System Restoration: The Blackout Event

Types and Causes, System Assessment

Student Guide

Prepared by:
State & Member Training
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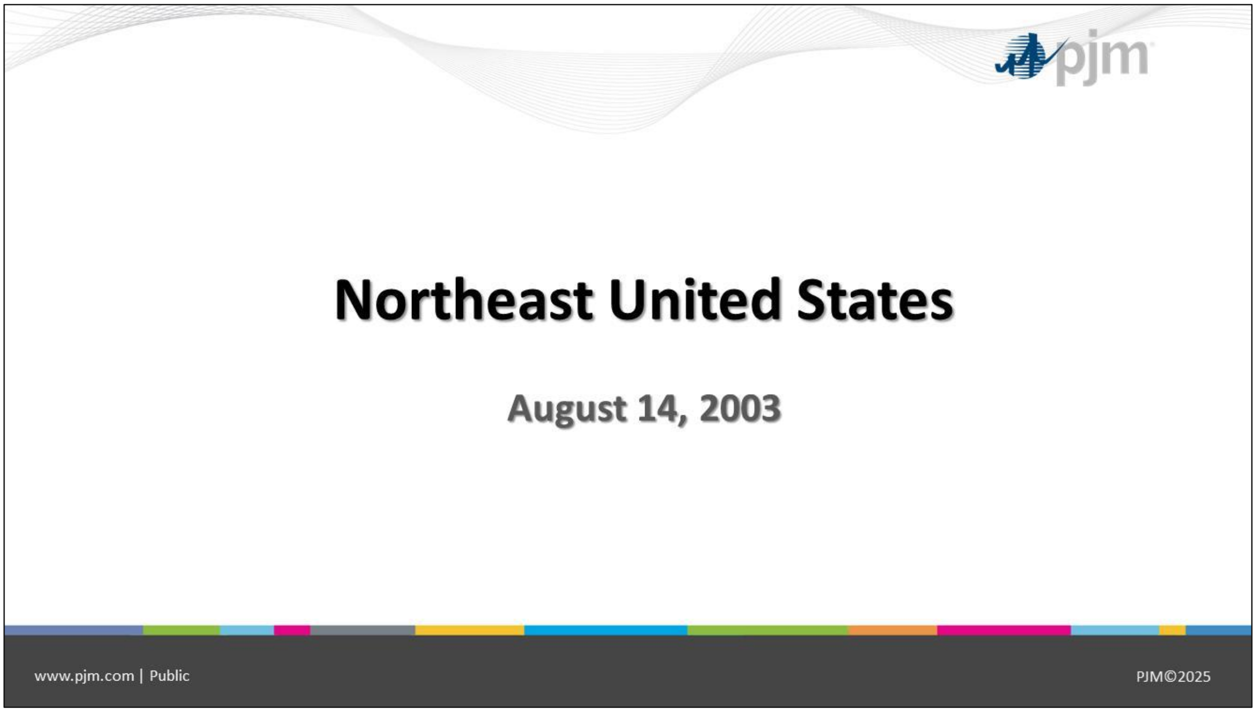
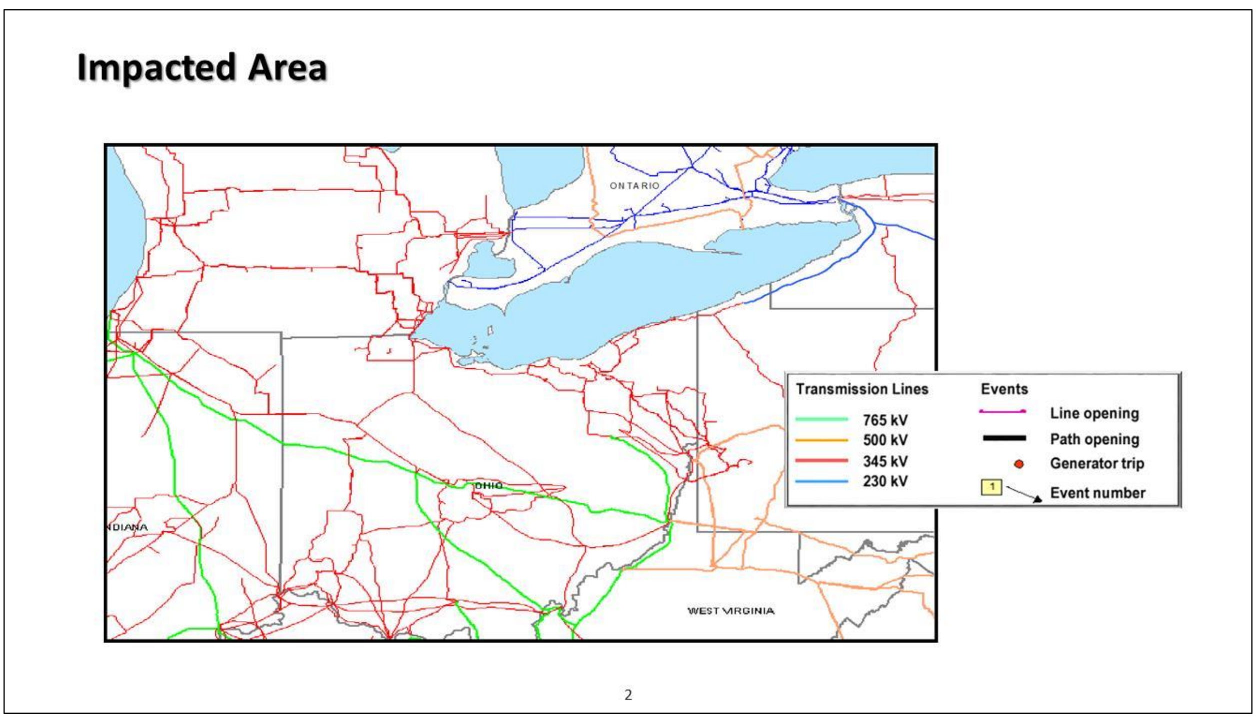
Objectives

- Identify lessons learned from significant blackouts in history
- Identify the types and causes of blackouts
- Describe the tasks associated with conducting a system assessment of conditions immediately following a disturbance

Northeast United States - August 14, 2003



Overview - Sequence of Events

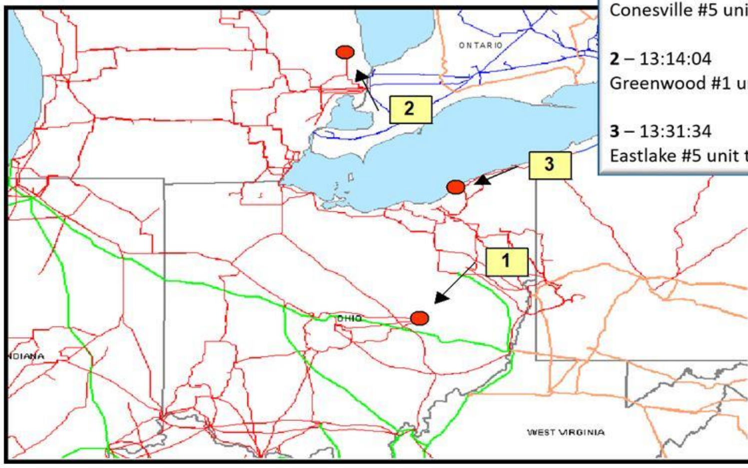


Events Leading to Blackout

1 – 12:05:44
Conesville #5 unit tripped (375 MW cap.)

2 – 13:14:04
Greenwood #1 unit tripped (785 MW cap.)

3 – 13:31:34
Eastlake #5 unit tripped (597 MW cap.)



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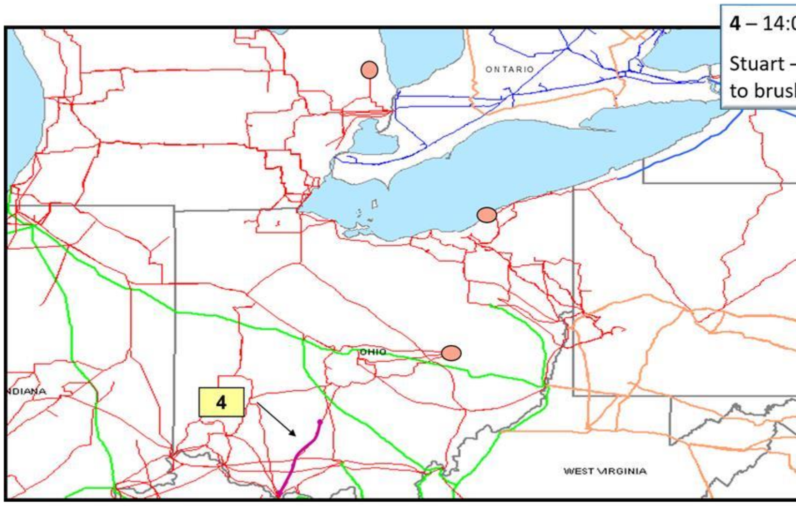
Events Leading to Blackout

4 – 14:02:00

Stuart – Atlanta 345 kV line trips due to brush fire under line



Note: Line is part of the transmission pathway from southwestern Ohio to northern Ohio

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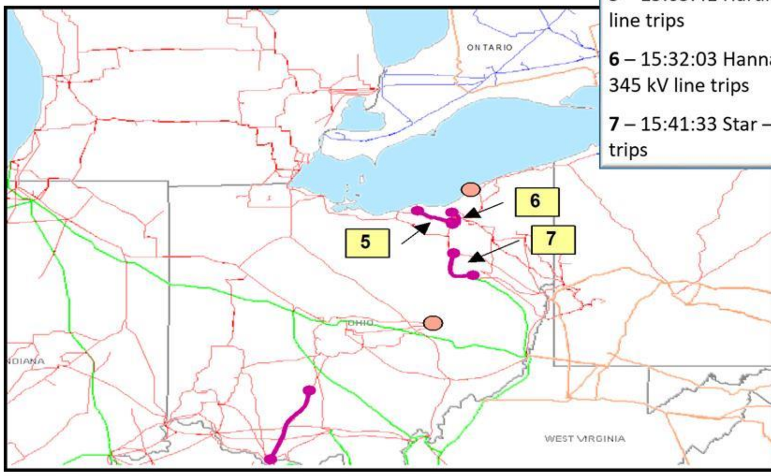
Events Leading to Blackout



5 – 15:05:41 Harding – Chamberlain 345 kV line trips

6 – 15:32:03 Hanna – Juniper 345 kV line trips

7 – 15:41:33 Star – South Canton 345 kV line trips

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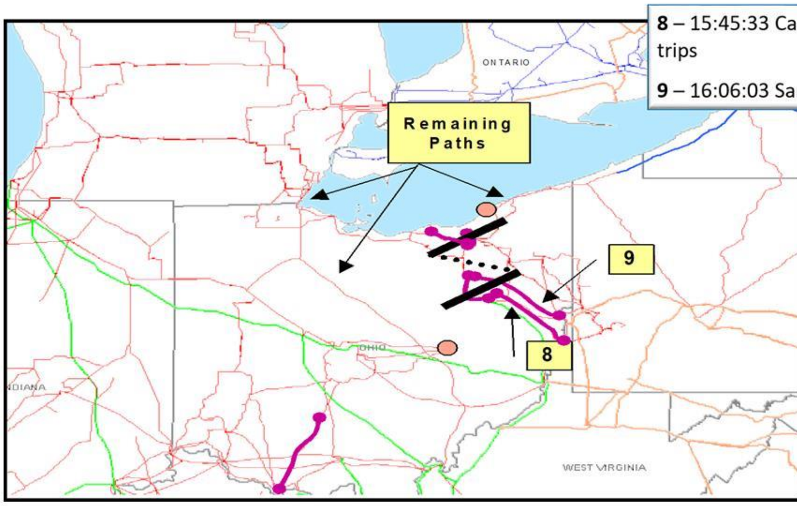
Events Leading to Blackout



8 – 15:45:33 Canton Central – Tidd 345 kV line trips

9 – 16:06:03 Sammis – Star 345 kV line trips

Note: Only three remaining paths left into Northern Ohio

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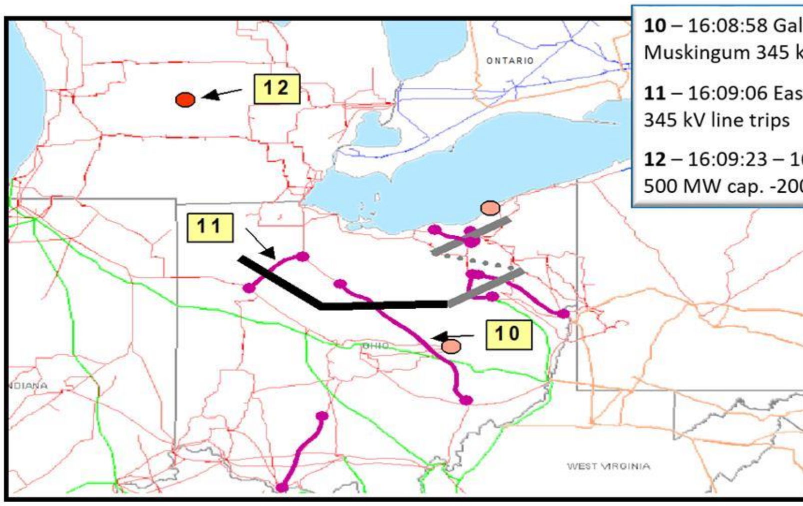
Events Leading to Blackout



10 – 16:08:58 Galion – Ohio Central – Muskingum 345 kV line trips

11 – 16:09:06 East Lima – Fostoria Central 345 kV line trips

12 – 16:09:23 – 16:10:27 Kinder Morgan trips 500 MW cap. -200 MW output

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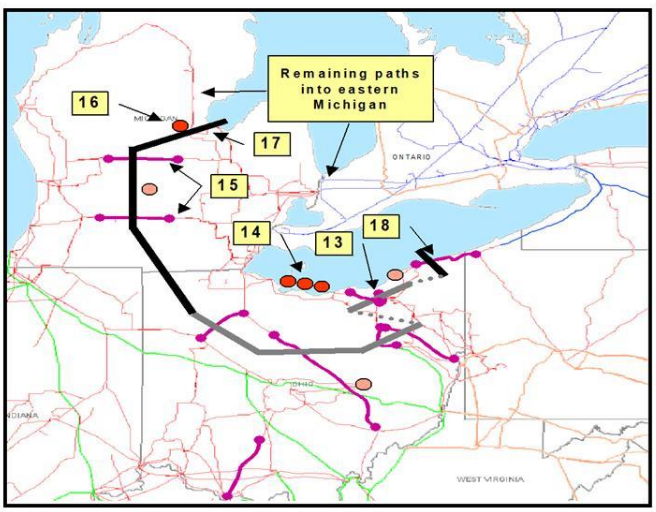
Events Leading to Blackout



13 – 16:10:00 Harding - Fox 345 kV line trips

14 – 16:10:04 20 Generators along Lake Erie in N. Ohio trip - 2174 MW

15 – 16:10:37 West – East Michigan 345 kV line trips

16 – 16:10:38 Midland Cogeneration Venture trips 1265 MW

17 – 16:10:38 Transmission system separates northwest of Detroit

18 – 16:10:38 Perry – Ashtabula – Erie West 345 kV line trips

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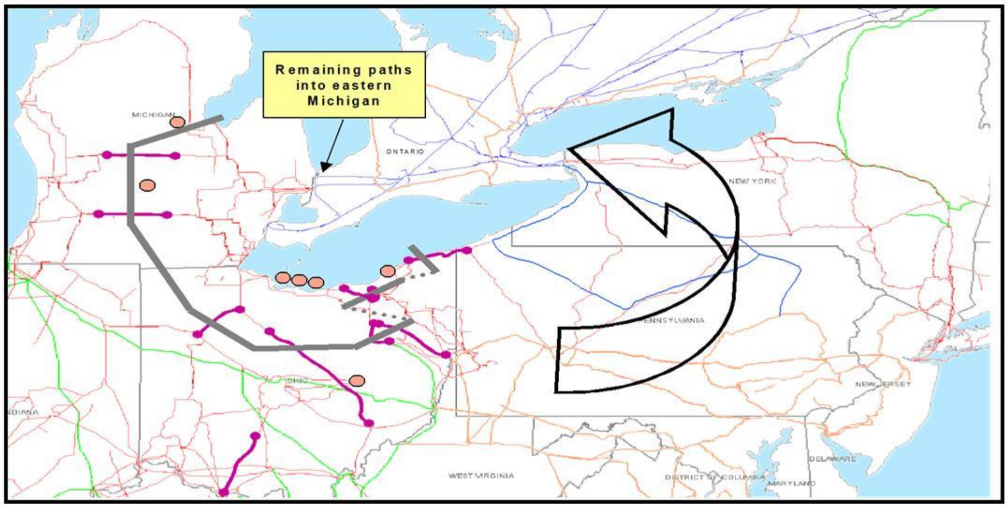
Events Leading to Blackout



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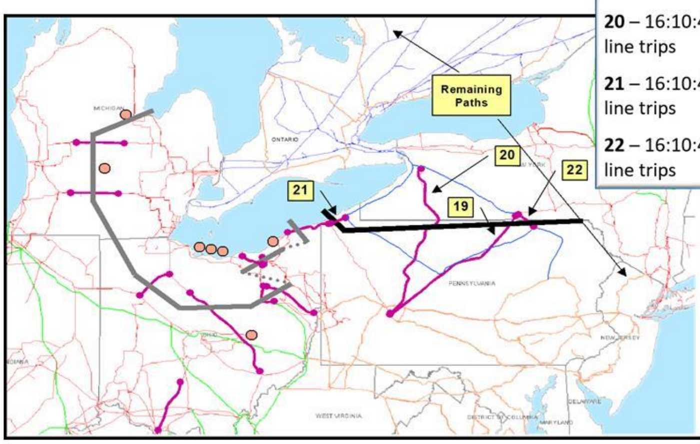
Events Leading to Blackout



19 – 16:10:40 Homer City – Watercure Road 345 kV line trips

20 – 16:10:40 Homer City – Stolle Road 345 kV line trips

21 – 16:10:41 South Ripley – Dunkirk 230 kV line trips

22 – 16:10:44 East Towanda – Hillside 230 kV line trips

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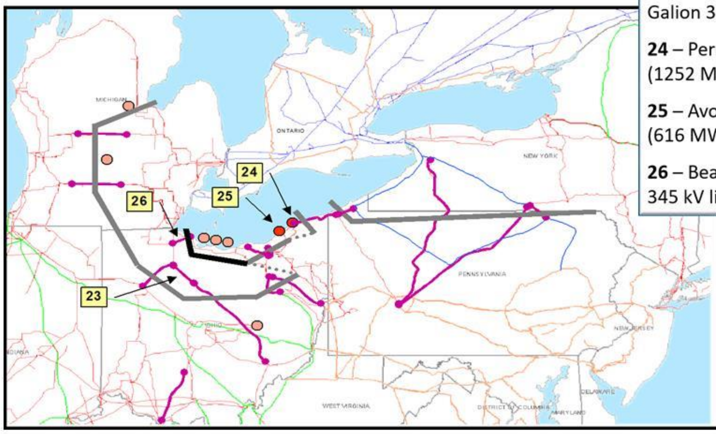
Events Leading to Blackout



16:10:41

23 – Fostoria Central – Galion 345 kV line trips

24 – Perry #1 nuclear unit trips (1252 MW cap.)

25 – Avon Lake #9 unit trips (616 MW cap.)

26 – Beaver – Davis Besse 345 kV line trips

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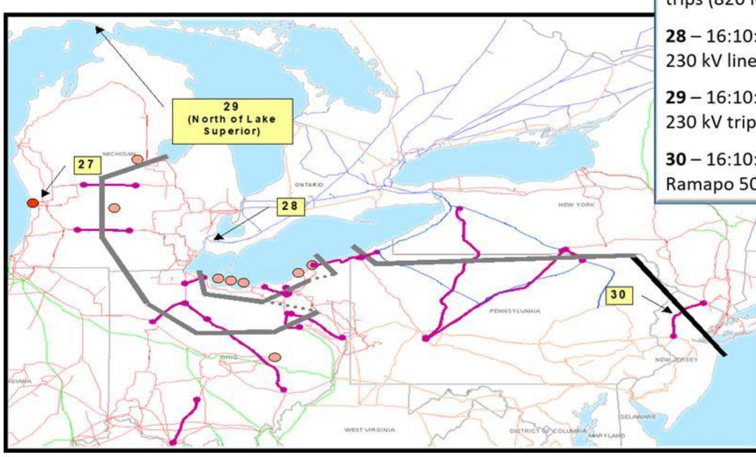
Events Leading to Blackout



27 – 16:10:42 Campbell #3 unit trips (820 MW cap)

28 – 16:10:43 Keith – Waterman 230 kV line trips

29 – 16:10:45 Wawa – Marathon 230 kV trips

30 – 16:10:45 Branchburg – Ramapo 500 kV line trips

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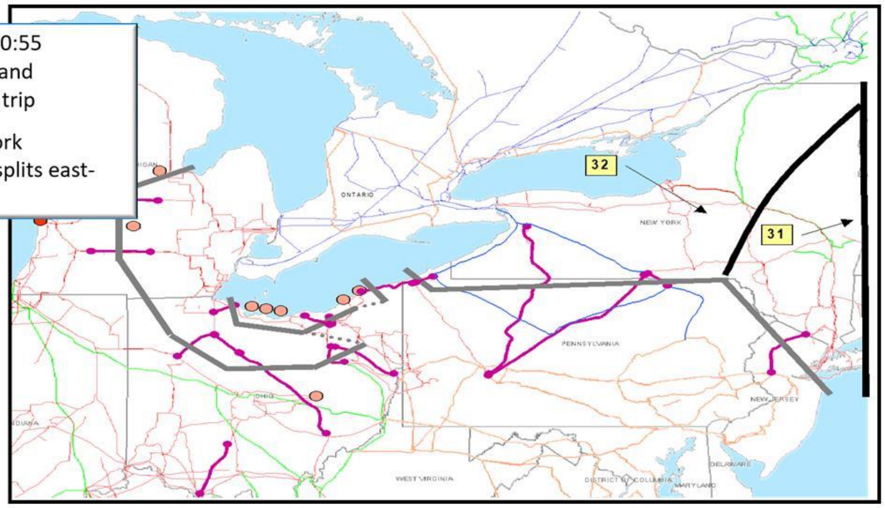
Blackout

31 – 16:10:46 to 16:10:55
New York – New England transmission tie lines trip

32 – 16:10:48 New York transmission system splits east-west



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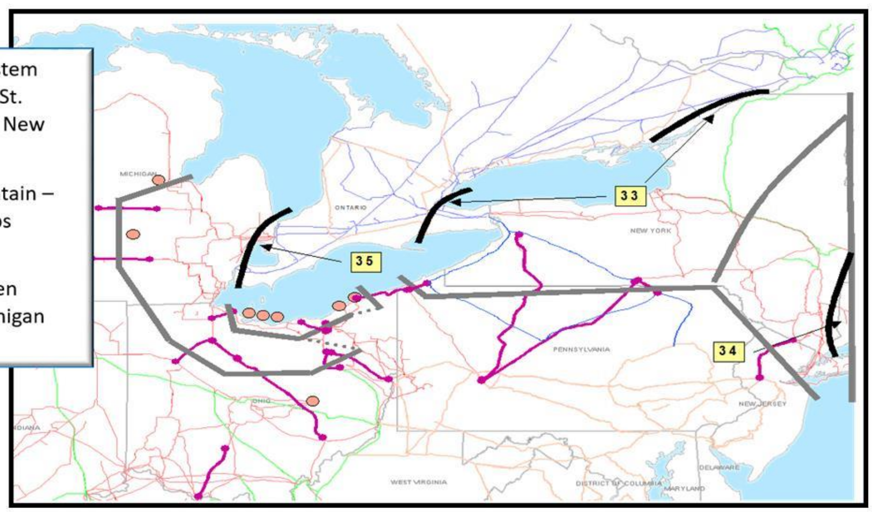
Blackout

33 – 16:10:50 Ontario System west of Niagara Falls and St. Lawrence separates from New York

34 – 16:11:22 Long Mountain – Plum Tree 345 kV line trips

35 – 16:11:57 Remaining transmission lines between Ontario and Eastern Michigan separate



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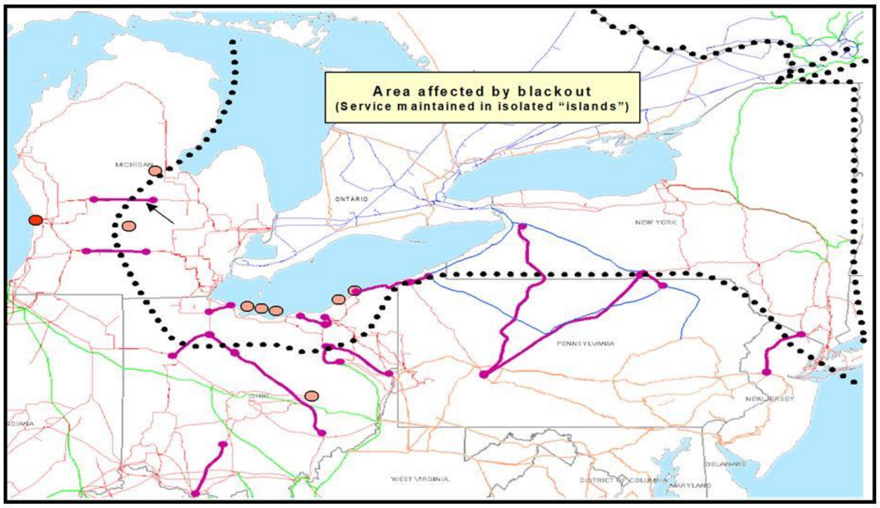
Blackout



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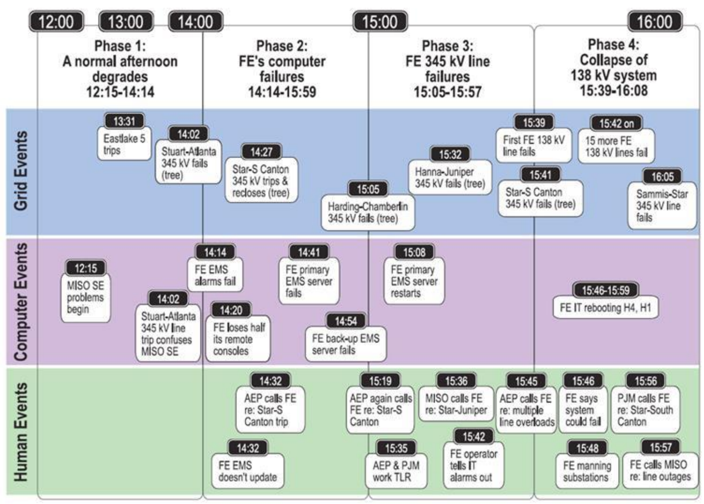
2003 Blackout Timeline



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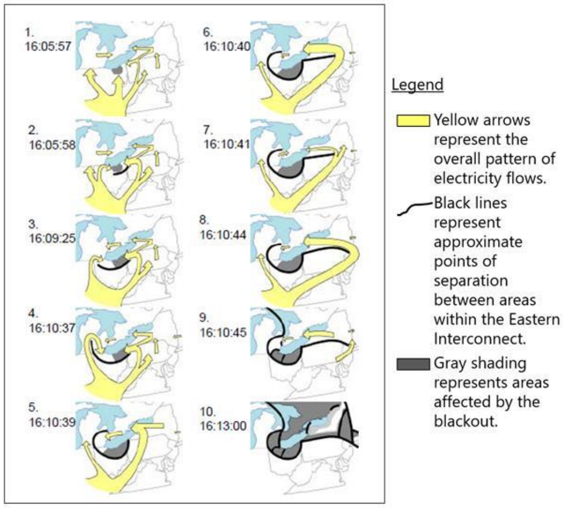
Cascade Sequence



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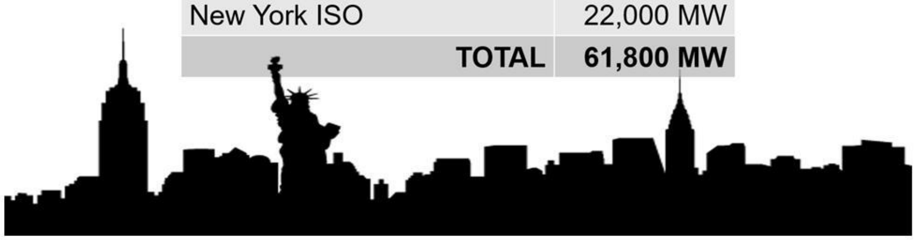
Impacts/Effects

Blackout Statistics

Approximate Load Lost	
PJM Interconnection	4,200 MW
MISO	13,000 MW
Hydro Quebec	100 MW
IESO – Ontario	20,000 MW
ISO New England	2,500 MW
New York ISO	22,000 MW
TOTAL	**61,800 MW**



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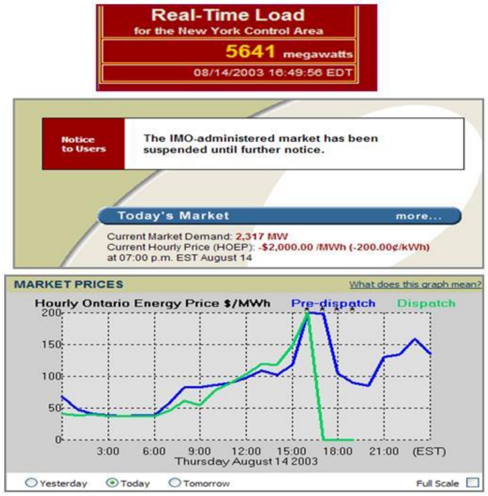
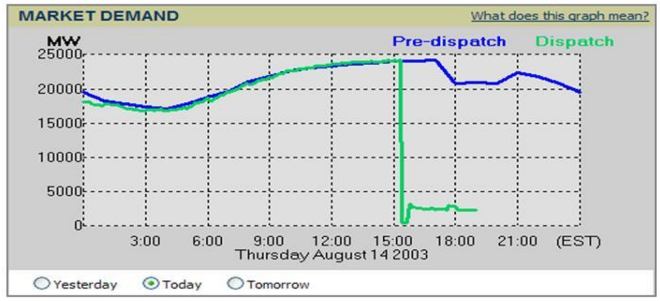
IESO (IMO at the time) Data





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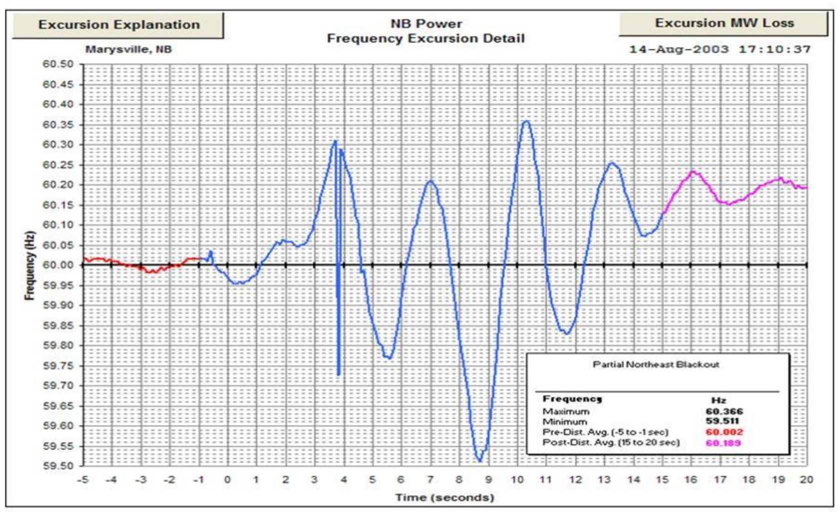
New Brunswick Frequency



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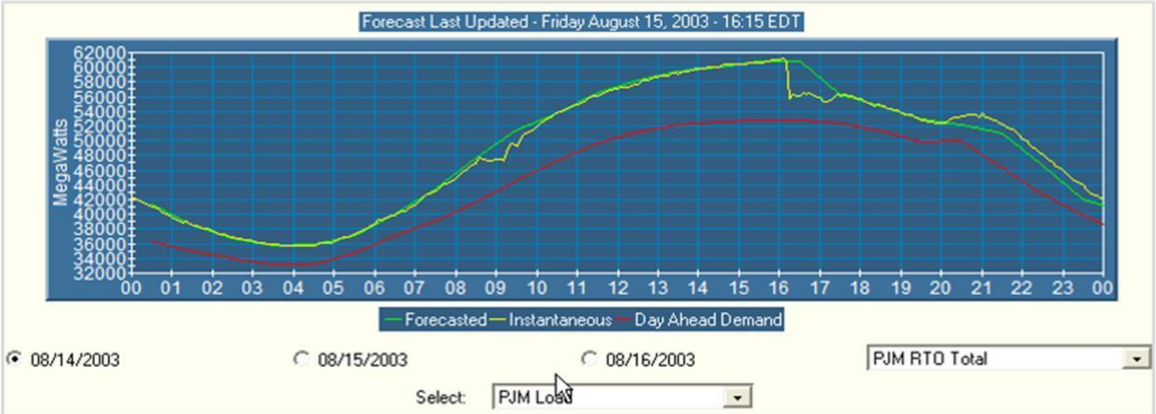
PJM Load Curve



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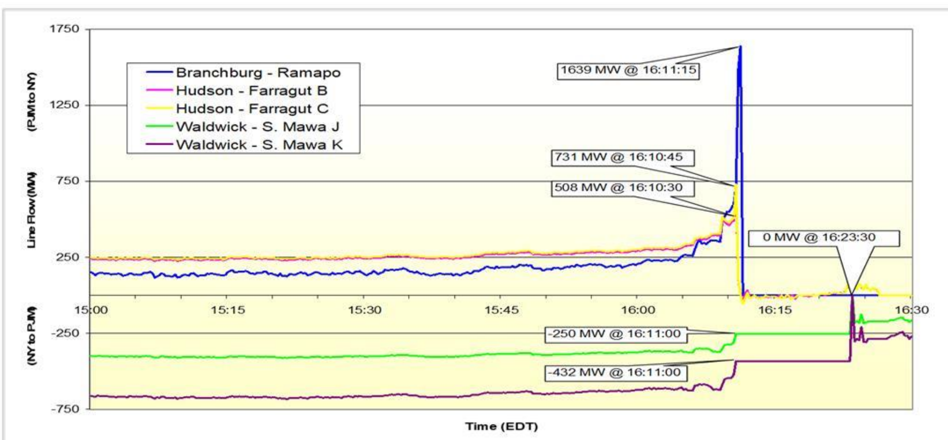
PSE&G (NJ) - NY Tie Lines



Note: Time stamps on line flow data may not match exactly with equipment outage times

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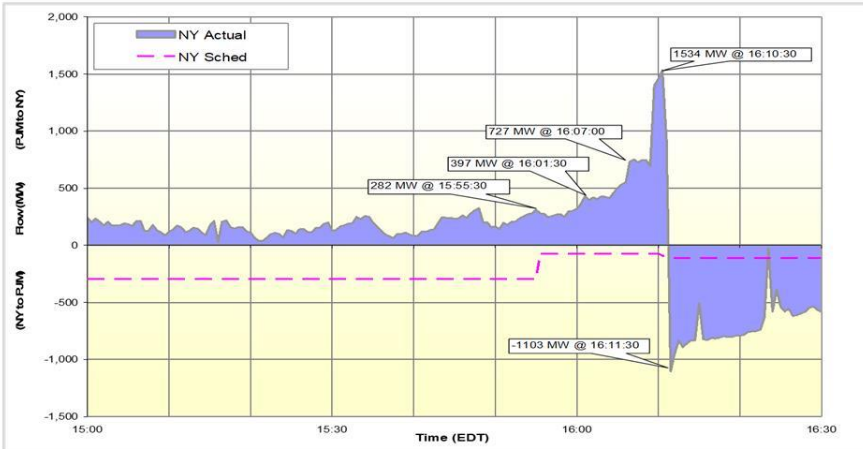
NY Interchange



Note: Time stamps on line flow data may not match exactly with equipment outage times

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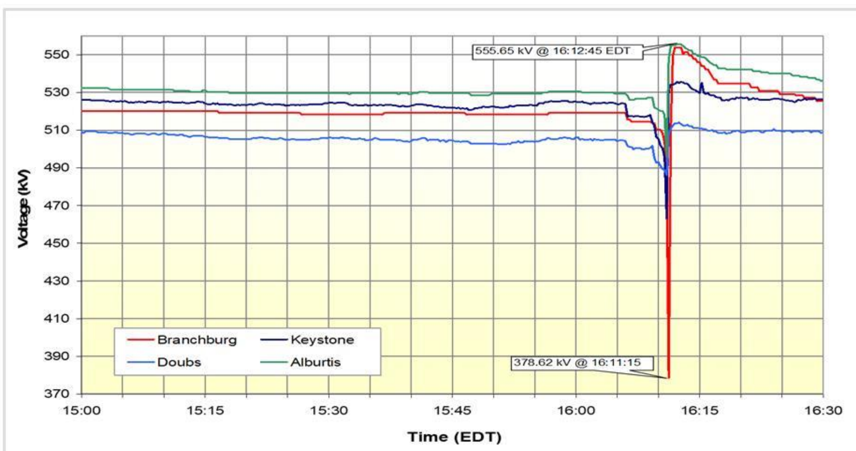
Significant PJM 500 kV Voltages



Note: Time stamps on voltage data may not match exactly with equipment outage times

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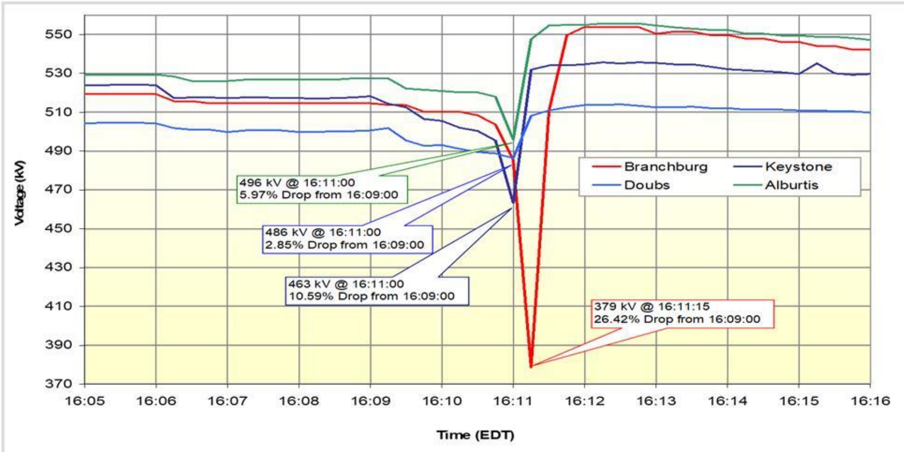
Significant PJM 500 kV Voltages



Note: Time stamps on voltage data may not match exactly with equipment outage times

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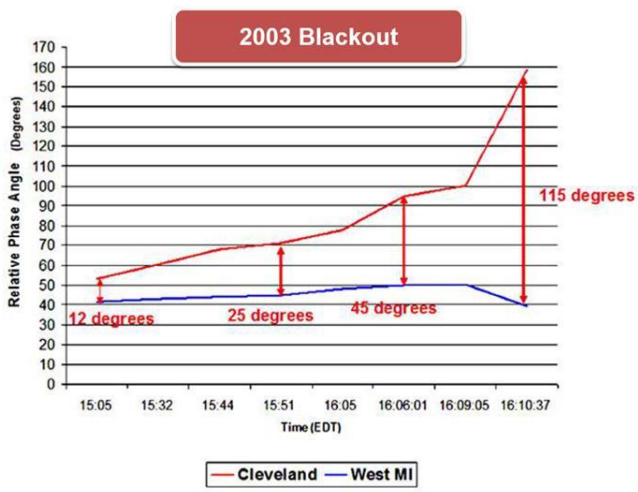
What was the Phase Angle?



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Arizona-Southern California - September 8, 2011

Arizona-Southern California

September 8, 2011

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Event Overview

- Late in the afternoon, an 11-minute system disturbance occurred in the Pacific Southwest, leading to:
  - Cascading outages
  - Approximately 2.7 million customers without power
- The outages affected parts of Arizona, Southern California, and Baja California, Mexico, and all of San Diego
- The disturbance occurred near rush hour on a business day, snarling traffic for hours

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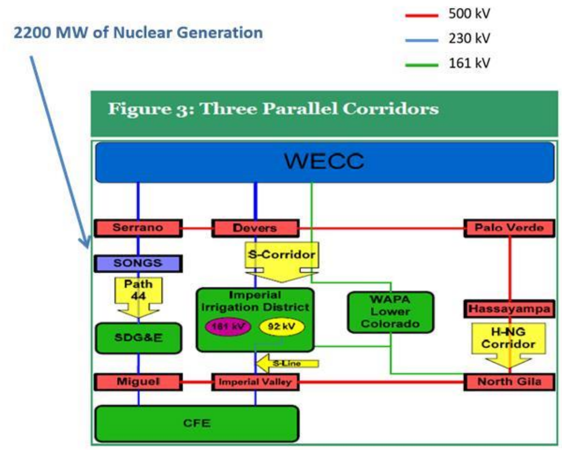
Event Overview

- The affected line: Hassayampa-N. Gila (H-NG) 500 kV line, Arizona Public Service (APS)
  - A segment of the Southwest Power Link (SWPL)
    - A major transmission corridor
    - Transports power in an east-west direction
    - Generators in Arizona
    - Runs through the service territory of Imperial Irrigation District (IID), into the San Diego area



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Event Overview

- A technician missed two steps in a switching scheme, causing:
  - Transformer, transmission line, and generating unit trippings
  - Flow redistributions, voltage deviations, and overloads
  - Automatic load shedding
- Path 44 attempted to carry all flows into the San Diego area, and parts of Arizona and Mexico
- The excessive loading on Path 44 initiated an inter-tie separation scheme at SONGS, leading to the loss of the SONGS nuclear units

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Event Overview

- During the 11 minutes of the event, the WECC Reliability Coordinator issued no directives (think: PJM Operating Instructions)
- Only limited mitigating actions were taken by the TOPs of the affected areas
- All affected entities had access to power from their own or neighboring systems and, therefore, did not need to use "black start" plans
- Although there were some delays in the restoration process due to communication and coordination issues between entities, the process was generally effective

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Significant Findings

- Lessons Learned:
  - Protection settings and coordination
  - Situational awareness of the operators
  - Lack of clarity among all involved operators concerning responsibilities for restoration efforts

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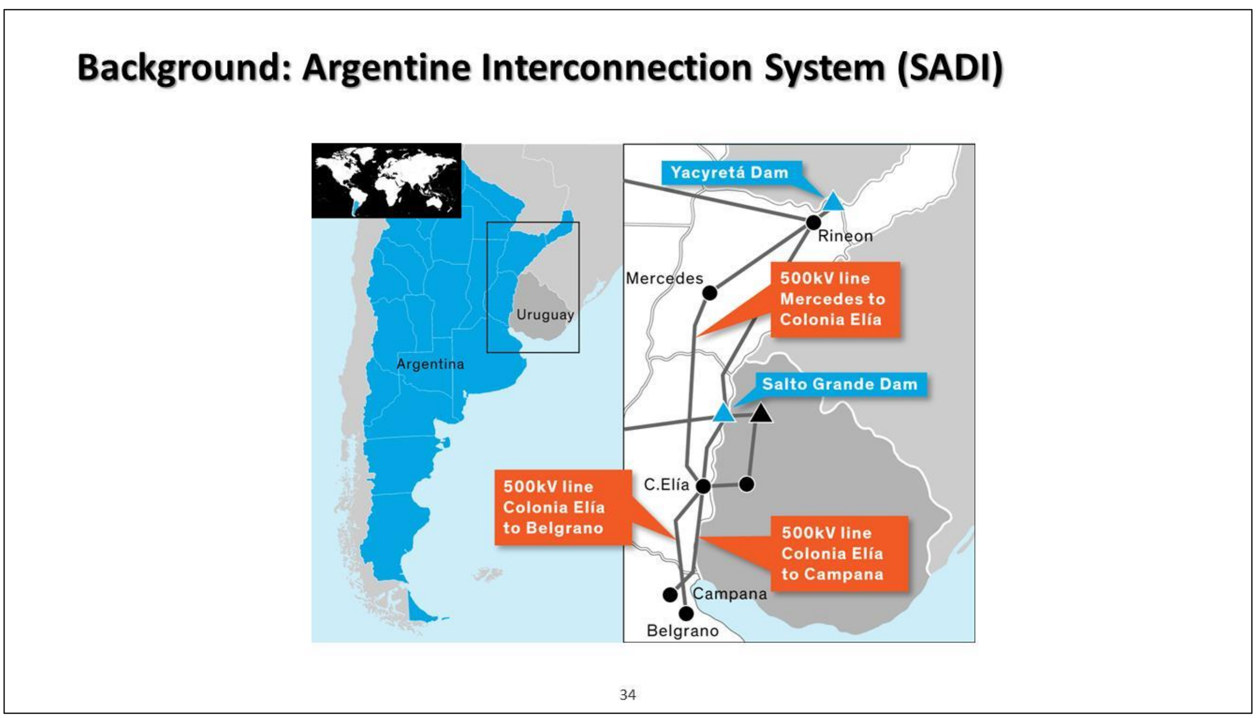
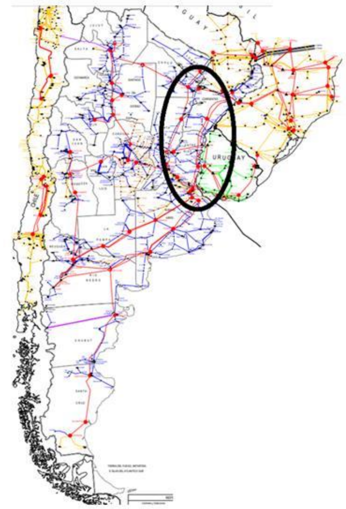
Argentina Blackout - June 16, 2019



Background: Sunday, June 16, 2019

- SADI system has ~39 GW of capacity
- Capacity mix: 2/3 thermal, 1/4 hydro, remainder nuclear
- Mild winter temps (southern hemisphere)
- Demand ~13.2 GW, about 70% of an average seasonal weekday
- June 16th had the 3.1 GW Yacyretá Hydro and the 1.9 GW Salto Grande Hydro near full output (high water levels)



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Argentina Blackout

- Grid Protection:
  - Automatic Disconnection of Generation — DAG (think SPS/RAS)
  - Seven levels of under frequency relays connected to 42% of their load
  - Careful monitoring by operators

> Argentina's grid protection systems and procedures have worked successfully for 30 years.

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The Event

- The 250 km (155 mile) north-south transmission line between Colonia Elia and Campana had been on a significant maintenance outage since April 2019
- Bypass built from Colonia Elia-to-Belgrano Station line
- At 07:06:24 there was a short circuit on the Colonia Elia-Belgrano line
  - Known DAG (again, think SPS/RAS) condition
  - **Action**: Temporarily disconnect a few power plants to reflect the sudden removal of demand

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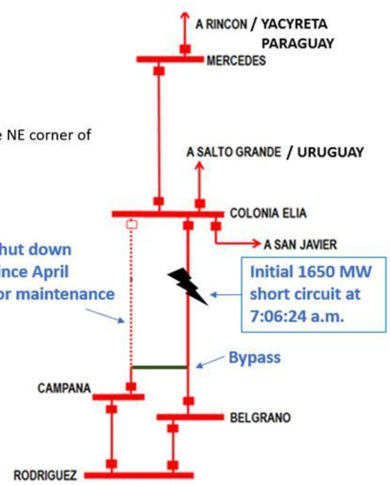
The Event

Simplified section of the NE corner of the Argentine grid



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The Event

Time: 07:06:24

- The "new" bypass was not configured properly - no grid/generation actions occurred
- Very quickly, SADI's system started having issues
  - Chain reaction of (non-DAG) breaker operations
  - Rapidly growing excess of generation over demand on the generation side of the fault

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The Event

Time: 07:06:26 (Two Seconds Later)

- Frequencies already far exceeded normal parameters
- Yacyretá and Salto Grande continued to operate at, or near, full power
- Grid breaks itself off into two separate "islands"
  - Nearly all of the demand on one side
  - The NE section of the grid (still tied to Uruguay and Paraguay) with the majority of the generation at the time
- The under frequency relays in the demand-heavy island failed to take adequate action, disconnecting 25% less than they should have
- Initial DAG failure resulted in poor/nonsensical information getting to operators

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The Event

Time: 07:06:30 (Another Four Seconds Later)

- Demand-heavy island loses 1.4 GW of generation
  - Embalse Nuclear plant
  - Three additional thermal plants
- Even with the conditions, these should not have tripped
- Demand-heavy island's imbalance is at 4.7 GW (38% of online generation)
- Island held together for an additional twenty-four seconds
  - Individual power plants making important decisions independently
  - No time to consult or coordinate

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The Event

Time: 07:06:54 (30 Seconds After Tripping)

- Generators around the country have independently disconnected from the demand-heavy island
  - Don't want to risk possible damage to their own assets
  - Disobeying existing protocols and procedures
- SADI had collapsed to below 2 GW
  - Recall that it was 13.2 GW at the time of the tripping (30 seconds ago)
- Approximately 48 million people were affected
  - All of Argentina and Uruguay
  - Parts of Paraguay

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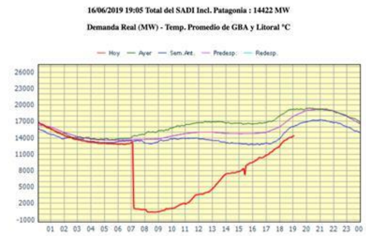
Summary

- Could have been worse: it was early on a Sunday morning with low demand
- Errors across the board
  - Grid operator failed to properly modify the DAG on the bypass
  - Distribution companies did not properly configure UFLS
  - Many, many generators took themselves offline, against established rules and regulations
- The numbers:
  - 48 million customers, across 3 countries
  - Collapse took ~30 seconds
  - System mostly restored in ~15 hours



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Not a List You Want to Be On

#	Event name	People affected (millions)	Countries affected	Date
1	India blackouts	620	India	July 2012
2	India blackout	230	India	January 2001
3	Bangladesh blackout	150	Bangladesh	November 2014
4	Pakistan blackout	140	Pakistan	January 2015
5	Java blackout	120	Indonesia	January 2019
6	Java-Bali blackout	100	Indonesia	August 2005
7	Southern Brazil blackout	97	Brazil	March-June 1999
8	Brazil-Paraguay blackout	60	Brazil, Paraguay	November 2009
9	Italy blackout	56	Italy, Switzerland	September 2003
10	Northeast blackout of 2003	55	United States, Canada	August 2003
11	**Argentina blackout**	**48**	**Argentina, Paraguay, Uruguay**	**June 2019**
12	Luzon blackout	40	Philippines	May 2002
13	Thailand blackout	40	Thailand	March 1978
14	Luzon blackout	35	Thailand	April 2001
15	Northeast blackout of 1965	30	United States, Canada	November 1965

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Impact of Major Blackouts on Society

Societal Impact of Blackouts

- Production
  - Loss of productivity
  - Loss of product or property
- Health
  - Food contamination
  - Medication problems
  - Anxiety
- Safety
  - Traffic accidents
  - Accidents due to visibility problems
  - Civil unrest

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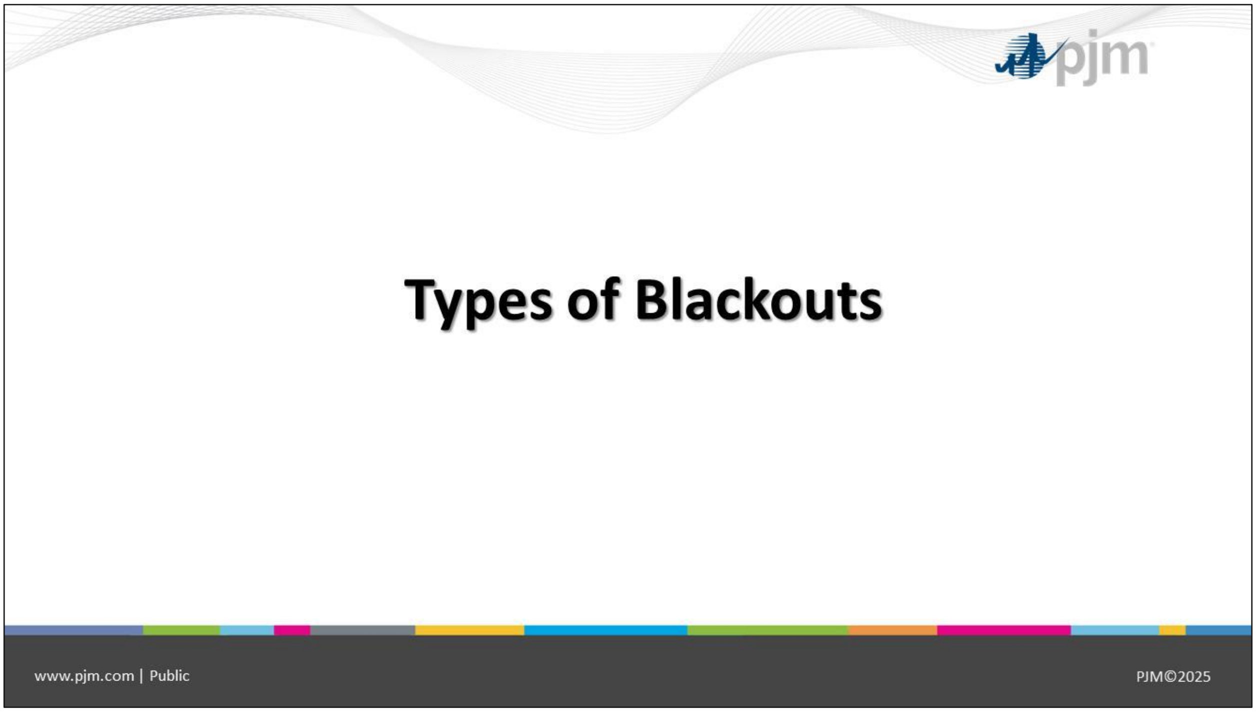
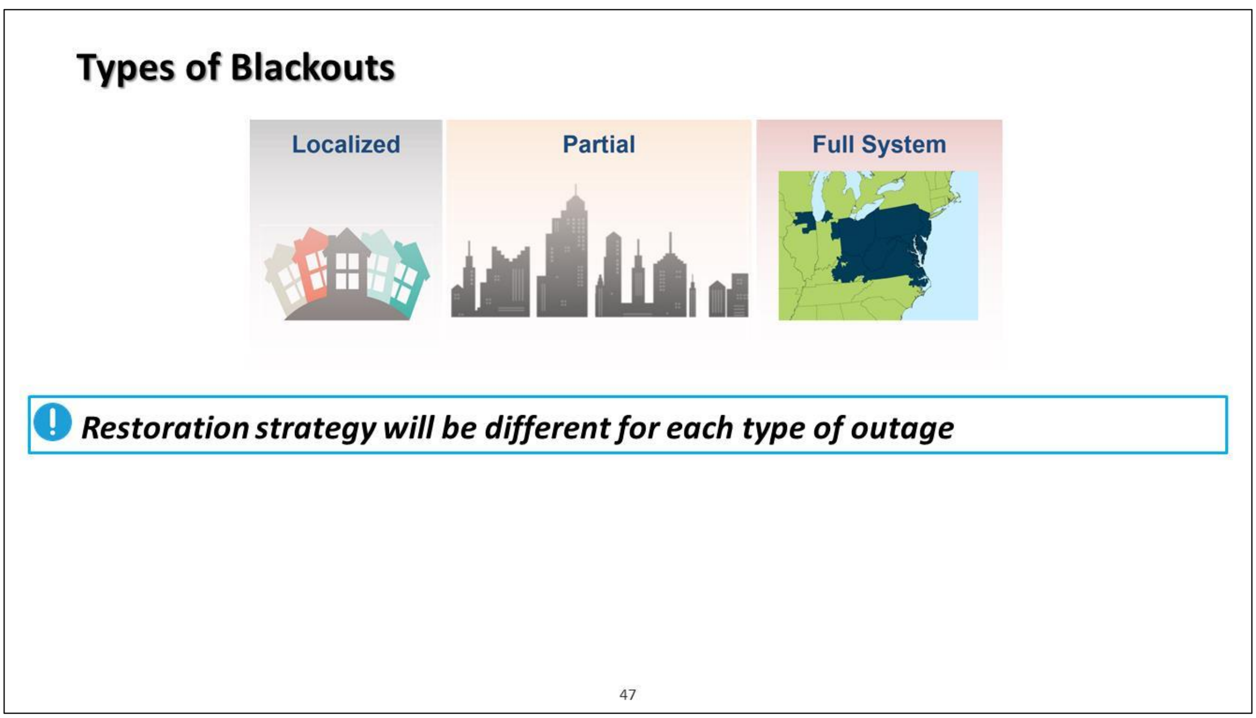
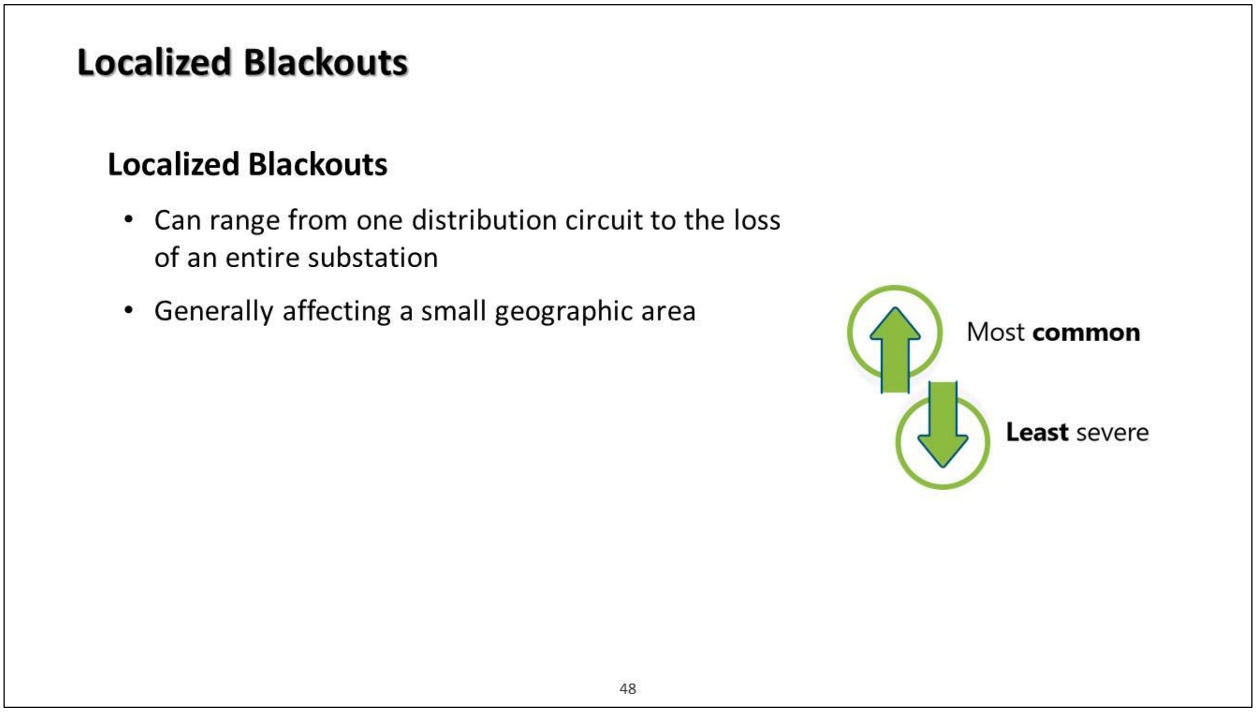
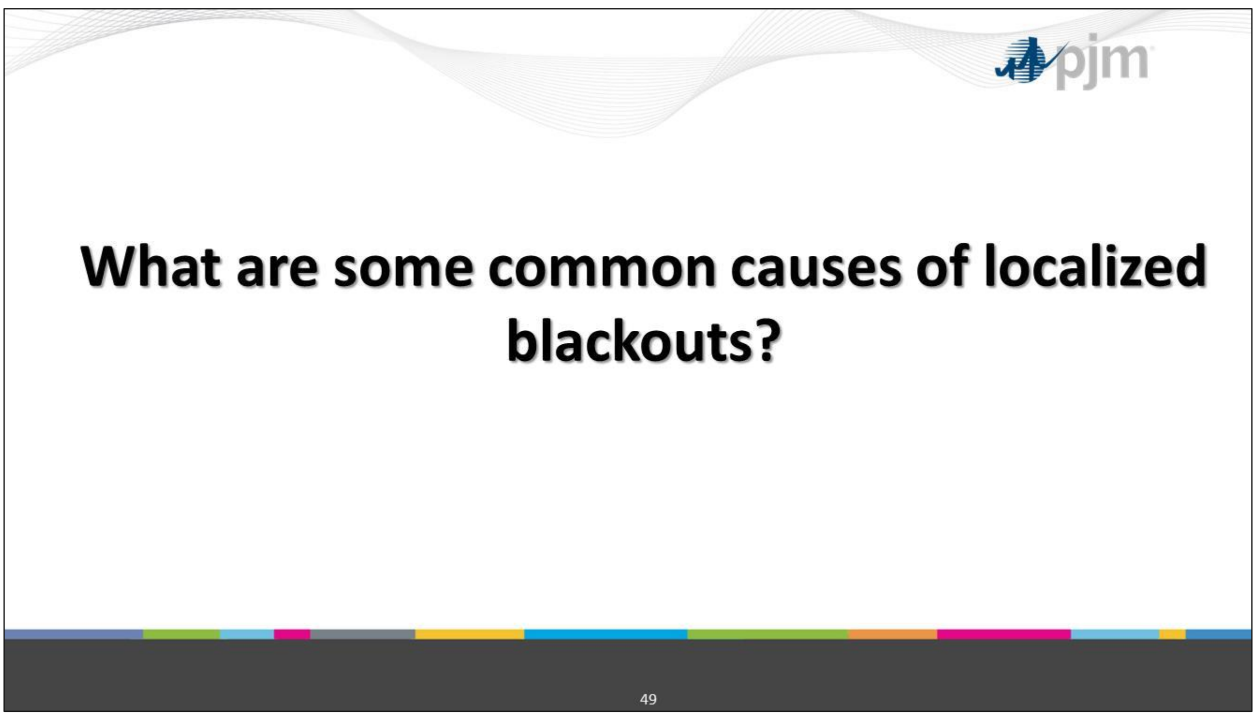
Types of Blackouts





Localized Blackouts





Localized Blackouts

- Effects on PJM:
  - May notice a rise in ACE if large amount of load was lost
  - May result in transmission issues

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Localized Blackouts

- Effects on other companies:
  - If on the distribution side, usually no impact
  - If on the transmission side, others may:
    - Feel a system "bump"
    - Have overtrip of relays
- Restoration method for Localized Blackouts:
  - Isolate faulted equipment
  - Restore load and remaining equipment through switching

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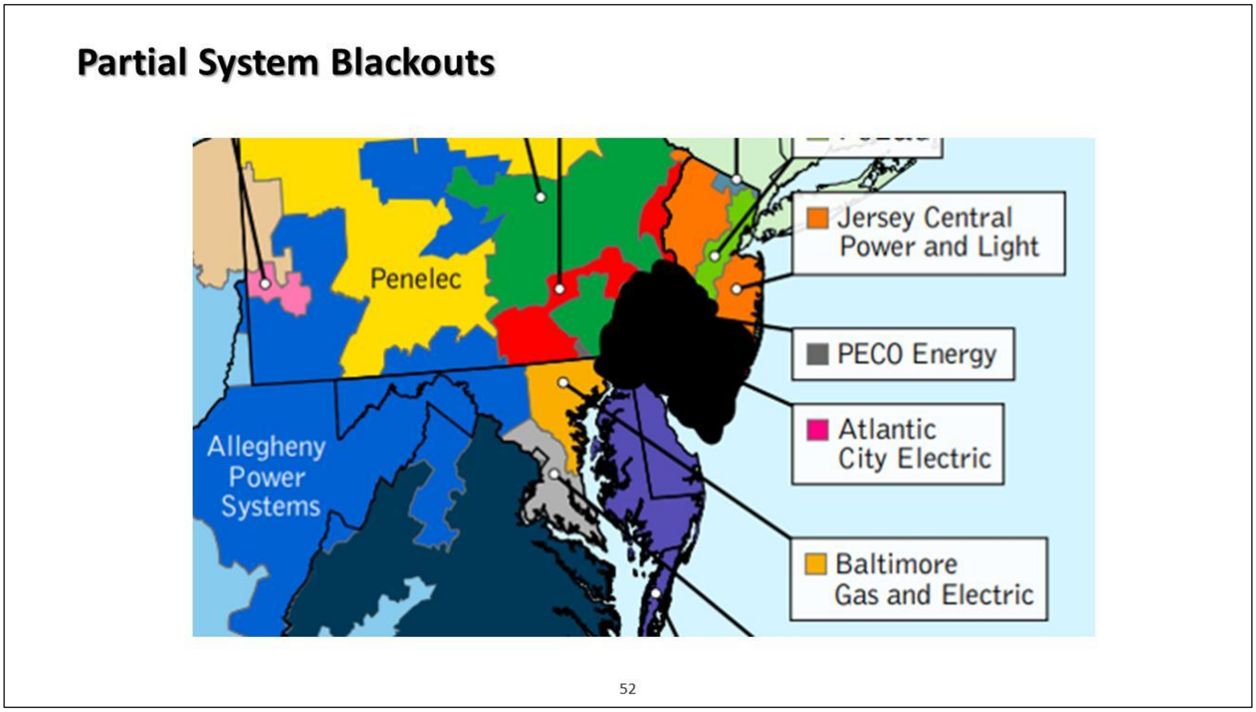
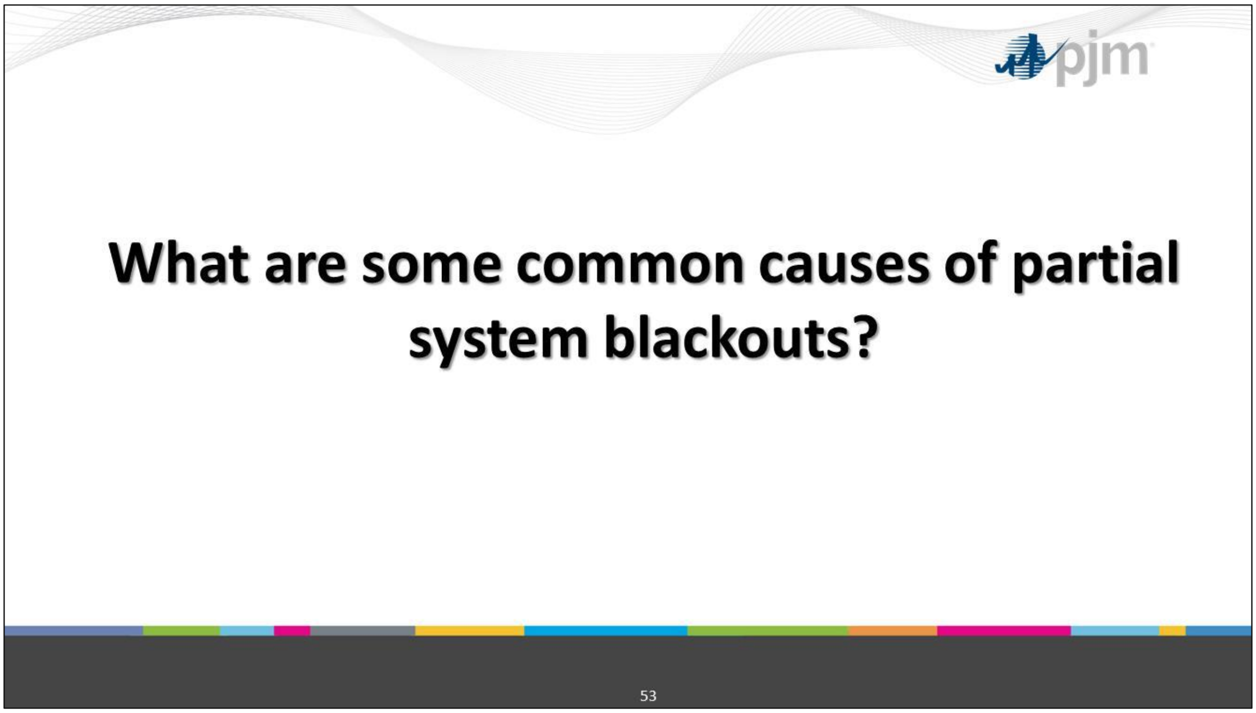
Partial System Blackouts



Partial System Blackouts

- Spans more than one substation
- May affect more than one Transmission Owner
- Generally affecting a large geographic area



Partial System Blackouts

- Most common causes of Partial System Blackouts:
  - Partial system voltage collapse
  - Cascading thermal overloads and trippings
  - Weather
  - Dynamic Instability
    - Multiple concurrent trippings of transmission, generation
    - Delayed fault clearing

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Partial System Blackouts

- **Effects on other companies:**
  - May also be partially blacked out
  - May experience voltage fluctuations (normally high)
  - May have transmission issues
- **Effects on PJM:**
  - Possible fluctuations in the ACE, voltages, and frequency

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Partial System Blackouts

- Restoration method for Partial System Blackouts:
  - Depends on the extent of the outage!
    - Restore through switching from unaffected system
    - Start generation in blacked out area
      - Create islands
      - Synchronize when possible

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Full System Blackouts

Full System Blackouts

Full System Blackouts

- One or more companies are totally blacked out
- Affects a very large geographic area and a large population of customers
- Each affected Transmission Owner may be in a different situation
  - Outside help available
  - No outside help available

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What are some common causes of full system blackouts?

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Full System Blackouts

- Most common causes of Full System Blackouts:
  - System voltage collapse
  - Frequency deviations
  - Dynamic instability
  - Cascading thermal outages
  - Severe weather event (e.g., hurricane, earthquake)
  - Sabotage, acts of war

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Full System Blackouts

- **Effects on other companies:**
  - May be blacked out or islanded
  - May be asked to provide assistance to neighbors
  - Will experience some operating issues
    - Power, voltage swings
- **Effects on PJM:**
  - Similar to company effects
  - May need to coordinate multiple islands
  - Will need to adjust interchange schedules

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Full System Blackouts

- Restoration method for Full System Blackouts, depends on:
  - If outside help is available
    - If it is, this opportunity should be investigated!
  - Individual company restoration philosophy

> ! Any opportunity to connect to the Eastern Interconnection should be explored as soon as possible

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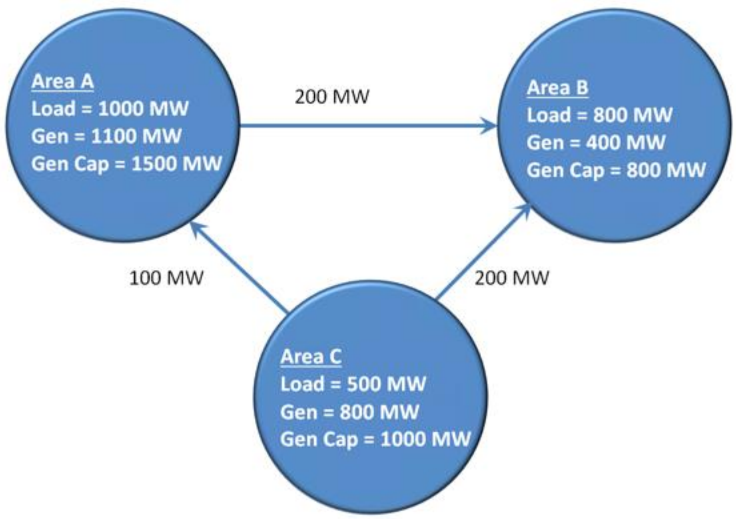
System Disturbance Exercise

System Disturbance Exercise

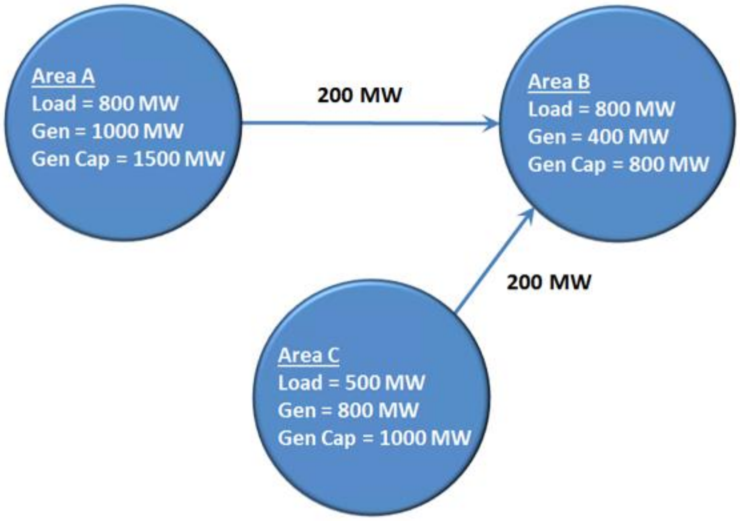
Initial Conditions



- An interconnection with three Control Areas is shown. Use this data to answer the following questions.

  - Frequency of this interconnection is 60.00 Hz.
  - All tie flows are on schedule.
  - Actual tie flows are shown.

Event A - Resulting Conditions



Use the diagram and compare to the initial conditions to determine:

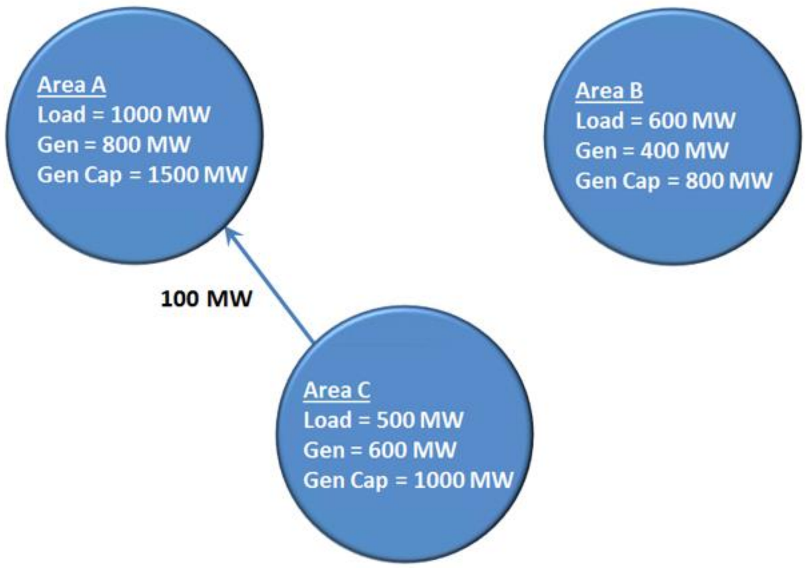
1. **What occurred on the system and in which area?**

2. **What impact did the event have on frequency in the system?**

3. **What other system problems might you expect?**

4. **What control actions do you suggest to recover the system?**

Event B - Resulting Conditions

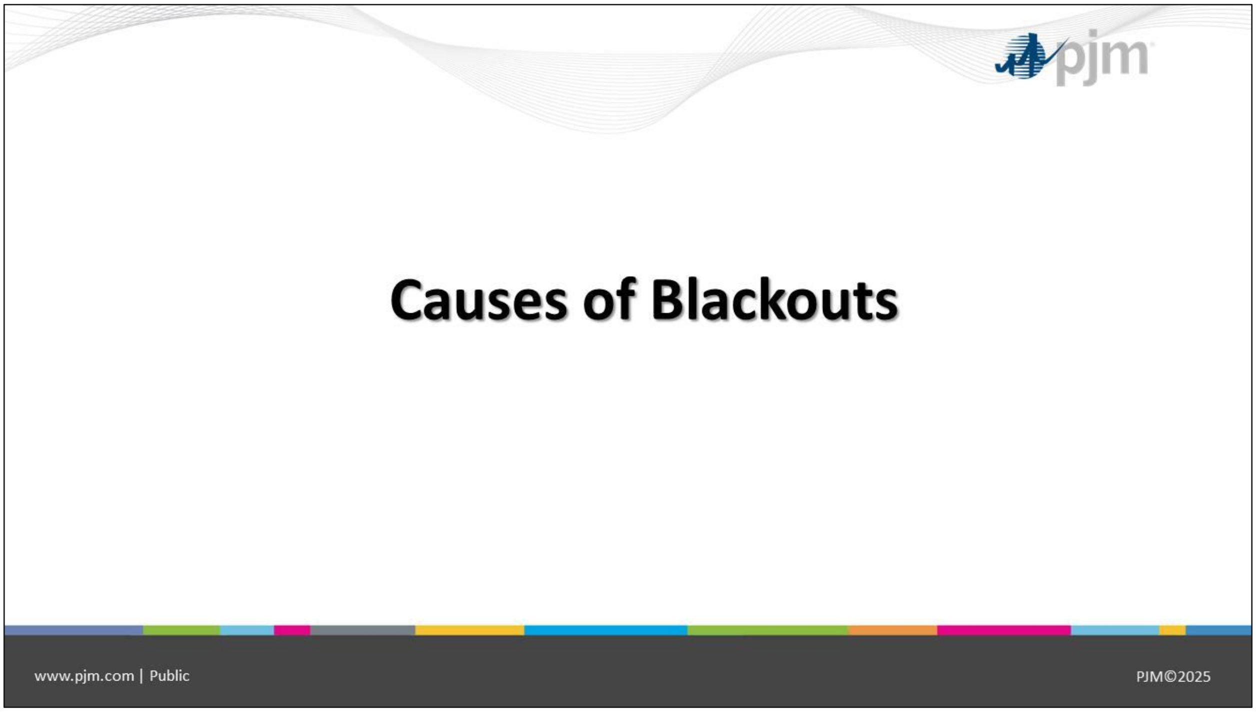


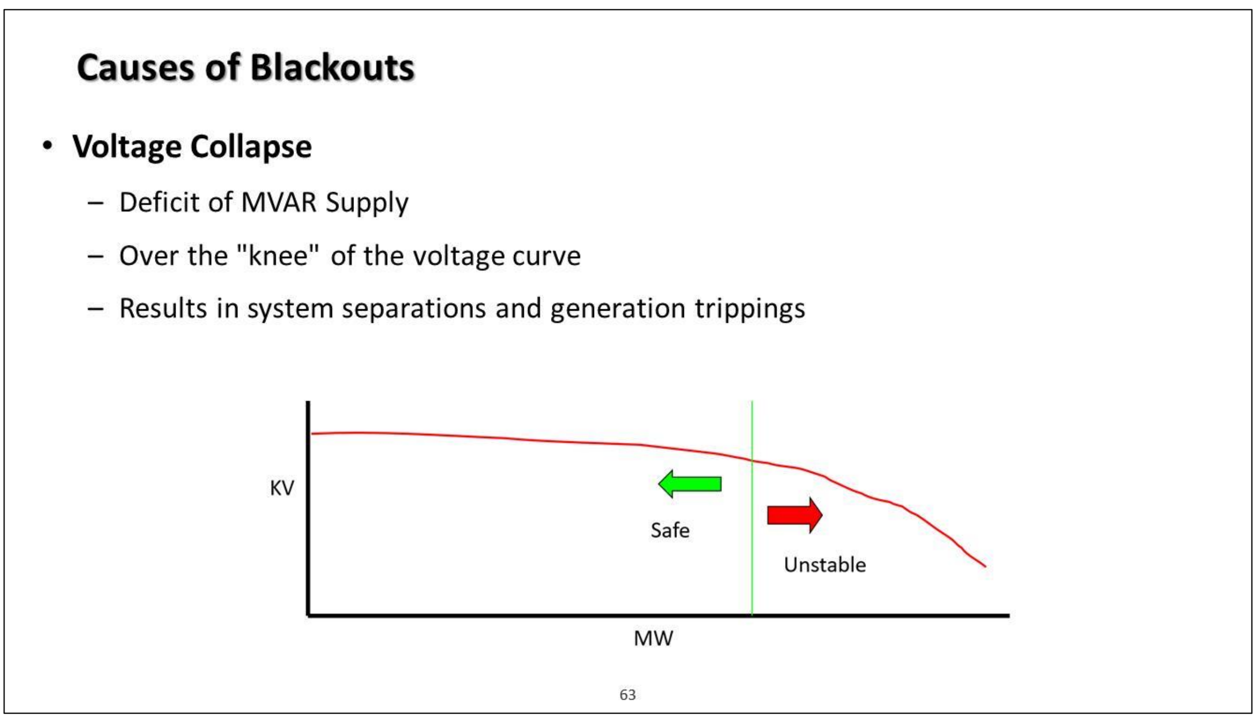
Cascading trippings on lines from A–B and B–C result in a new set of conditions:

5. **What concerns do you have as an operator looking at the three systems?**

6. **Area B blacks out due to low frequency. How would you suggest that they proceed in restoration?**

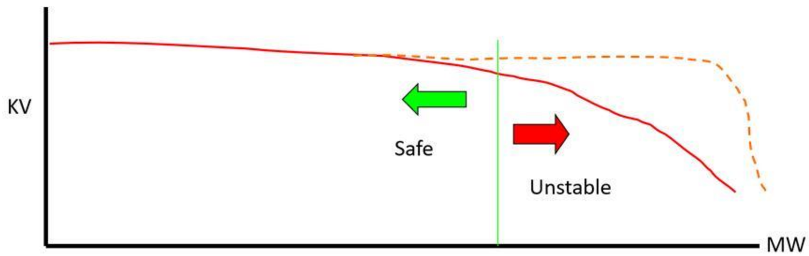
Causes of Blackouts





Causes of Blackouts

- **Voltage Collapse**
  - Impossible to predict boundaries of separation
  - May be detected by looking for areas of voltage decay
    - Use of shunt capacitors can maintain near normal voltage up to the point where voltage support resources run out
    - Voltage curve starts to look like a right angle



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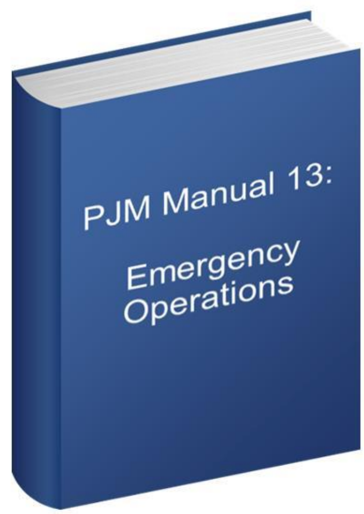
Causes of Blackouts - Voltage Collapse

Rapidly decaying voltage (especially in high load periods) should be considered an emergency situation!



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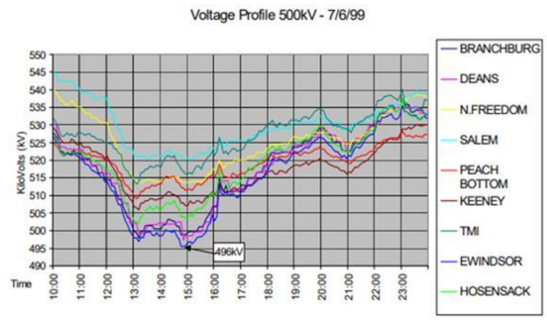
PJM Voltages - July 6, 1999

Times of Notable Events

1358	5% Voltage Reduction
1500	Cut 100 MWs of Spot Ins
1515	TLR Issued (1202 MWs cut for 200 MWs relief)
1600	Cut 100 MWs of Spot Ins
1608	Red Bank Station Trips



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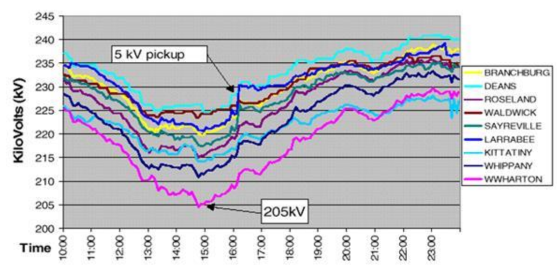

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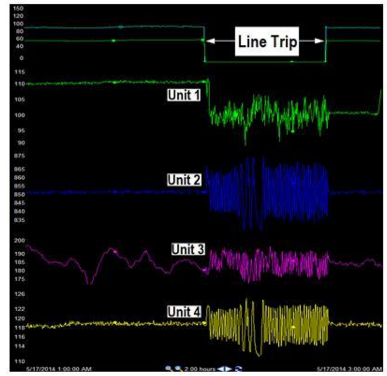
Causes of Blackouts

- **Dynamic Instability**
  - System does not damp out normal oscillations
  - Groups of generators "swing" against each other, resulting in large oscillations in MW, MVAR
  - Could result in:
    - Generation trippings
    - Voltage collapse
    - Equipment damage
  - **Time Frame:** 5-15 seconds



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Causes of Blackouts

- **Cascading Thermal Overloads**
  - Transmission Operating Criteria is designed to prevent cascading overloads (first contingency)
    - No equipment can be operated such that the loss of a single facility causes any other facility to exceed its emergency thermal rating
  - Could also be caused by severe weather
  - **Time Frame:** minutes to several hours

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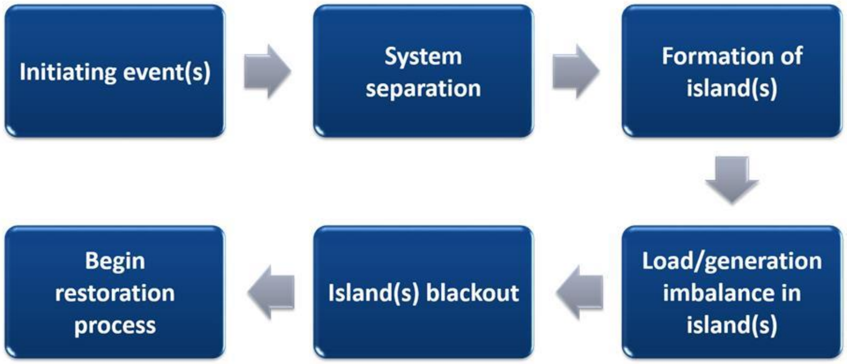
Common Sequence of Events in Blackouts



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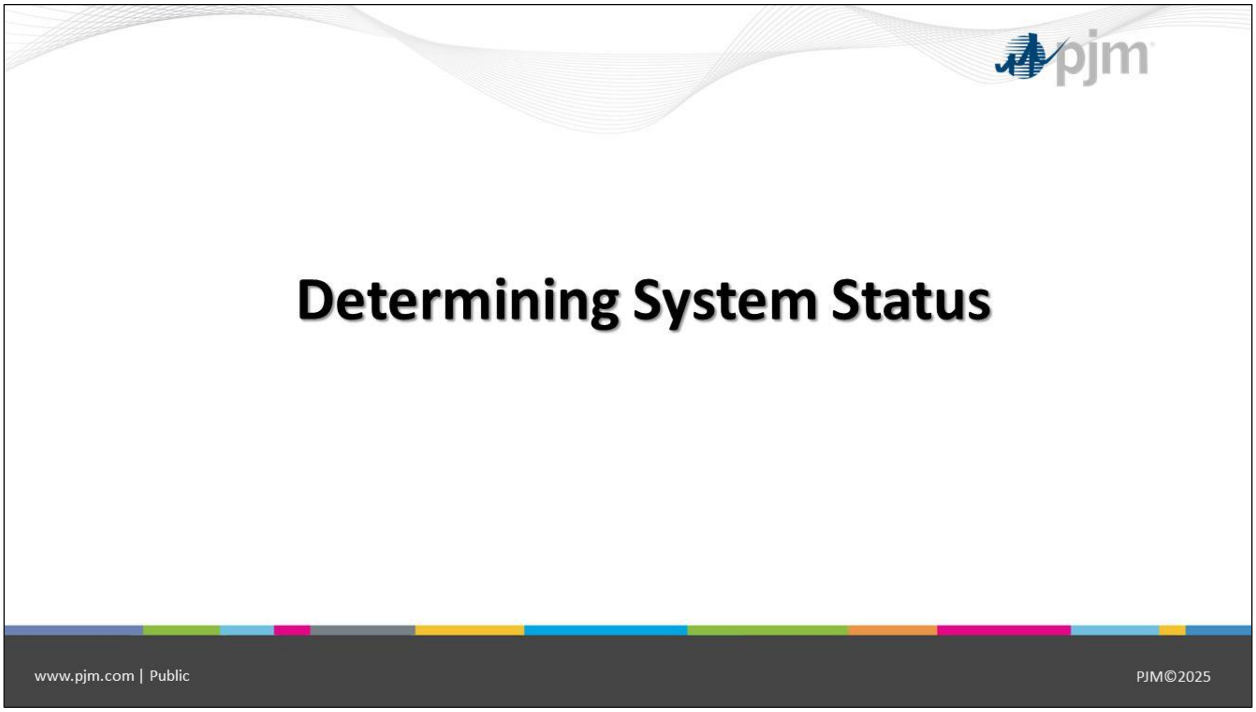
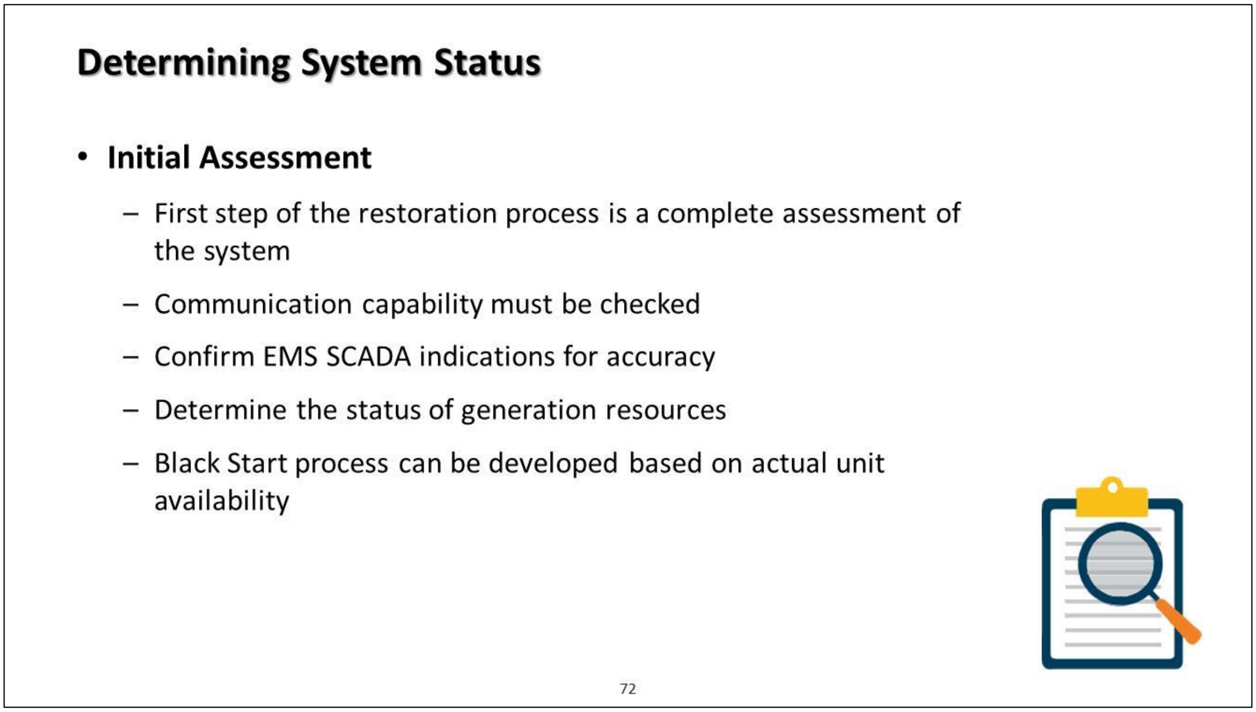
Initial Assessment





Initial Assessment

EMS Alarms

- First indication of a problem
- Barrage of alarms will appear
  - Smart event processing may reduce redundant alarms
- Alarms will aid in assessing the system and post-event analysis

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Initial Assessment

Other EMS considerations

- State Estimators and Security Analysis functions will not work in a complete or partial blackout situation
- Slow EMS due to amount of alarm processing
- Telemetry and control may be spotty due to:
  - Communication failures
  - RTU failure or substation battery failure
- Data received may be of questionable integrity

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Initial Assessment - Communications

- Functional communications are critical for the assessment of the extent of a blackout
- **First** action following a blackout is to verify communication with:
  - PJM
  - Neighbors
  - Generating Stations
  - Substations
- Backup communication systems should also be verified since it may be necessary to utilize these systems

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- The ability to communicate under adverse conditions is critical to any efforts in the process of system restoration. All methods of communication are important during the restoration of the system including:

  - Voice
  - Print
  - SCADA
  - Data exchange

Initial Assessment - Communications

- Eliminate non-productive telephone communications
- Establish a communication center **outside** of dispatch center for communication with:
  - Governmental agencies
  - Media
  - Customers
- Call for help
  - Extra dispatchers
  - Support personnel
  - Substation manpower

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COMPANY INITIAL RESTORATION REPORT

Reporting Company:	Date:
Reporting Contact:	Time:
Generation Lost (Capacity)	MW
Generation Still Operating (Capacity)	MW
Generation Still Operating (Energy)	MW
# of Generators on Line	
# of Subsystems (Islands)	
Customers Load Lost	MW
% of Customer Load Lost	%
# of Customers Lost in (000)	THS.
% of Customers Lost	%
Total Restoration Expected to be Completed by, Date/Time	

Equipment Damage: ____

____

____

____

____

____

Comments (Any outside ties with systems external to PJM that may have survived, etc.): ____

____

____

____

____

____

Capacity – Rated Load Carrying Capability

Energy - MW Loading on a Machine

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PJM Composite Initial Restoration Report

Date: / /

Time: HRs

Generation Data by transmission Zone

Company Report Time:								FE-E	FE-E	FE-E																PJM
Company:	RECO	PS	PE	AE	DPL	PL	UGI	JC	ME	PN	BC	PEP	SMECO	DOM	FE-S	DLCO	DAY	AEP	COM	Rochelle	FE-W	CPP	DUKE	EKPC	OVEC	Total
Generation Lost (Capacity) MW																										
Generation still Operating Capacity (MW)																										
Generation still Operating Energy (MW)																										
# of Generators on Line																										
# of Subsystems																										

Load Data by Transmission Zone

Company Report Time:								FE-E	FE-E	FE-E																PJM
Company:	RECO	PS	PE	AE	DPL	PL	UGI	JC	ME	PN	BC	PEP	SMECO	DOM	FE-S	DLCO	DAY	AEP	COM	Rochelle	FE-W	CPP	DUKE	EKPC	OVEC	Total
Customer Load Lost MW																										
% of Customer Load Lost																										
# of Customers Lost (000)																										
% of Customers Lost																										
Estimate for Total Restoration (Date/Time)																										

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Generator Assessment

Determining Generator Status

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Determining Generator Status

Determine surviving on-line generation
Stabilize surviving on-line generation
Determine status of off-line generation
Determine preferred sequence of starting off-line generation
Prepare off-line generators for start-up
Restore auxiliary power to off-line generation

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Determining Generator Status

- Determine the status of **on-line generation**:
  - Location
  - Damage incurred during the event
  - Generator stability
  - Marginal generation
  - Connectivity to the system (e.g., islanded or connected to the interconnection)

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Determining Generator Status

- Determine the status of **off-line generation**:
  - Operating status prior to the event
  - Black-start capability
  - Individual unit characteristics
  - Damage assessment
  - On-site source of auxiliary power versus the requirement of cranking power
  - The availability and location of cranking power

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Determining Generator Status

- Sequence of restoration of off-line generation will be determined by:
  - Generator type
  - State of unit operation prior to the event
    - Hot units may be returned quicker than cold units
  - Unit availability

Type of Generator	Time to Start
Hydro	Quick start - minutes
Small Combustion Turbine (CT)	Quick start - ~10 minutes
Large CT	>1 hour
Drum-Type Steam	1 - 20 hours (Status)
Super Critical Steam	4 - 20 hours (Status)
Nuclear	24-48+ hours

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Determining Generator Status

- Restore **auxiliary power** to off-line generation:
  - Auxiliary power is restored to generators as soon as possible to improve their availability
  - Station emergency generators and back-up batteries may provide power for only the most essential safety systems, but cannot be counted on as a source for a unit start-up
  - Early restoration of auxiliary power to the non-black start units will help control equipment damage and minimize the time for required unit re-starts

! Short delays in restoring auxiliary power could result in long delays in restoring generation

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What are some consequences of not restoring auxiliary power quickly enough?

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- Congealed fuel oil
- Sludge thickening in scrubbers (large demand of aux power; as much as 30MW)
- Battery life expended
- Bearing damage
- Bowed shaft due to loss of turning gear

Determining Generator Status

- Prioritization of available cranking power depends on:
  - NRC requirements
  - Transmission Owner (TO) restoration plan
  - Start-up time of unit
  - Availability of on-site auxiliary power
  - Distance of cranking power from generation
- Effective communication with generating stations is essential in this process!

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Determining Generator Status

Generating Plant Operator Actions:

- Steam plant operators implement start-up procedures immediately following a plant shutdown unless instructed otherwise by the dispatcher
- Governors must be in service to respond to large frequency deviations
- Frequency control is maintained between **59.75 Hz** and **61.0 Hz**
- Plant operators must take action on their own to control frequency outside the range of **59.5 Hz - 61.0 Hz**

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Generation Assessment Exercise

Generation Assessment Exercise

Generation Assessment

__	Small CT that had been off-line prior to blackout that is electrically close to a nuclear plant
__	Drum-type steam unit that was on-line prior to the blackout
__	Coal-fired steam unit that has been off-line for 2 weeks
__	Nuclear unit that is off-line for re-fueling outage for 6 more weeks
__	Large CT that was off-line prior to the blackout
__	Supercritical steam unit that was on-line prior to the blackout
__	Run-of-river hydro unit with plenty of water available, electrically removed from other generation
__	Nuclear unit that was on-line prior to the blackout

Your system has just suffered a complete blackout. You do a quick assessment of your generation resources and list them below. ***Rank the following units from 1 (highest priority) to 8 (lowest priority) in order of start-up priority.***

Transmission Assessment

Determining Transmission Status

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Determining Transmission Status

- Key EMS indications to determine extent of outage include:
  - Frequency measurements (if available)
  - Voltage measurements
  - Circuit breaker status
- If possible, verify EMS indications with field personnel

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Determining Transmission Status

Open circuit breakers may indicate:

- Permanent faults which may have initiated system shutdown
- Out-of-step conditions
  - As system collapses, power flow may swing through the impedance settings of line relays and trip the line
  - These lines do not have a fault and **are available for restoration**
- Temporary faults in lines, transformers, reactors, and capacitors
  - Caused by cascading overloads, line sag, equipment providing neutral over-current
  - Generally, this equipment's relays lock out and must be manually reset
  - Equipment *may* be available for restoration, though may require additional testing to ensure no internal damage

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Determining Transmission Status

Closed circuit breakers may indicate:

- De-energized line with no problem
- Damaged equipment that was never cleared by relay action
- Equipment that was damaged **after** the system shutdown

Determination of initiating event of the system shutdown will go a long way in determining the status of transmission

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Determining Transmission Status

- The first step of the restoration process is a complete evaluation of the transmission system.
  - SCADA indications should be confirmed by field personnel as required or verifying key indications from other sources.
  - All known and/or suspected transmission damage should be identified.
- It should be noted that SCADA systems are designed so that alarm processing does not prevent the detection of problems and are capable of continued operation during system disturbances/blackouts.

> ⚠ After a blackout event has taken place, circuit breaker positions will not provide a reliable indication of faulted versus non-faulted equipment.

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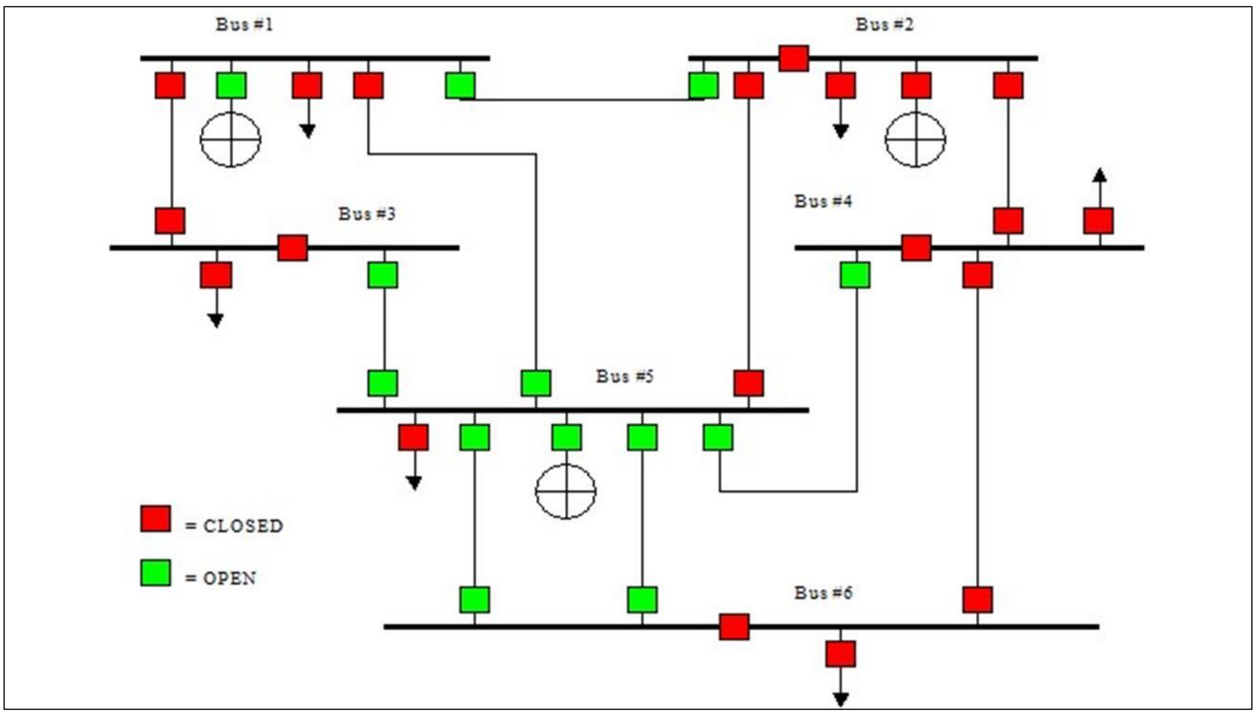


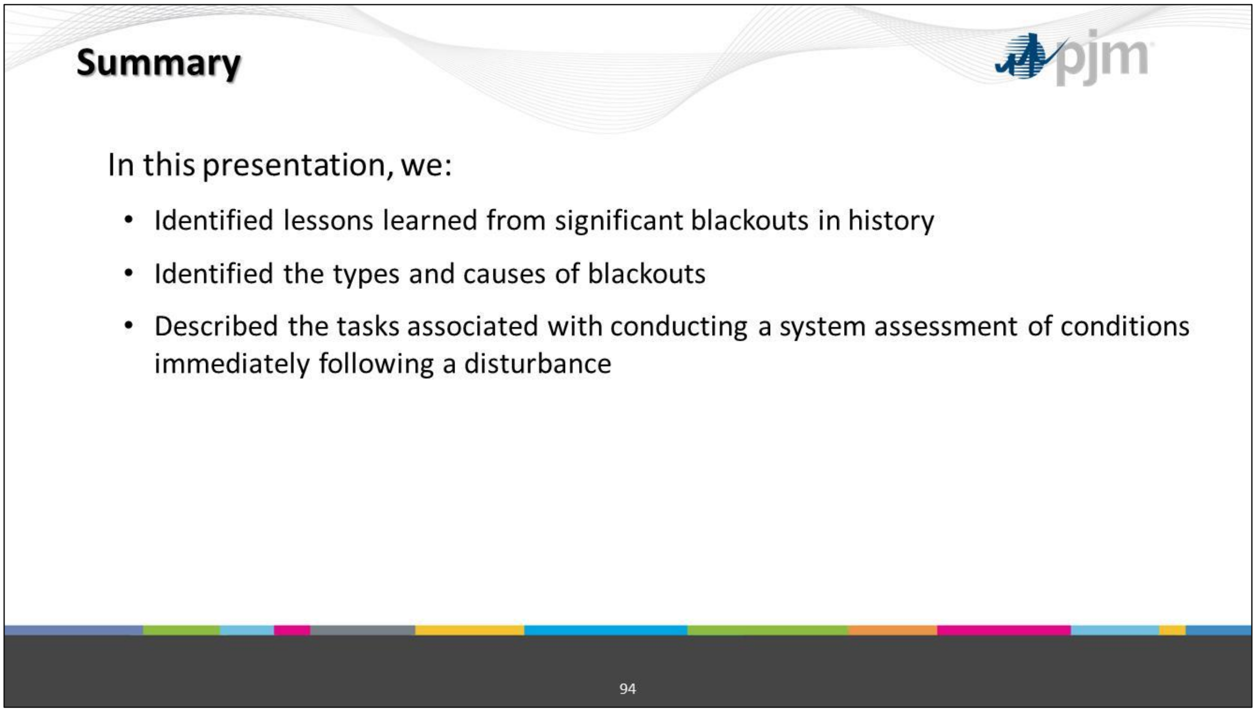
Based on the diagram, consider the following questions:

- Is the system in the diagram blacked out?
- If the system is still energized, which generator(s) survived the event?
- Which buses are still energized?
- How many circuits with load are energized?

- Without any type of verification, what would be the best solution in order to get cranking power to the generator connected to Bus #1?

- Using the line from Bus #1 to Bus #5, how would you proceed?

Summary



Questions?

PJM Client Management & Services	
Telephone:	(610) 666-8980
Toll Free Telephone:	(866) 400-8980
Website:	www.PJM.com
Email:	trainingsupport@pjm.com

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