Use of PMUs in EA
IESO-MECS Voltage and Flows Measured from Lambton

Source: Ontario PSDR

MW/MVAR

Time - EDT

kV

MW

MVAr


Source: Ontario PSDR
Power System Dynamic Recorders (PSDRs)

**Time**

- 16:10:30 to 16:11:00

**Power Flows (MW)**
- New York into Ontario
- New York into New England
- Ontario into Michigan
- PJM into New York

**Frequency (Hz)**
- Lambton
- ONT-MI
- NY-East
- NY-West

**Events**
- 16:10:30: Start of split between East and West MI.
- 16:10:36: Detroit, Cleveland separated from W. MI.
- 16:10:38: Cleveland cut off from PA.
- 16:10:40: Cleveland separates from islands.
- 16:10:45: NY separates from PA.
- 16:10:46: Cleveland separates from Toledo, islands.
- 16:10:49: NY separates from NJ.
- 16:10:52: Split complete between East and West NY.
- 16:10:55: Ontario splits from West NY.
- 16:10:56: Ontario reconnects with West NY.
New York to Ontario 345 kV Line Flow at Niagara

(does not include 230 kV line flow)
Detroit Units Slip Poles

Keith-Waterman (J5D) 230 kV - Tie Line

Classical Stability

Severe Voltage Depression in Downtown and Southern Detroit Region

Toledo/Cleveland Island Separates from Detroit

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

Significant Generation Loss and/or Transmission Separation in Detroit

Keith-Waterman Trips at 16:10:43.2

Remaining Detroit Generation Slips 2 Poles as Frequency Falls at

Seconds from 16:10
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

Seconds from 16:10:00

Hz

Beck 2
Claireville
Kenora
Lambton
Longwood
Porcupine
Richview
St Lawrence
Nine Mile Point Unit 2 Trips

Nine Mile Point Unit 2 Generation Data
(Reconstructed)

- Disturbance Begins
- Unit 2 Accelerates During Frequency Increase
- 60.3 Hz
- 63.0 Hz
- 63.1 Hz
- Governor Runback
- Excitation System Tripped
- Reactor Trip on Low Turbine Control Hydraulic Pressure
- Breakers Open

Generatio Net Output MWe

System Frequency

Seconds from 16:10 August 14, 2003
8 Years Later
PMU Data from SONGS

South of SONGS - Calculated Phase Current

Phase Current (Amps)


11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000
Simulation vs. Actual Flows

South of SONGS Flows

[Graph showing MW vs. Local Time (PDT) with distinct lines for Simulated and Actual (PMU) flows]
South of SONGS - Calculated Phase Current

1. Trip of Hassayampa – North Gila 500 kV Line
2. Trip of Gila 161/69 kV Transformers
3. Trip of Coachella Valley 230/92 kV Transformers
4. Trip of El Centro – Pilot Knob 161 kV Line
5. Trip of Ramon 230/92 kV Transformer
6. SONGS Separation
We heard there was a blackout in Southern California

- Was it an attack tripping multiple lines?
- Did the San Onofre plant trip cause San Diego to go black?
- Was it a simple switching error?
- Did generation trip in Mexico cause it?
Initial (overnight) Analysis
From RA Tool

CAISO Freq/ACE 1635-1705 MST

CISO Freq/ACE 1635-1705 MST
1-Min. CAISO Freq. 1500-0530 MST

From RA Tool
WECC Freq ~1538 - SDGE Sep.

From FMA Tool
System Separation & SONGS Trip

- Loss of San Onofre Gen.
- Loss of SDGE Load

From RA Tool
Initial FNet FDR Angular Plot

AZ-NM-CO

California
Sequence of Events Analysis with PMUs
Initiating Event - Voltage Divergence
Hassayampa - North Gila 500 kV Trip

Series Capacitor
Bypass Switch
Arcs Over
Hass. - N. Gila 500 kV Line Trip

South of SONGS Current

- CCM Unit 1 generator trip
- Hassyampa – N. Gila 500 kV line trip

Phase Current (Amps)

Local Time (PDT)
Critical PMU Locations
Phase 4 Example

Frequency and South of SONGS Flow

Two GTs & UVLS
CV-Niland
UVLS
Motor stalling
Colmac GT
Blythe-Niland

Local Time (PDT)
Phase 6 Example

Frequency and South of SONGS Flow

- Blythe RAS
- ‘S’ line RAS generators
- ‘A’ line trip
- ‘S’ line RAS generators

South of SONGS Calculated Current

Local Time (PDT):
15:37:53 to 15:38:07
Using Tesla as the reference angle, zeroed
Questions?