Impacts and Actions Resulting from the August 14, 2003 Blackout

David W. Hilt P.E.
July 29, 2006
Illinois Society of Professional Engineers
August 14, 2003
What Happened?

4:10:44 to 4:13:00 p.m.
Summary of August 14 Blackout

**Impacts**
- 8 states/2 provinces
- Over 50 million people
- 60-65,000 MW
- 30 hours to restore
- Manufacturing disrupted
- 531 generators tripped
  - 19 nuclear generators at 10 plants

**Statistics**
- Line trips began at 3:05 PM
- Cascading began at 4:06 PM
  - Lasted approximately 12 seconds
- Thousands of discrete events
Every Blackout has Impacts

- **November 9, 1965 - NY Blackout**
  - 30,000,000 people and over 20,000 MW of demand – up to 13 hours

- **July 13, 1977 - New York City**
  - 9,000,000 people and 6,000 MW of demand – up to 26 hours

- **July 2, 1996 - Western US**
  - 2,000,000 customers (10% of the Western Interconnection) and 11,850 MW of demand for up to several hours

- **August 10, 1996 - Western US**
  - 7,500,000 customers; 28,000 MW of demand for up to 9 hours
August 14, 2003

Warm But Not Unusual for August
Situational Awareness

- 2:14 PM – First Energy Alarm logger fails and operators are not aware of any line outages
  - S. Canton - Star 345 kV line trip and reclose at 2:27 PM

- FirstEnergy IT staff reboots system when paged – did not communicate with operators

- No contingency analysis by FirstEnergy of events during the day

- Midwest ISO – Failure of part of monitoring system due to data error
What happened on August 14

At 1:31 pm, FirstEnergy lost the Eastlake 5 power plant, an important source of reactive power for the Cleveland-Akron area.

Starting at 3:05 pm EDT, three 345 kV lines in FE’s system failed – within normal operating load limits -- due to contacts with overgrown trees.
East Lake 5 Exciter Failure Causes Trip

MW / MVAr

Exciter Control trips to manual and backs off overloaded MVAr output

Rated MVAr Limit

MVAr

Exciter System trips completely off as operator returns it to automatic voltage control

Voltage

11:00 12:00 13:00 14:00

Time - EDT

kV

600 400 200

360 350 340 330
Hanna - Juniper Tree Contact

poor ground clearance = premature failures
What Happened - Ohio

138 kV Cascade Contributes to the ultimate overload of the Sammis-Star 345 kV line.

This line begins the spread of the cascade beyond Ohio.
What Happened -- Ohio

After the 345 kV lines were lost, at 3:39 pm FE’s 138 kV lines around Akron began to overload and fail; 16 overloaded and tripped out of service.
Communications

Phone Calls to Control Area (FE)

- CA receives calls from MISO, AEP, and PJM but did not recognize evolving emergency
  - 2:32 AEP calls regarding trip & reclose of Star-S. Canton
  - 3:19 AEP calls confirming Star-S. Canton trip & reclose
  - 3:36 MISO calls regarding contingency overload on Star-Juniper for loss of Hanna-Juniper
  - 3:45 tree trimming crew calls in regarding Hanna-Juniper flashover to a tree
  - PJM calls MISO at 3:48 and FE at 3:56 regarding overloads on FE system
At 4:05 pm, FirstEnergy’s Sammis-Star 345 kV line failed due to overload.
Actual Loading on Critical Lines

- Harding - Chamberlin Line Trip
- Hanna - Juniper Line Trip
- Sammis - Star Line Trip
- Star - South Canton Line Trip
- East Lake 5 Trip
Actual Voltages Leading to Sammis-Star

Voltage (kV)

- 100% Voltage
- 95% Voltage
- 90% Voltage

Star
Hanna
Beaver
Perry

Harding - Chamberlain 345 kV Line Trip
Hanna - Juniper 345 kV Line Trip
Star - South Canton 345 kV Line Trip
Sammis - Star 345 kV Line Trip

Time - EDT
15:00 16:00
What Happened -- Cascade

1) 4:06
2) 4:08:57
3) 4:10:37
4) 4:10:38.6
NY to Ontario 345kV Line Flows at Niagara
Progressively Worsening Stability Conditions

New York to Ontario 345 kV Line Flow at Niagara
(does not include 230 kV line flow)
What Happened -- Cascade

5) 4:10:39
6) 4:10:44
7) 4:10:45
8) 4:13
Severe Voltage Depression in Downtown and Southern Detroit Region

Toledo/Cleveland Island Separates from Detroit

Detroit Area Generation Pulls Out of Sync and Slips 2 Poles as Frequency Increases to ~62 Hz

Significant Generation Loss and/or Transmission Separation in Detroit

Remaining Detroit Generation Slips 2 Poles as Frequency Falls

Keith-Waterman Trips at 16:10:43.2

Classical Stability

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Classical Stability
Severe Under Frequency Condition
View Into Detroit from Lambton
Frequency in Ontario and New York

Frequency Separation
Interior Ontario and Northern New York

Northwest Ontario Stays with Manitoba
Beck Re-Separates from Interior Ontario System
Beck and St Lawrence Stay Separated from Interior Ontario but Connected to New York State

Beck Reconnects to Interior Ontario System
Beck and St Lawrence Separate from Interior Ontario System
Generation

The blackout shut down 263 power plants (531 units) in the US and Canada, most from the cascade after 4:10:44 pm – but none suffered significant damage.

Generation outages did not initiate this cascading blackout.

On-line units in the Cleveland area were running at maximum MVAR.
Nine Mile Point Unit 2 Trips

Nine Mile Point Unit 2 Generation Data
(Reconstructed)

-200 0 200 400 600 800 1000 1200 1400

30 40 50 60 70 80 90 100 110 120

Seconds from 16:10
August 14, 2003

32 36 40 44 48 52 56 60 64

System Frequency

Generator Net Output MWe

Disturbance Begins
Unit 2 Accelerates During Frequency Increase
Governor Runback
Governor Runback

60.3 Hz
63.0 Hz
63.1 Hz

Unit 2 Accelerates

Reactor Trip on Low Turbine Control Hydraulic Pressure
Excitation System Tripped
Breakers Open
Power System High Level Sequence

- Premature failure of three 345kV lines
  - first trip and reclose at 2:27 PM due to ground fault
  - starting at 3:05 PM, three permanent outages within 40 minutes due to ground faults
  - ampere loading less than Emergency long time rating
  - failure of ground clearance management (trees)

- Northeast Ohio 138kV cascade began 3:39 PM

- Northern Ohio 345kV high speed cascade of three overloaded lines 4:05:57 - 4:09:07 PM

- Eastern Interconnection Separates by 4:11PM

- Blackout Complete by 4:13 PM
When the Cascade Was Over

- 50+ million people
  8 states and 2 provinces
- 60-65,000 MW of load initially interrupted
  - Approximately 11% of Eastern Interconnection
- Sammis - Star trip at 4:06 PM
  - Blackout essentially complete by 4:13 PM
- High speed cascading lasted approximately 12 seconds
- Thousands of discrete events to evaluate
  - Time stamping - critical
Investigation Organization Overview

Steering Group

U.S – Canada Task Force

Investigation Team
Lead – D. Hilt

Project Planning and Support

Root Cause Analysis Cooper Systems

Investigation Process Review

Vegetation/ROW Management

MAAC/ECAR/NPCC Coordinating Group

MAAC

ECAR

NPCC

MEN Study Group

NERC & Regional Standards/Procedures & Compliance

Restoration

Data Requests and Management

System Modeling and Simulation Analysis

Sequence of Events

Operations - Tools, SCADA/EMS Communications Op Planning

Frequency/ACE

System Planning, Design, & Studies

Transmission System Performance, Protection, Control Maintenance & Damage

Generator Performance, Protection, Controls Maintenance & Damage
Causes of the August 14 Blackout

- Inadequate situational awareness
- Ineffective vegetation management
- Inadequate diagnostic support at MISO
- Failure to follow NERC Operating & Planning Standards
Key Findings

- Inadequate system planning and design studies, operations planning, facilities ratings, and modeling data accuracy
- Operating with insufficient reactive margins
- More effective system protection and controls could slow or minimize spread of cascading outage
- Problems from prior blackouts were repeated
The Old

● The three “T’s”
  ▪ **Tools** – for the operator to monitor and manage the system
  ▪ **Trees** – vegetation management to prevent tree contacts
  ▪ **Training** – operators need to provided training and drills to be prepared to respond to system emergencies
The New

- Failure of tools
  - Information Technology support – communications
  - “Game Over”
- Generation protection
  - Consideration of performance during dynamic and extreme low voltage events
  - Coordination of plant controls with the transmission system
NERC Actions

- Initial Near-Term Actions
- Actions Resulting from Investigation
  - Corrective Actions
  - Strategic Initiatives
  - Technical Initiatives

Goals:
1. Correct root cause deficiencies
2. Address contributing factors
3. Identify objective and measurable actions
Corrective Actions: FE

- Voltage criteria and reactive resources
- Operational preparedness and action plan
- Emergency response capabilities and preparedness
- Control center and operator training
Corrective Actions: Reliability Coordinators

- MI SO
  - Reliability tools
  - Visualization tools
  - Operator training
  - Communications
  - Operating agreements

- PJ M
  - Communications protocols and procedures
NERC Strategic Initiatives

- Strengthen compliance
- Readiness audits
- Vegetation-related outage reporting
- Track implementation of recommendations
Strengthen Compliance with NERC Standards

- Strengthen standards & measures
- *Confidential* reports to the NERC Board
  - Specific violations
  - Results of audits
- Release of confirmed violations
  - Identification of violators
- Legislation needed to make rules mandatory
Readiness Audits

- Audit all control areas and reliability coordinators
  - Based on preparedness to comply with NERC requirements
  - Seek to achieve excellence
- Complete within 3 years and repeat on a 3-year cycle
- Reports to the Board

Not a Compliance Audit
Vegetation-Related Outage Reports

- Report tree contacts to the Regions (230+ kV)
- Regions report to NERC
- Regions to conduct and report on annual vegetation management surveys
Recommendations Tracking

● NERC and Regions will track:
  - Implementation of recommendations
  - Compliance audits
  - Readiness audit recommendations
  - Lessons learned from system disturbances

  - Recommendations implemented
Technical Initiatives

- Forward looking to prevent future blackouts
  - New standards, procedures, protocols
  - Existing technologies to be considered
  - New technologies
  - Changes in system planning, design, and assessment
  - Changes to operator training programs
Suddenly, knowing a lot about the U.S. power grid became sexy at cocktail parties.
Next Steps

- Continue to implement strategic initiatives and recommendations
- Readiness audits
- Mandatory standards and compliance enforcement

NERC’s Proposal for a Strong and Effective ERO
Proposed Implementation Schedule

- July 2006
  - FERC approves NERC (conditionally)
- October 2006
  - Compliance filing addressing conditions
- First quarter 2007
  - Standards approved for implementation
  - Entities notified of penalty – no monies collected
- Six months later
  - Penalties applied
What’s Really, Really Important

- Strong and competent ERO
- Clear, consistent, enforceable, and technically excellent reliability standards
- Consistent, firm compliance enforcement
- Effective relationships with regulators, regions and stakeholders
- Continuous reliability improvement
- Performance monitoring
ERSO Membership

- Open and voluntary
- No membership fee
- ERSO membership distinct from standards ballot body

Members elect committee
- 2 per industry sector for 2-year staggered terms
- Additional Canadian representation as needed (0 – 4)
- Region members elect regional representative
- Committee elects chairman and vice chairman
- Non-voting observers appointed by board
Governance

- Maintain independent board
  - 11 trustees (2 Canadian)
- Retain nominating committee of board
  - Chaired by trustee
  - Stakeholder representatives
- Board approves changes to certificate, bylaws, rules of procedure, regulatory filings
- Members rights
  - Elect board members
  - Vote on changes to bylaws
  - Advise board
  - Call meeting of members
Funding

- Funding for ERO and regional delegated functions allocated to load-serving entities
  - Bulk power system users
  - Based on NEL
- Rationalize across balancing authorities, regions and countries
- ERO will fund regions for delegated functions
- Use practical collection mechanisms
Reliability Standards

● Retain ANSI-accredited process and RBB
● Retain SAC elected by segments
● Revise standards manual
  ▪ Pro rata segment votes and editorial changes
● Filed existing 104 standards
  ▪ Key issue: enforceability
  ▪ Standards roadmap
● Coordinate annual work plan with regulators
● Remands/directives through regular process
Regional Standards

- **All** reliability standards are ERO-approved standards
  - Regional criteria are not standards

- Regions may use ERO-approved procedure
  - Open, fair, inclusive, balanced and transparent
Compliance Enforcement

- Strong ERO oversight of regional compliance programs
- Retain existing compliance disclosure principle
- Compliance authority applies to bulk power system owners, operators, and users
Regional Compliance Program

Essential Features

- Compliance program independence
  - Including independence of staff making compliance determinations
- Monitor designated standards for all entities
- Timely reporting of information and all violations
- No sub-delegation
- Adequate compliance resources
- ERO oversight with audits every 3 years
- Single appeals procedure
Penalties and Sanctions

- **Matrix of base penalties**
  - Risk factors: high, medium, low
  - Levels of non-compliance: low, moderate, high, severe

- **Quantitative adjustment factors**
  - Entity size
  - Repeat infractions and prior warnings
  - Time horizon

- **Other qualitative factors for consideration, e.g.**:
  - Self-reporting and self-correction
  - Quality of entity compliance program and overall performance
  - Deliberate violations

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<thead>
<tr>
<th>Violation Risk Factor</th>
<th>Violator Size &amp; Time Horizon Limits</th>
<th>Violation Severity Level</th>
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<tbody>
<tr>
<td>Lower</td>
<td>Standard Penalty: $1,000 $3,000 $6,000 $10,000</td>
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<tr>
<td></td>
<td>Lower: $1,000 $1,000 $1,500 $2,000</td>
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<td>Medium</td>
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<tr>
<td></td>
<td>Upper: $70,000 $100,000 $140,000 $200,000</td>
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**FERC statutory limit:** $1,000,000 per day
Organization Registration & Certification

- Maintain list of responsible entities
  - All bulk electric system owners, operators and users
  - Registration by functional model
- Certify balancing authorities, transmission operators and reliability coordinators
- ERO program with responsibilities delegated to regions
Additional ERO Programs

- Reliability assessments and performance
  - Traditional reliability assessments
  - Event analysis and benchmarking
- Reliability readiness audit and improvement
- Training and education
  - System personnel certification
  - Continuing education provider certification
- Situation awareness and infrastructure security
Business Planning and Budgets

- ERO annual budget process
  - Includes ERO functions
  - Budget filed in August and approved by regulators in October

- ERO reviews regional budgets for delegated functions
  - Regions may have other non-ERO functions not funded through ERO

- Flexibility on funding collection methods

- Apply penalty funds first to marginal costs by NERC and region for compliance enforcement for particular entity
Key Features of Transition Plan

- Naming of ERO and compliance order
- Form new corporation; transfer from members
- Recognition in Canada
- Execution of delegation agreements
- Update standards manual
- Update standards and roadmap
- Plan for fill-in-the-blank regional standards
- 2007 budget and funding allocation
- Compliance enforcement program 2007
  - 6-month trial period for financial penalties
- ERO reorganization and staffing adjustments
- Role of committees
Questions