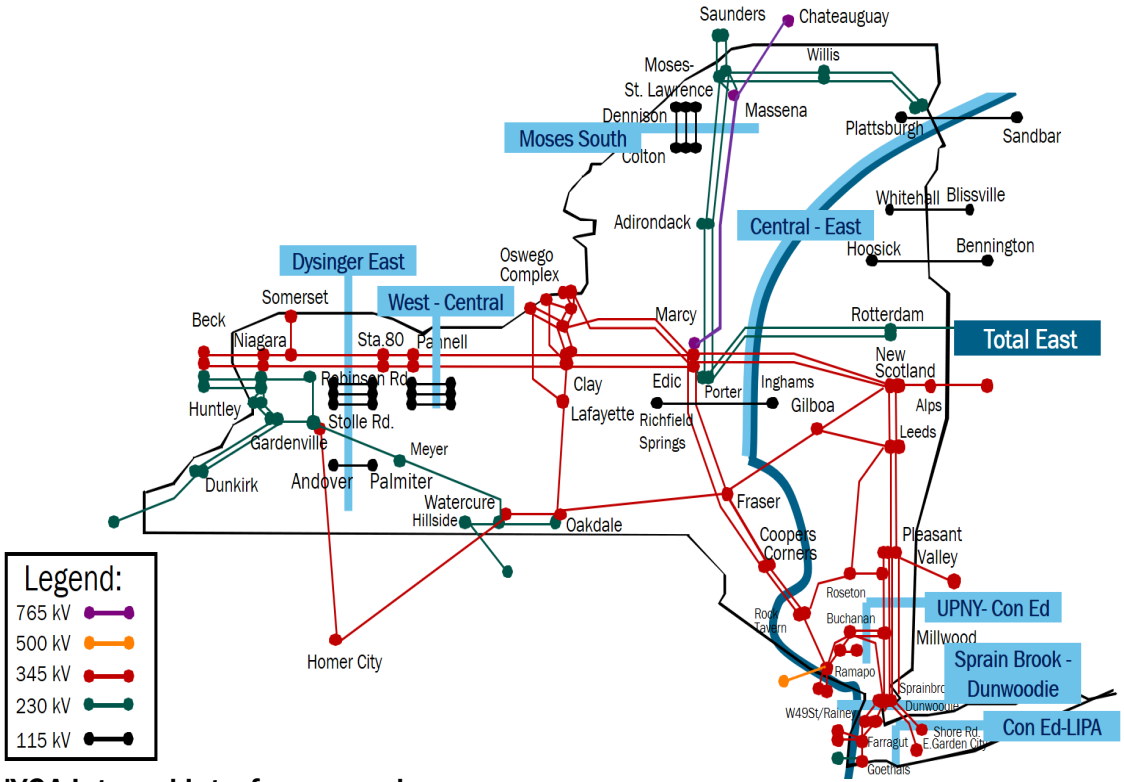


Transmission Interfaces

- Definition of Interface
  - A defined set of transmission facilities that separate Load Zones and that separate the NYCA from the adjacent Control Areas
- Internal Interface
  - Obey transfer limitations across the internal interface to deliver generation to load within NYCA
- External Interface
  - Comply with transfer limitations across the external interface to import or export scheduled power transactions between RTO/ISOs

NY Internal Transmission Interfaces

- Multiple transmission lines make up an interface
- Interface limits can create constraints on the flow of power
- Some interfaces are more impacting on the flow of power



* Not all NYCA internal interfaces are shown

Interface Transfer Limits

- Transfer limits create constraints on the flow of energy
- Types of Transfer Limits
  - Thermal Limits – Summer and Winter Ratings
  - Voltage Limits – Varies on equipment in-service
  - Stability Limits – Varies on lines in-service or load on selected lines

Interface Transfer Limits

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Total Transfer Capability = Min(Thermal Limit, Voltage Limit, Stability Limit)

- Real time transfer limits vary with system conditions and are posted at the 5-minute level, both positive and negative limits

Operational Ancillary Services

Operational Ancillary Services

- Purpose Behind
- Voltage Support Service
  - Regulation & Frequency Control
  - Operating Reserves
  - Black Start Service

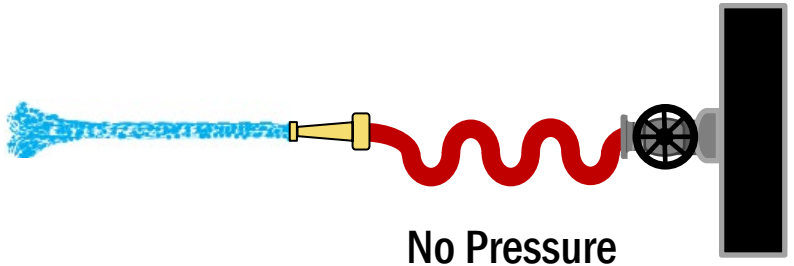
Voltage Support Service

Garden Hose: Transmission cable
Water flowing through hose: Electrical current flow
Water pressure: Voltage

↓ Water Pressure → ↓ Water flow

↓ Voltage → ↓ Electrical current flow

Water Pressure Analogy



No Pressure
No Flow

- **Voltage Support is needed to:**
  - Transfer power from the generation to the load
  - Prevent equipment damage from high voltages
  - Prevent voltage collapse during high load periods

Voltage Support Service

- Voltage and Reactive Power
  - VAR = Volt-Amperes Reactive = Reactive Power
  - Reactive Power supports the Voltage that must be controlled within limits for System Reliability
    - Too few VARs, Voltage goes Down
    - Too many VARs, Voltage goes Up
  - Not load; but cannot move WATTs without VARs

Voltage Support Service

- System Voltage Control
  - Voltage Control is a continuous process
  - System Voltage Control provided by the Voltage Support Service is an Optional program in which Generators can participate
    - Generator monitors local voltage
    - Must utilize Automatic Voltage Regulator (AVR)
  - Transmission Owners are responsible for local control within their Network

Voltage Support Service

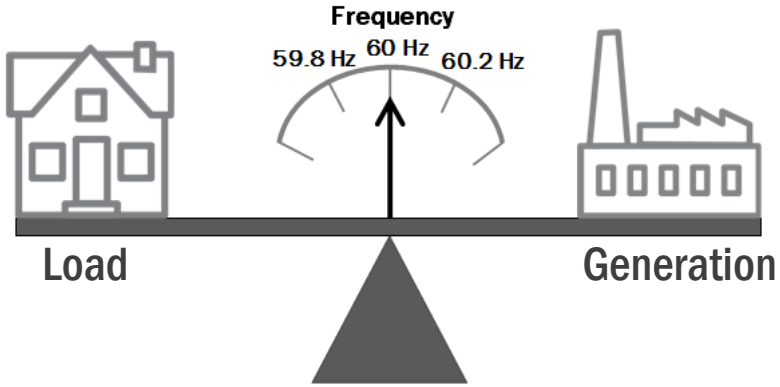
Voltage Support Service Suppliers:

Generators	VAR production and absorption
Synchronous Condenser	VAR production and absorption
Static VAR Compensator	VAR production and absorption
Static Compensators	VAR production and absorption
Shunt Capacitor Banks	VAR production
Shunt Reactor	VAR absorption

Note: Non-Generator VSS suppliers, spread throughout the state as Reactive Power does not travel

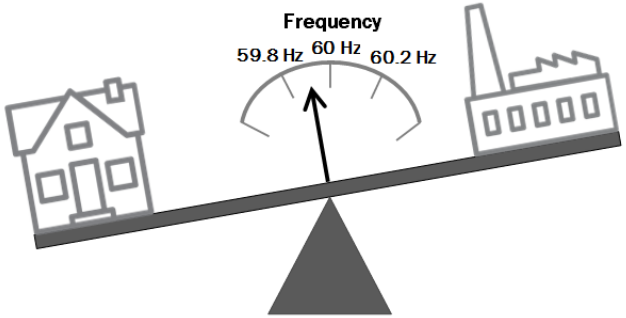
Regulation and Frequency Control

- Control Area Operation
  - Criteria is set forth to instantaneously Balance Load and Generation throughout the Eastern interconnection
    - In order to sustain a 60 Hz Frequency

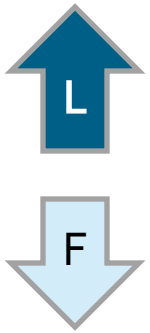


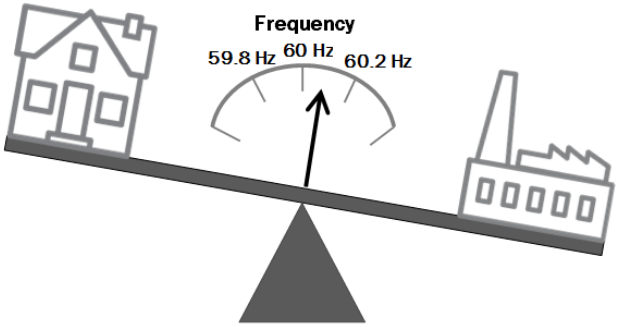
Regulation and Frequency Control

- System Frequency Changes



Load Increases without Generation Increase





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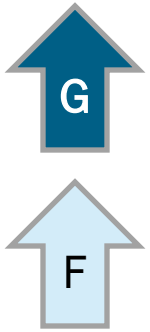
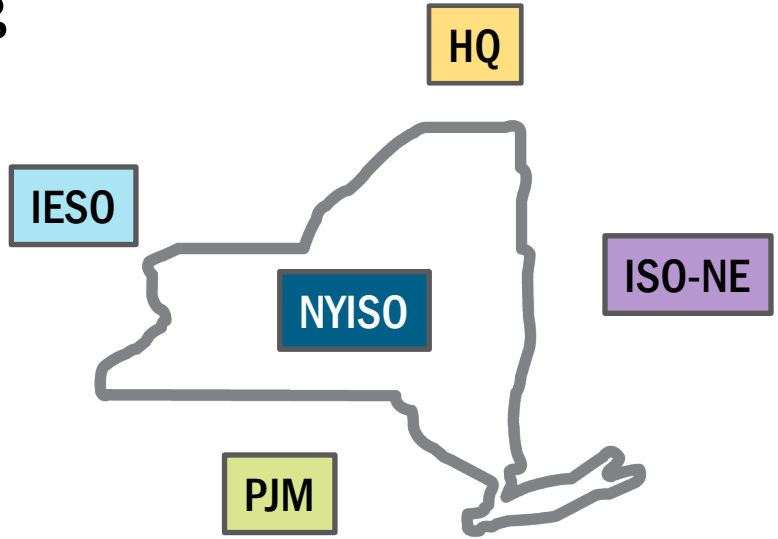


Regulation and Frequency Control

- System Frequency Impacts
  - Industrial & Commercial Equipment Operating at 60 Hz will be impacted
    - Industrial Motors, Refrigerators, Laundry Machines, Clocks, etc.
  - Generator's Rotational Speed is tied to the Frequency of the System
  - Cascading effect to Generation
    - Load continually increasing, Generation trips off-line

Regulation and Frequency Control

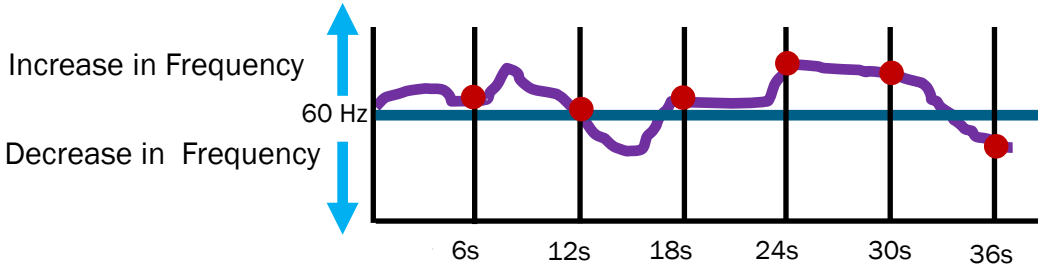
- Areas are controlled by Functional Entities defined by NERC as Balancing Authorities (BA)
- The NYISO is a Balancing Authority



Regulation and Frequency Control

New York ISO

- Area Control Error (ACE)
  - ACE is an error signal related to frequency regulation and interchange scheduling
  - A negative ACE means that the control area is under generating
  - A positive ACE means that the control area is over generating
  - The ACE signal is used to move the regulating units up or down



- RTD Base Load
- 6 second signals for Regulation providers to maintain 60 Hz frequency

Regulation and Frequency Control

- Automatic Generation Control (AGC)
  - Compensates for Over or Under Generation
  - NYISO measurements are gathered every 6 Seconds
  - Automatic control provided by Regulating units (Regulation Service)
    - Regulating units are dispatched every 6 Seconds based on ACE

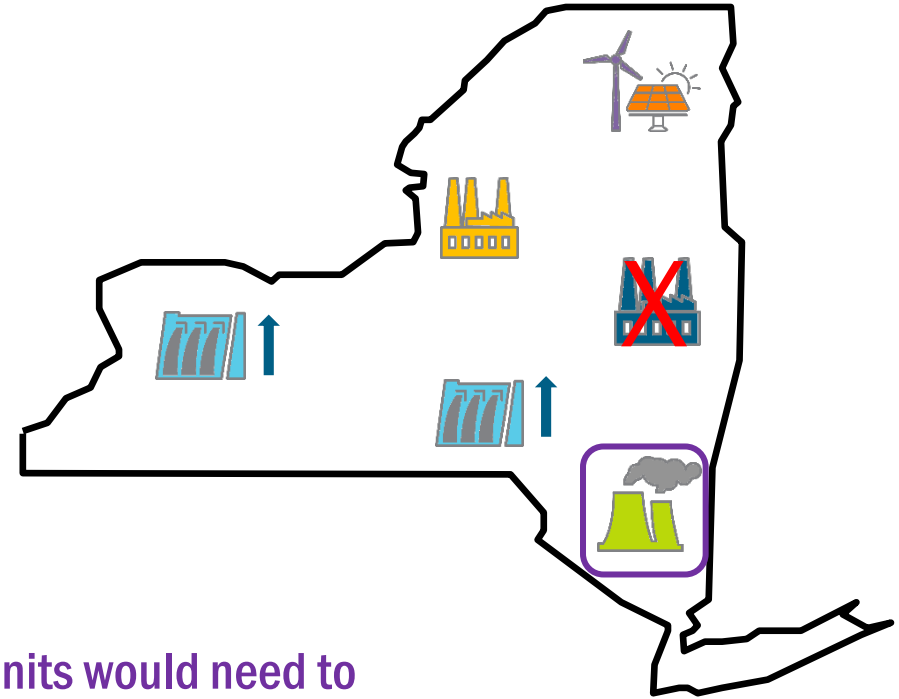
Operating Reserves

- Backup Generation in the event of a System Contingency
  - NYSRC Total Operating Reserve Requirement:
    - Must Procure ≥ to 1.5 x times the Largest Single Contingency (in MW)
      - Largest Single Contingency is 1310 MWs
- NYISO Procures 2 x Largest Single Contingency
  - 2 x 1310 = 2,620 MWs of Total Reserves each Market Day
    - Regional/Locational Requirements
    - Time/Product Type Requirements

Example: Operating Reserve Pickup

1. If there is a large and sudden loss of generation

2. The Operating Reserves being held for the Market Day would be dispatched to make up the shortfall

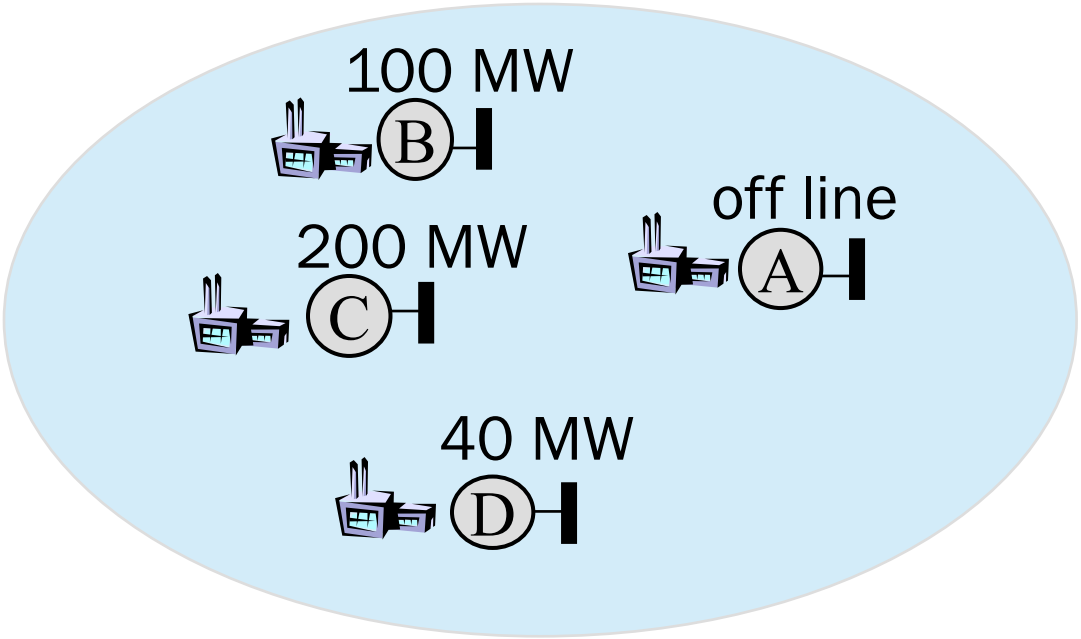


3. New reserve units would need to be selected to maintain Operating Reserves

Operating Reserves

Largest Single Contingency

Q: What is the largest single generation contingency for this system?

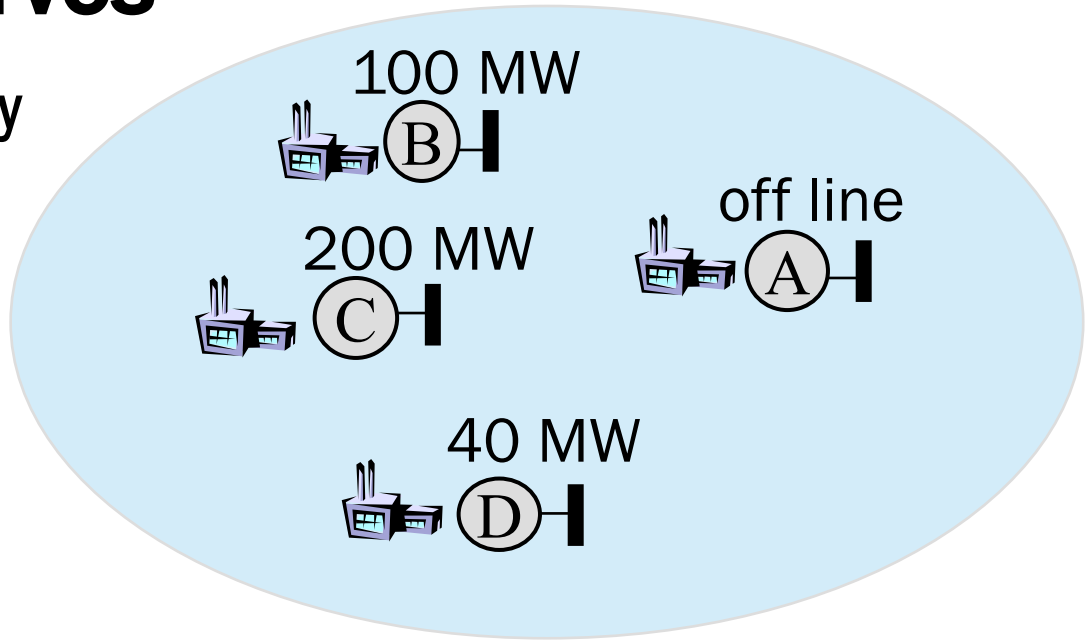


Operating Reserves

Largest Single Contingency

Q: What is the largest single generation contingency for this system?

Q: According to NYISO's Reserves scheduling process, how much in Operating Reserves would be scheduled in this example?



Black Start Service

- Generators capable of starting without an outside electric supply, following a system-wide blackout
- Purpose: System Wide Restoration
- Last time Black Start Service was used:
  - 14 August 2003 – Northeast Blackout

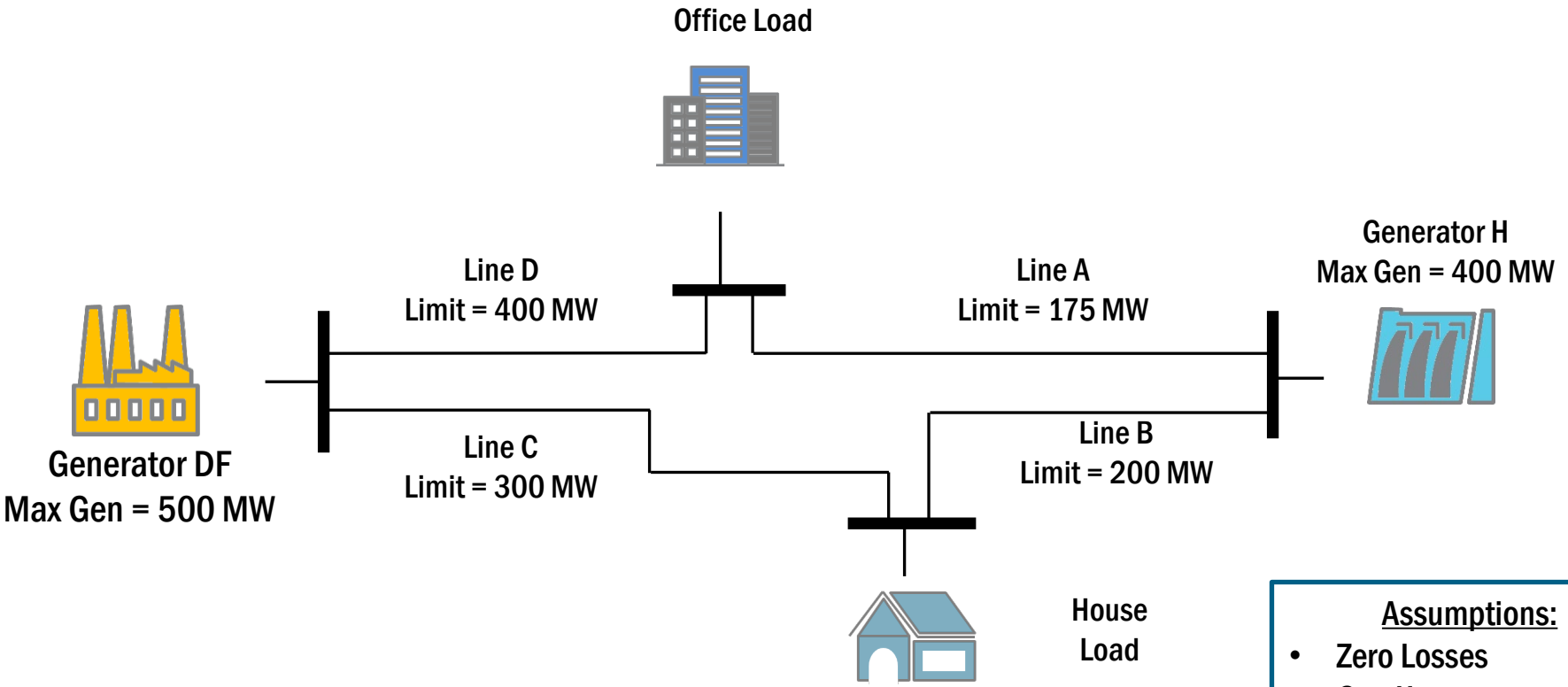
Let's Review

Image provided by 'The Extend Activity Bank
https://extend-bank.ecampusontario.ca/

‘Putting it all Together’

- The following is an *Exercise* in Maintaining Reliable Operations of a Simplified NYCA Power System
- It Highlights:
  - The Principles Driving Generation Dispatch
  - Factors Affecting Transmission System Limitations
  - The Criteria for a Reliable Operating Scenario
  - The Impact of Contingencies

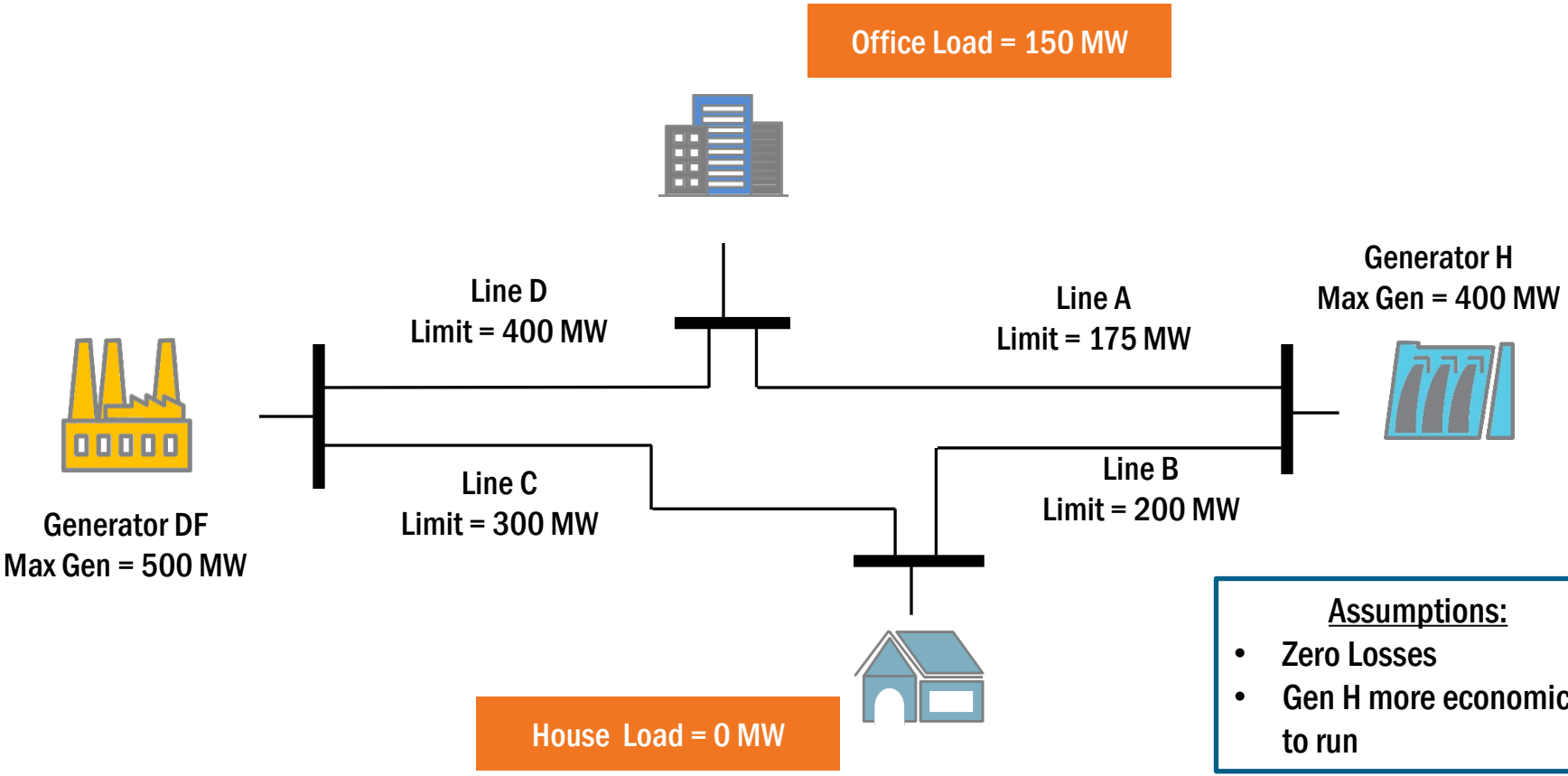
Simple Power System Analysis



Assumptions:

- Zero Losses
- Gen H more economical to run

1. Scenario: Generation Load Balance



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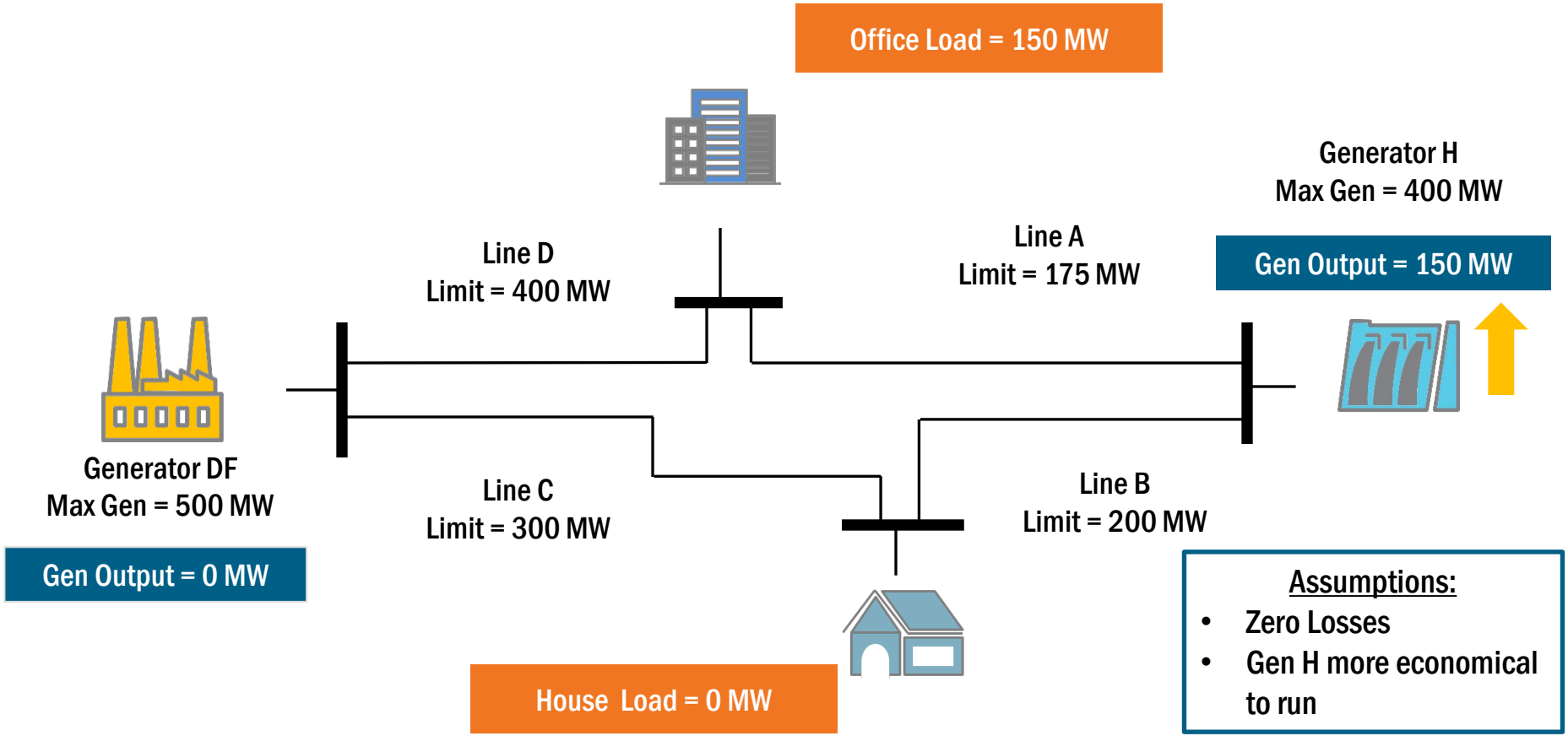

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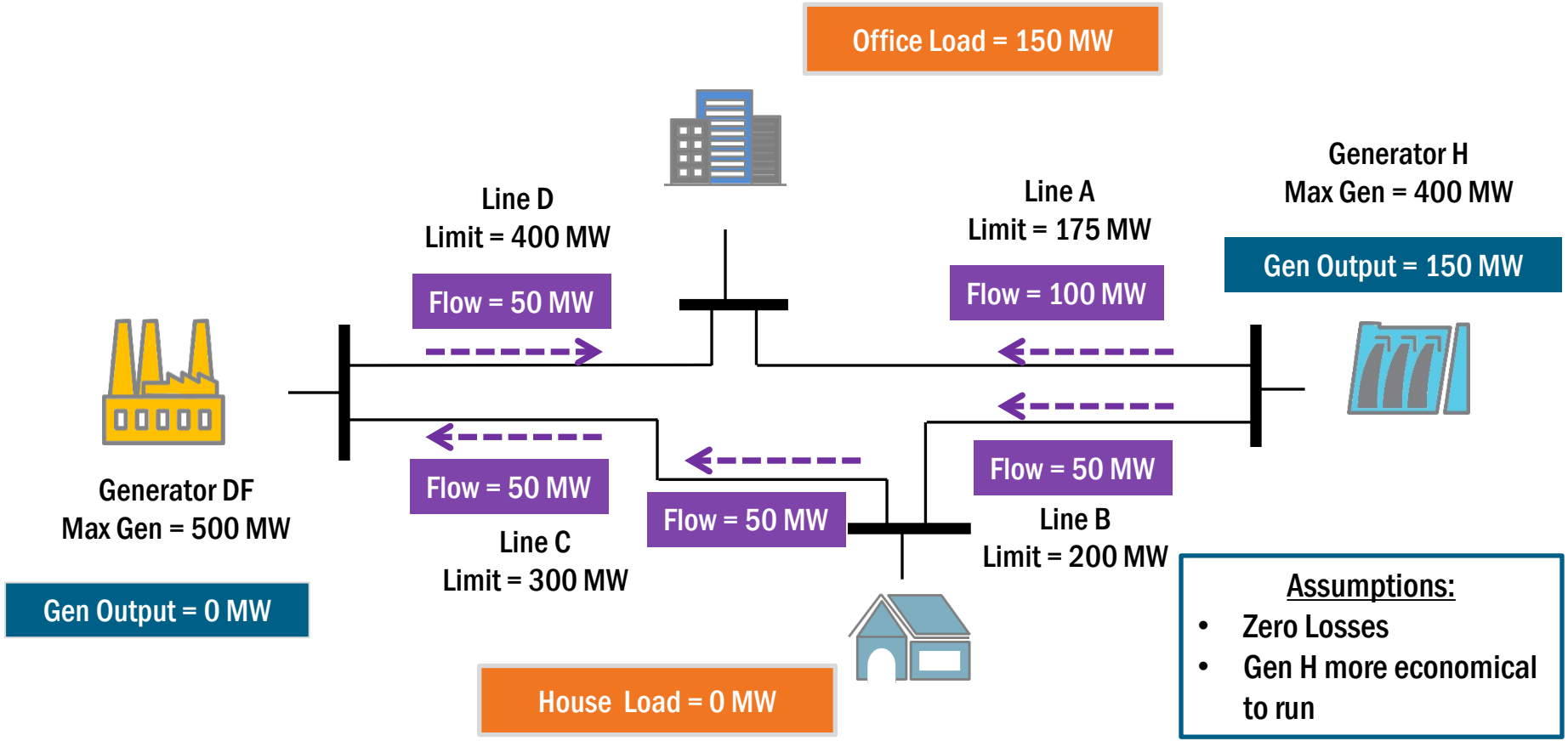
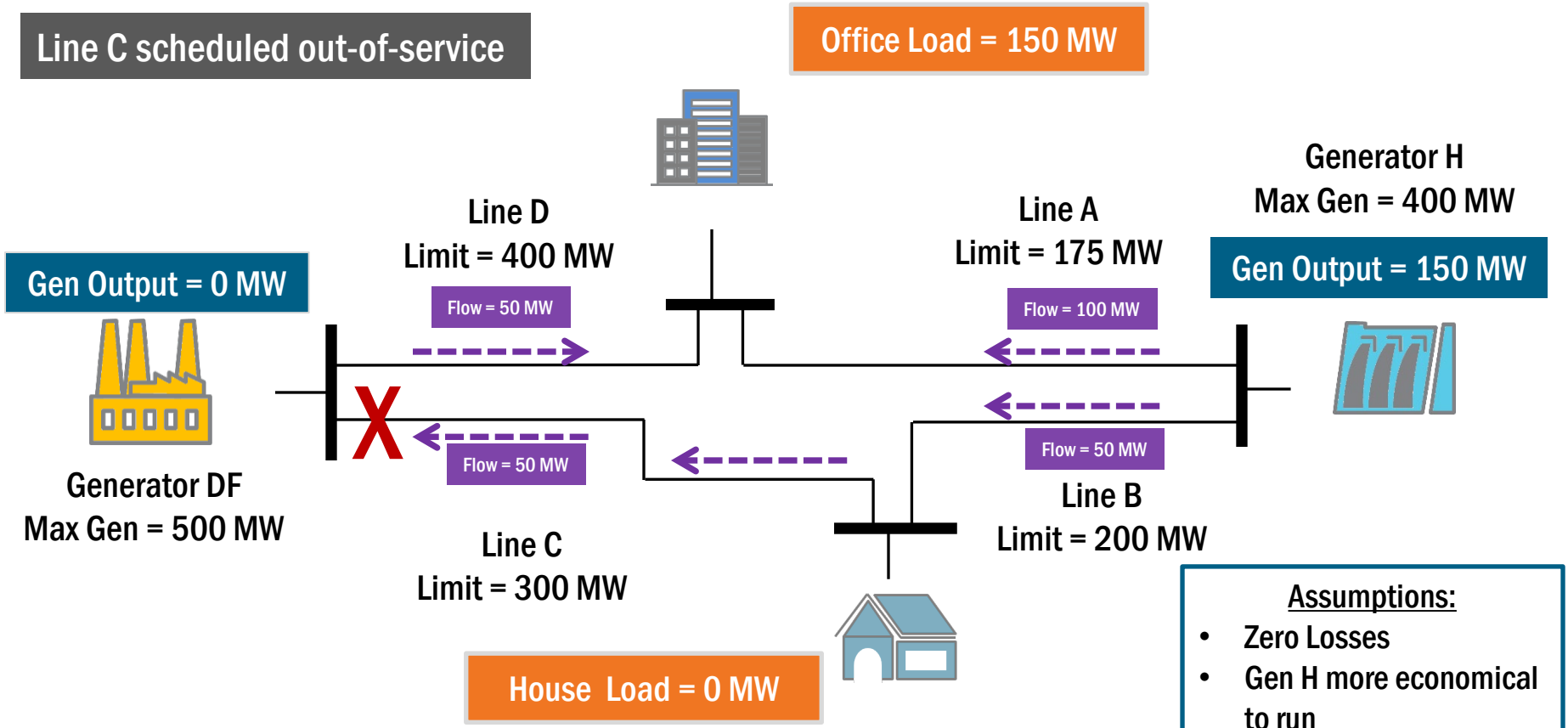


2. Scenario: Transmission Line Constraint



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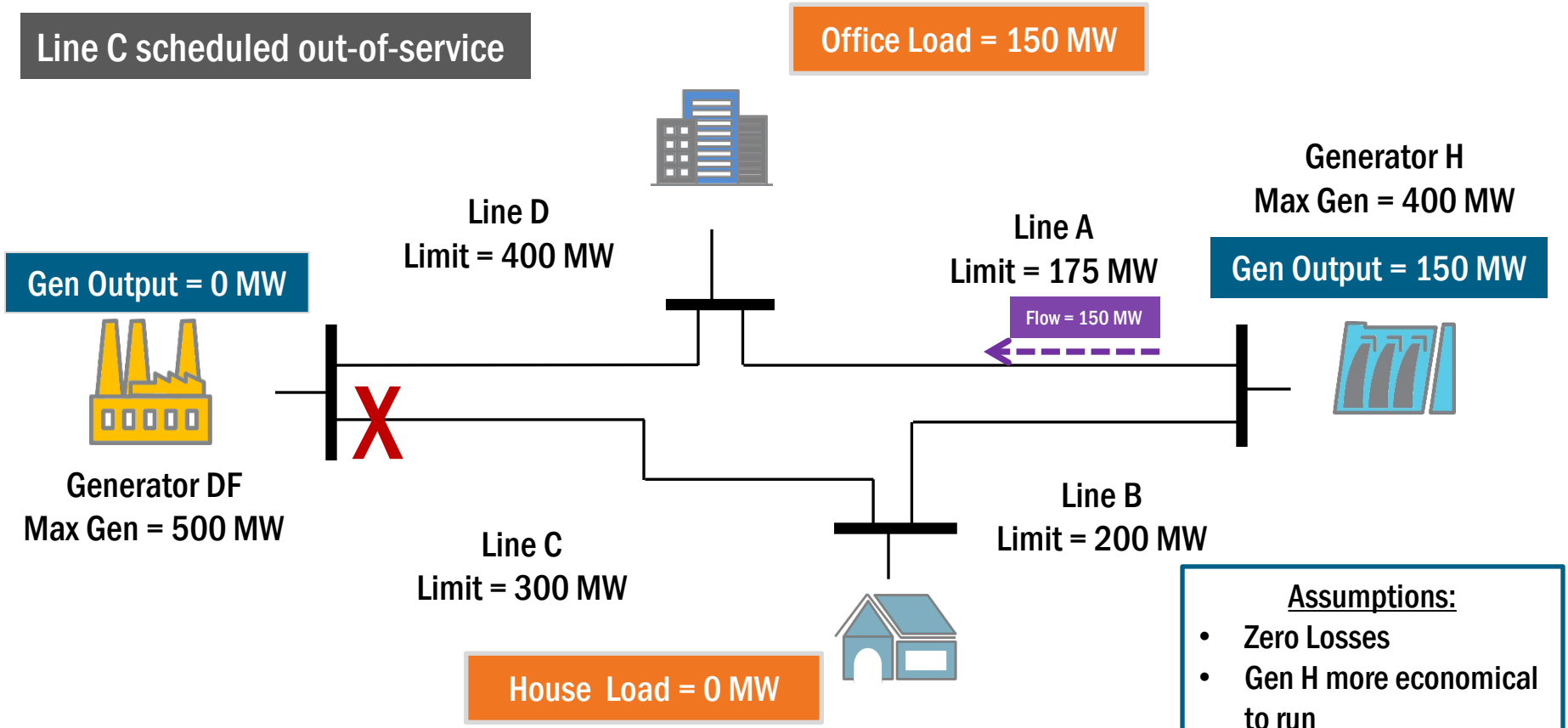
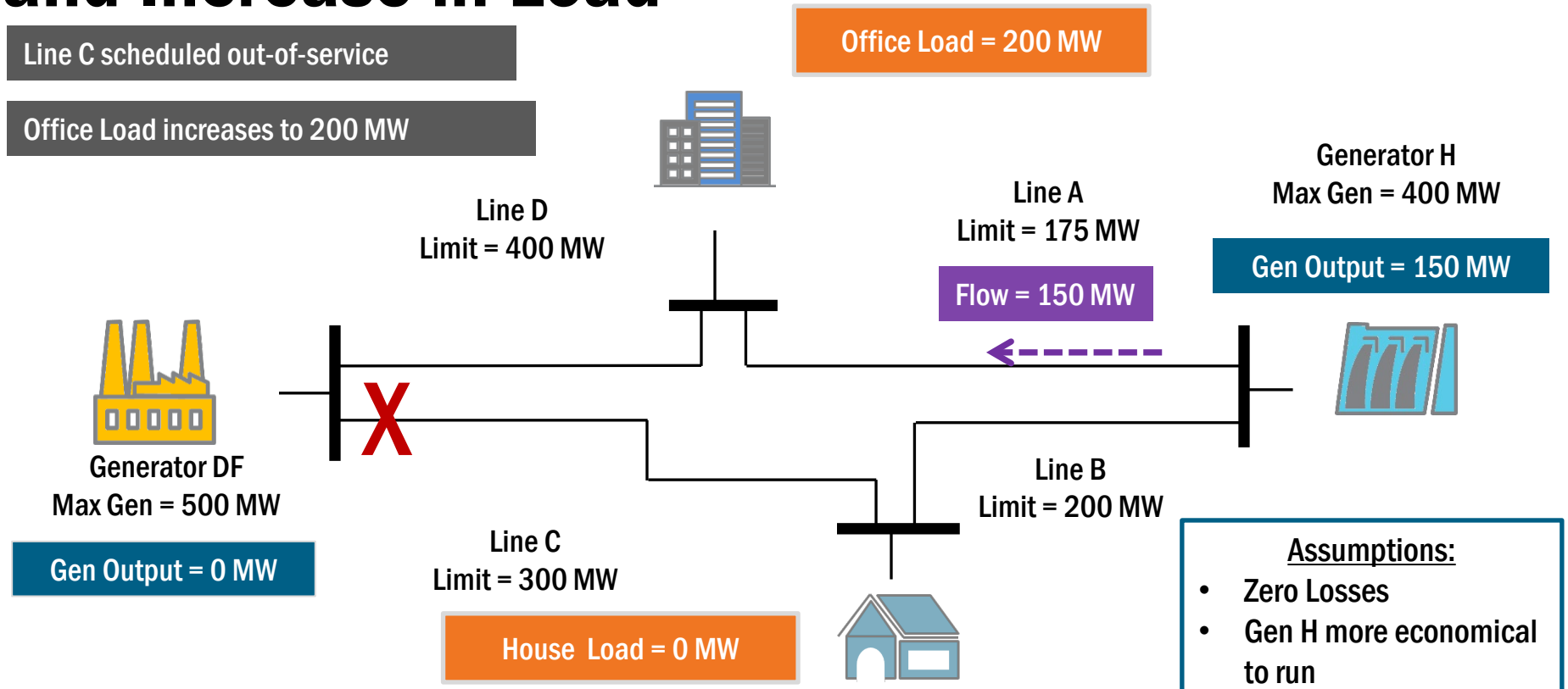


3. Scenario: Transmission Line Constraint and Increase in Load

New York ISO

Line C scheduled out-of-service

Office Load increases to 200 MW



Assumptions:

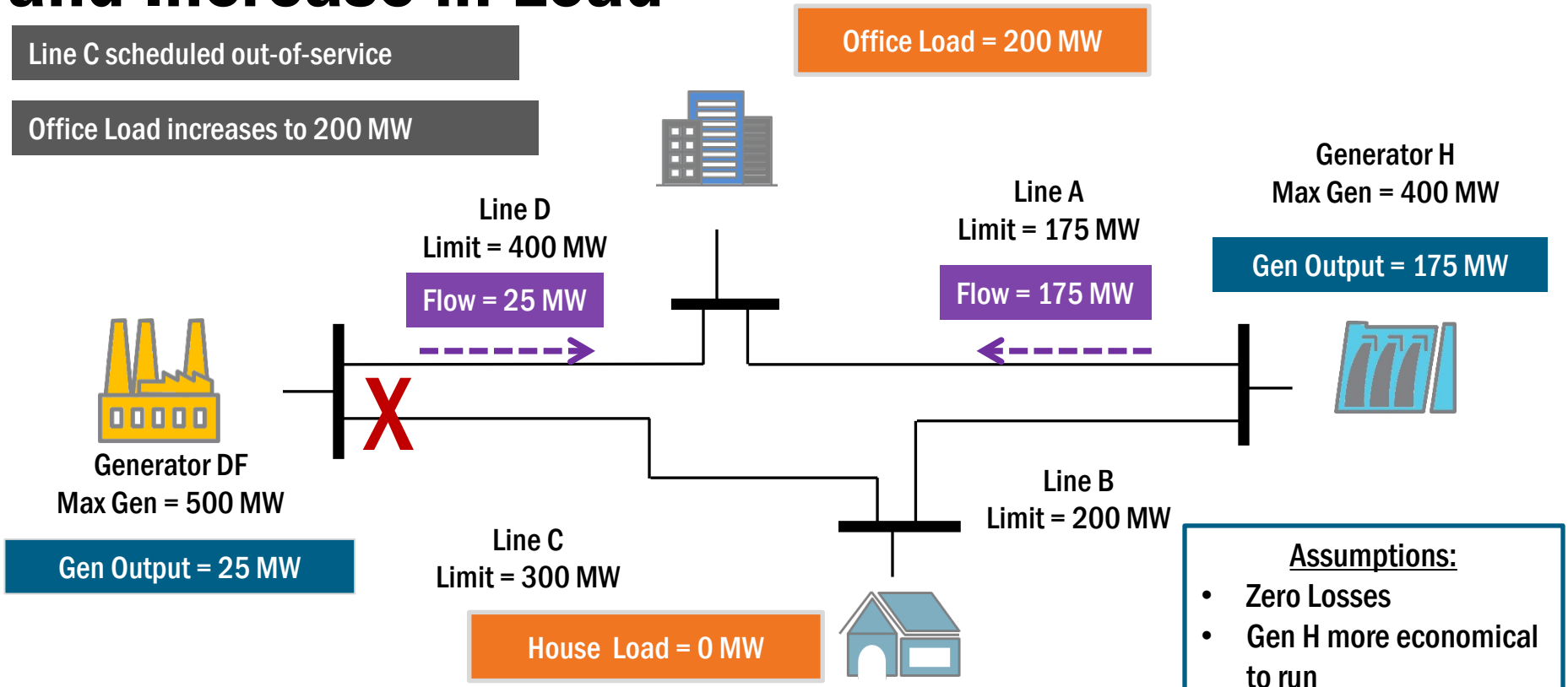
- Zero Losses
- Gen H more economical to run

3. Solution: Transmission Line Constraint and Increase in Load

New York ISO

Line C scheduled out-of-service

Office Load increases to 200 MW



Assumptions:

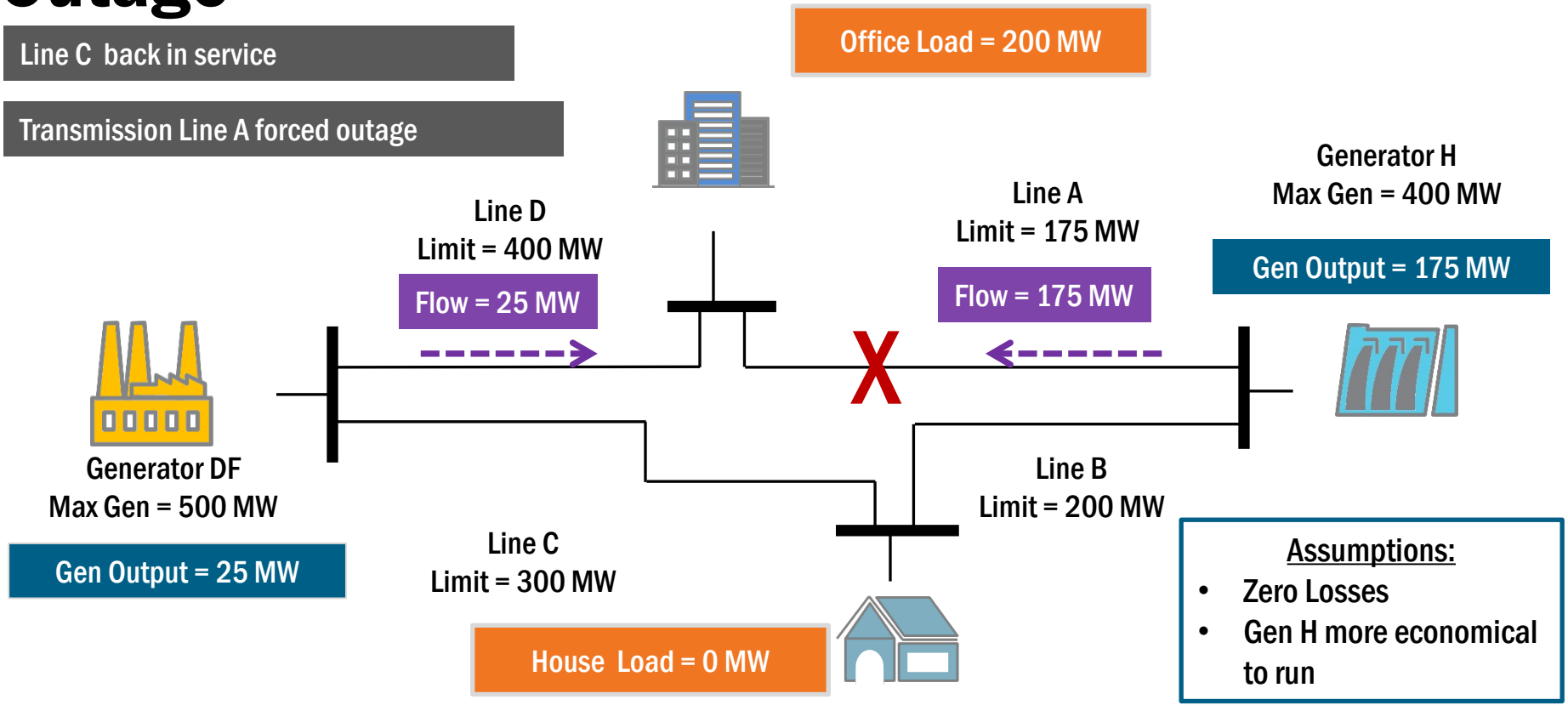
- Zero Losses
- Gen H more economical to run

4. Scenario: Transmission Line Forced Outage

New York ISO

Line C back in service

Transmission Line A forced outage



Assumptions:

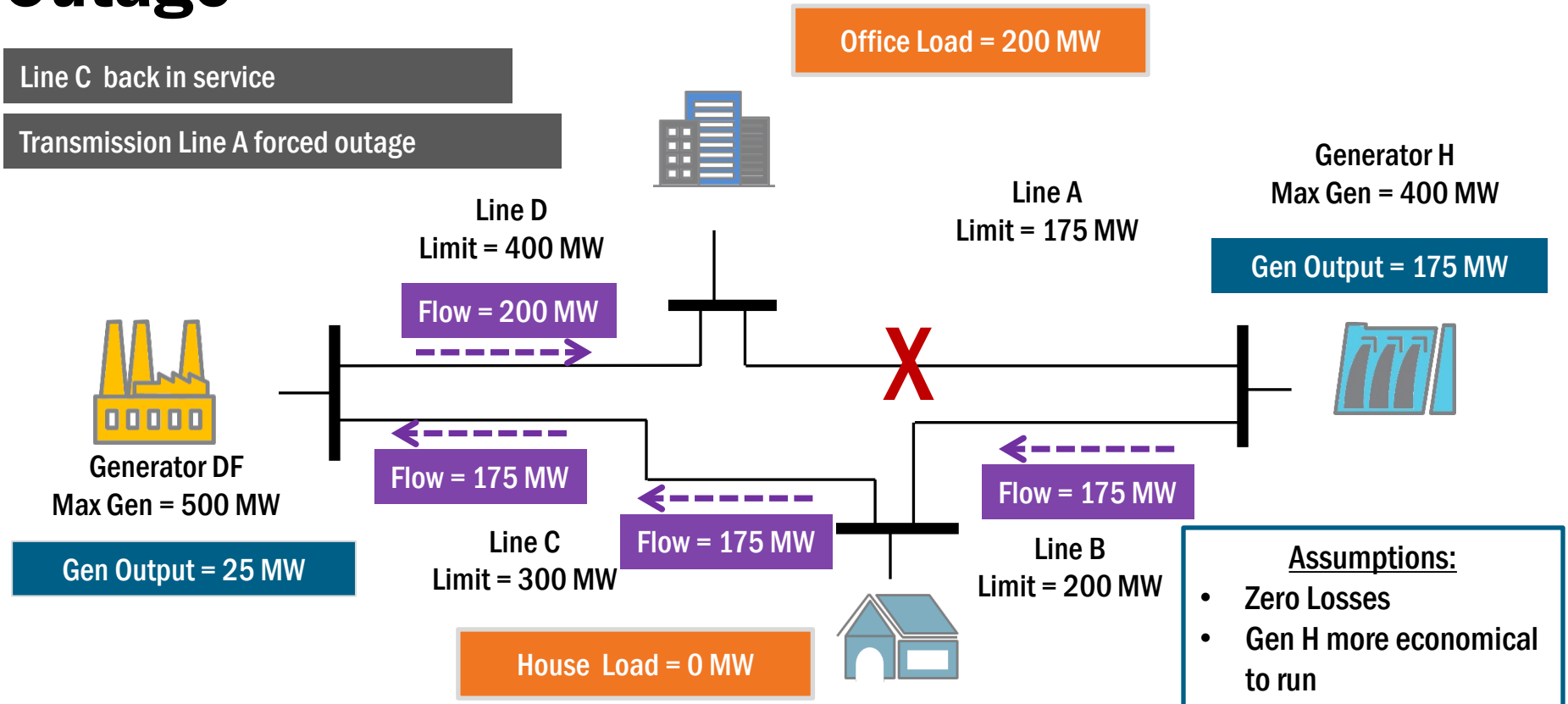
- Zero Losses
- Gen H more economical to run

4. Solution: Transmission Line Forced Outage

New York ISO

Line C back in service

Transmission Line A forced outage



Assumptions:

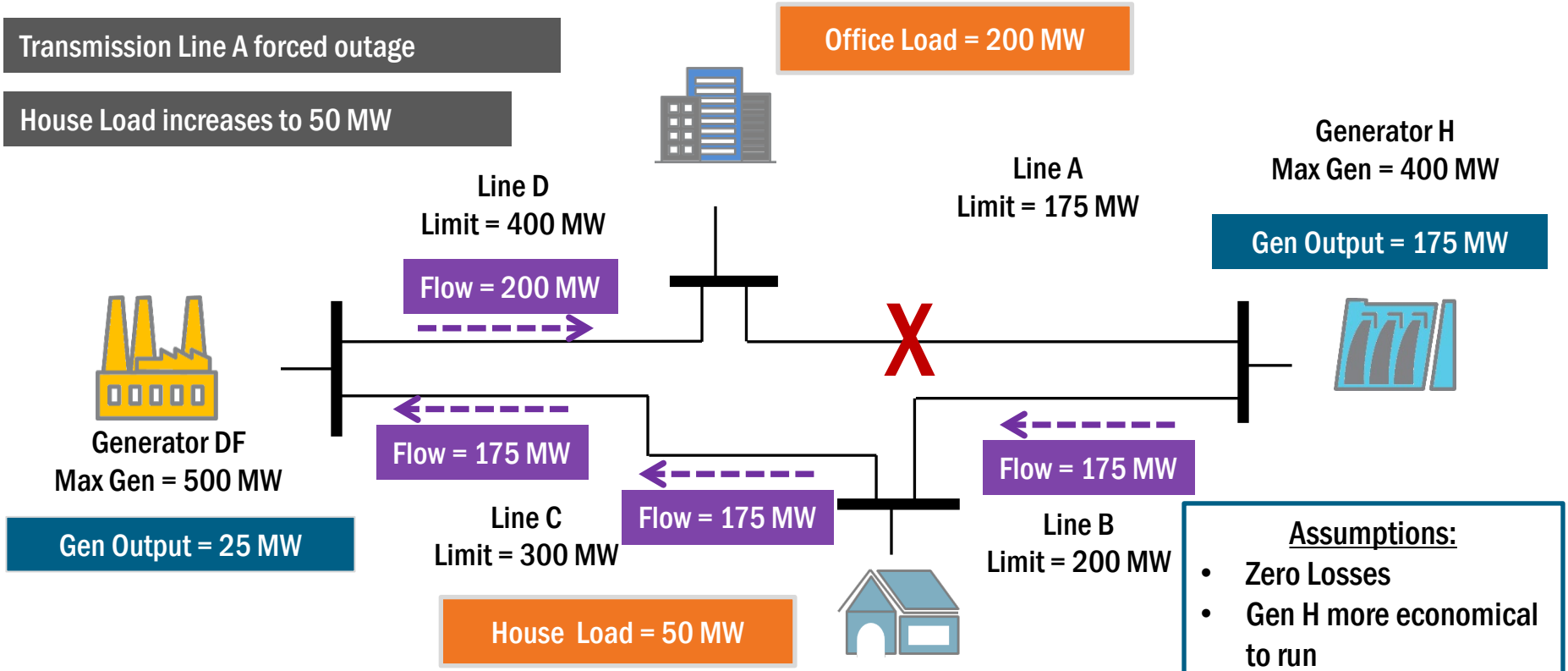
- Zero Losses
- Gen H more economical to run

5. Scenario: Transmission Line Forced Outage and Increase in Load

New York ISO

Transmission Line A forced outage

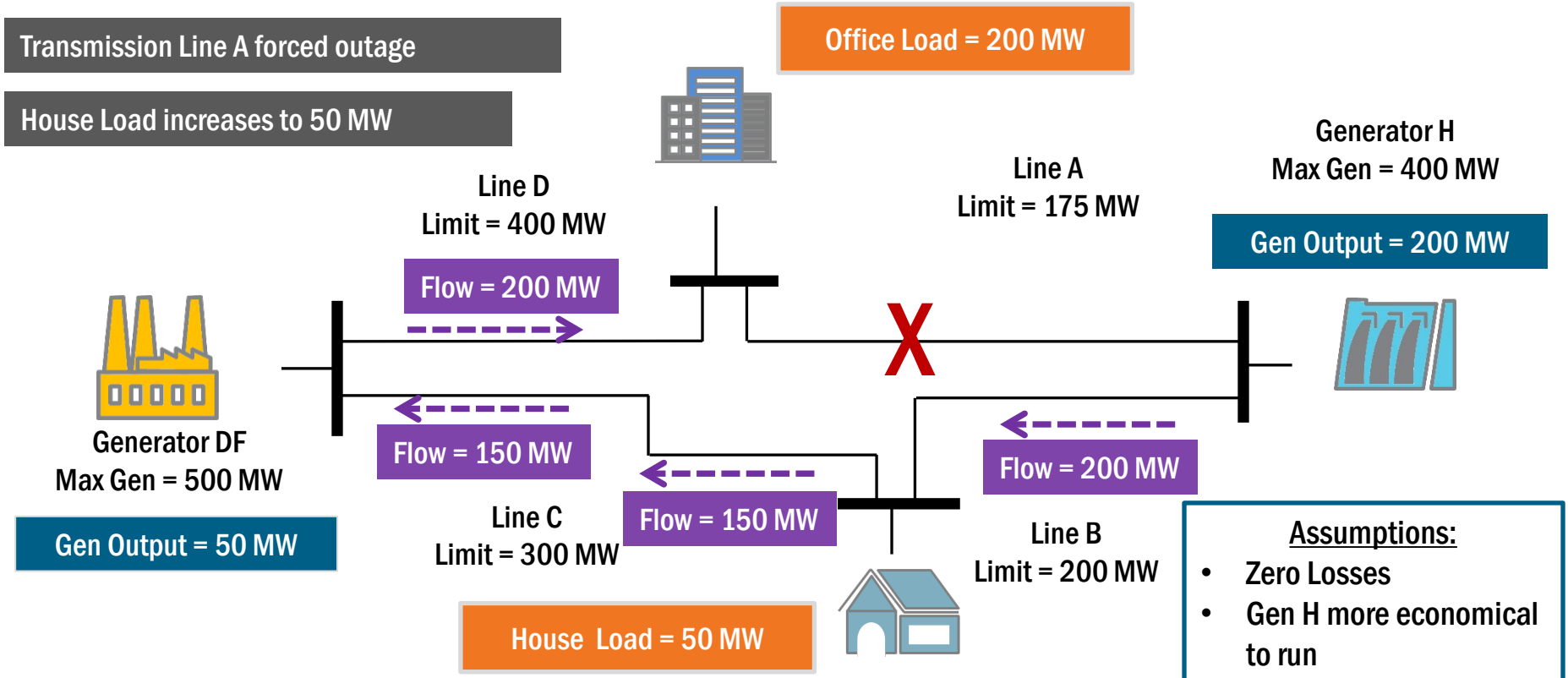
House Load increases to 50 MW



Assumptions:

- Zero Losses
- Gen H more economical to run

5. Solution: Transmission Line Forced Outage and Increase in Load



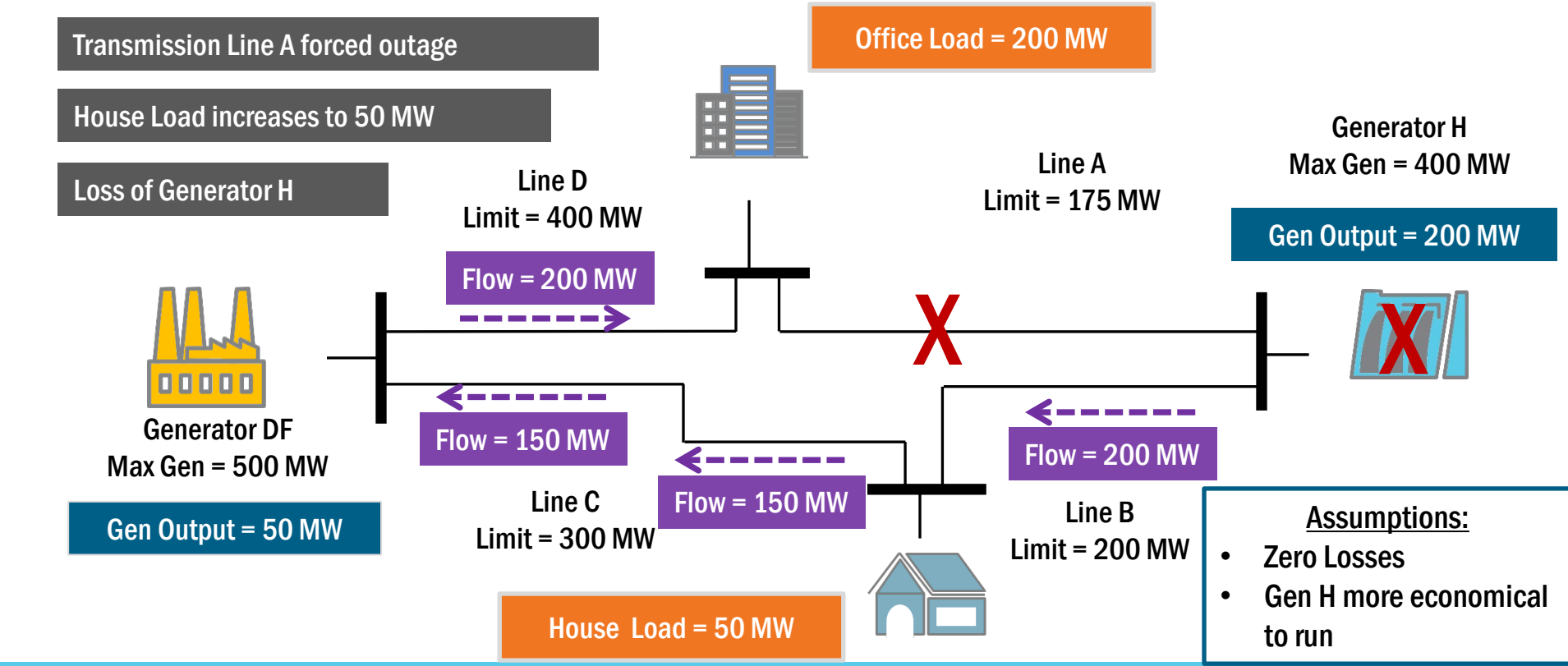
6. Scenario: Transmission Line Forced Outage, Increase in Load and Generation Loss

New York ISO

Transmission Line A forced outage

House Load increases to 50 MW

Loss of Generator H



Assumptions:

- Zero Losses
- Gen H more economical to run

6. Solution: Transmission Line Forced Outage, Increase in Load and Generation Loss

New York ISO

Transmission Line A forced outage

House Load increases to 50 MW

Loss of Generator H

Office Load = 200 MW

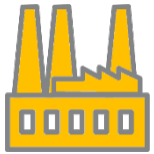
Line D
Limit = 400 MW

Flow = 200 MW

Line A
Limit = 175 MW

Generator H
Max Gen = 400 MW

Gen Output = 200 MW



Generator DF
Max Gen = 500 MW

Gen Output = 250 MW

Flow = 50 MW

Flow = 50 MW

Line C
Limit = 300 MW

Line B
Limit = 200 MW

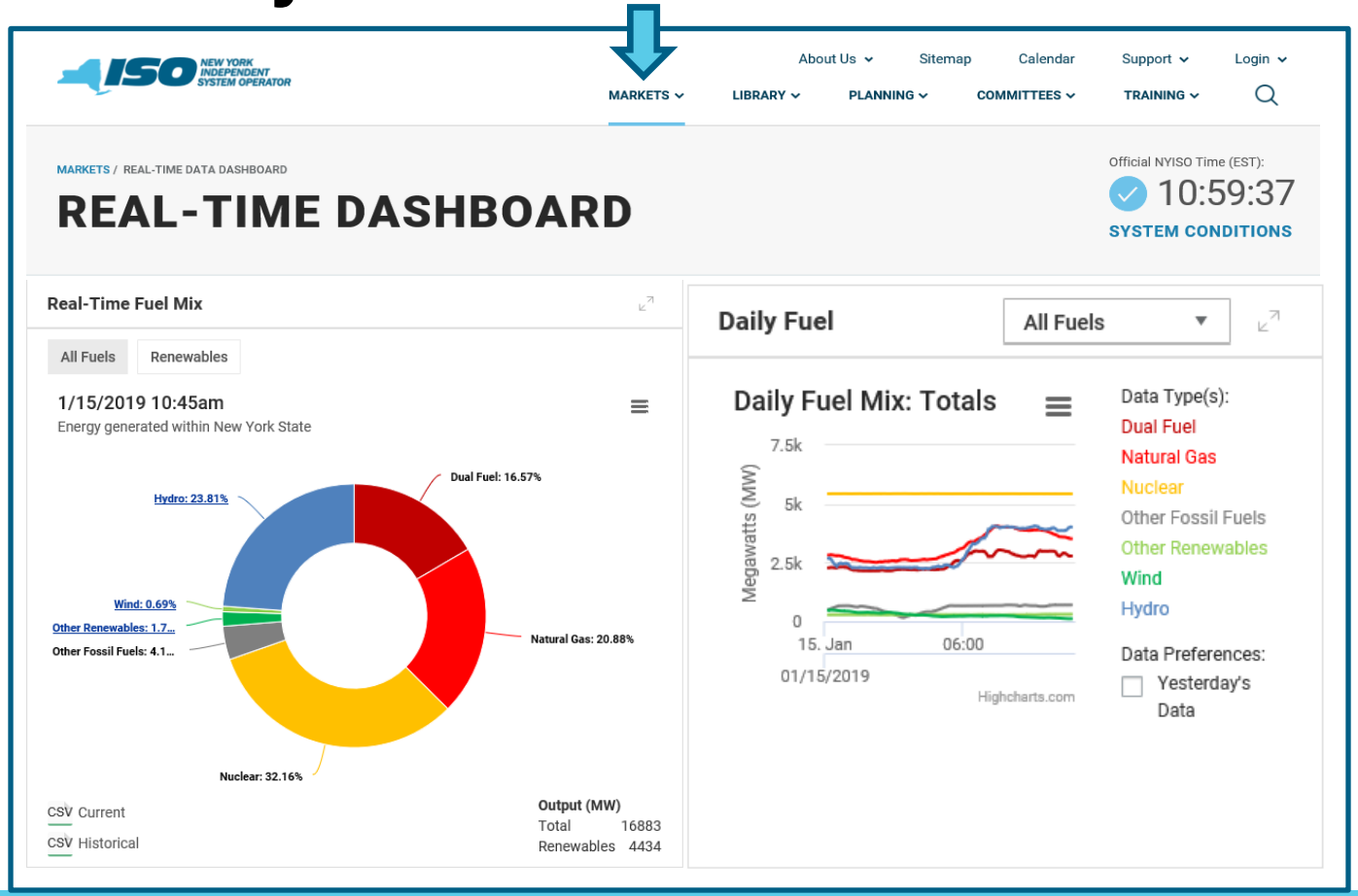
House Load = 50 MW

Assumptions:

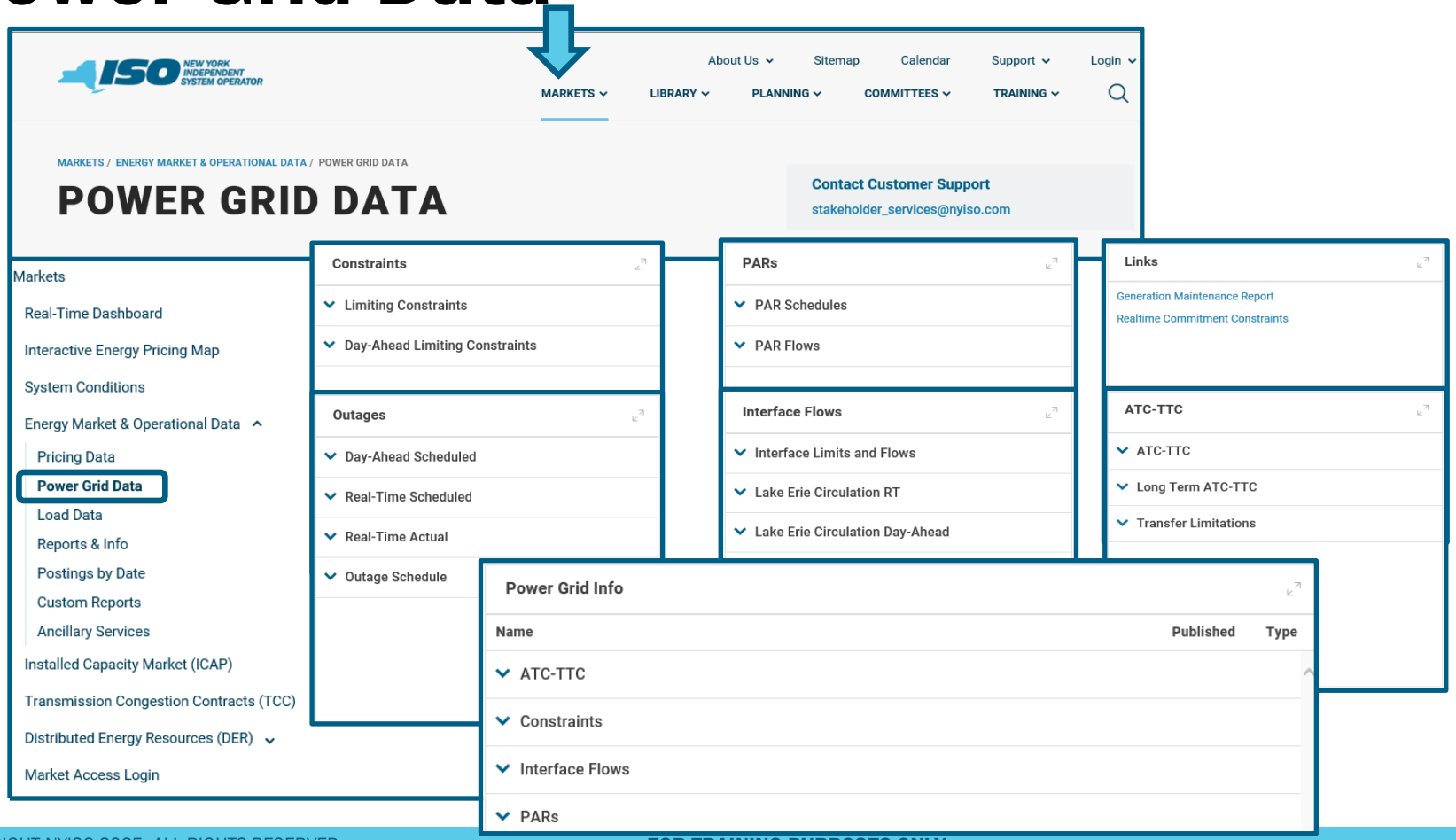
- Zero Losses
- Gen H more economical to run

Power System Fundamentals– NYISO Website Data

Real Time System Conditions

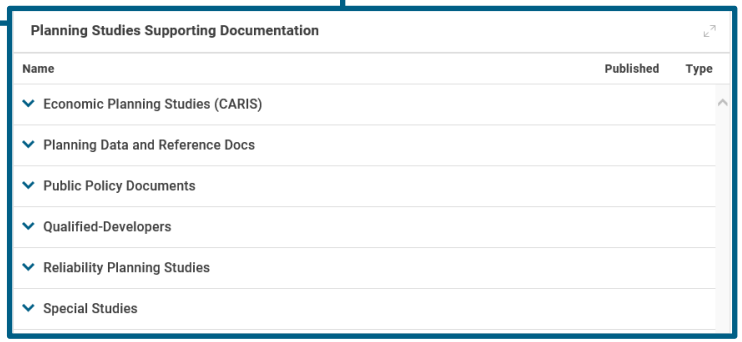


Power Grid Data



System Planning at NYISO

New York ISO



FOR TRAINING PURPOSES ONLY

Summary

- Power Systems Fundamentals
  - NYISO Responsible for NYCA Bulk Power Operations
  - Three Primary Components to Power System
    - Load, Generation, & Transmission
  - Operational Ancillary Services in place to meet the following System Requirements:
    - Maintaining power transfer capability of the transmission system (Voltage Support)
    - Maintaining balance between Generation and Load (Regulation and Frequency Support)
    - Securing System for Contingencies & Constraints (Reserves)
    - System Restoration (Black Start Service)

Additional Resources

- Open Access Transmission Tariff (OATT)
- Market Services Tariff (MST)
- Ancillary Services Manual
- NYISO Power Trends
- NYISO Load and Capacity Data Report