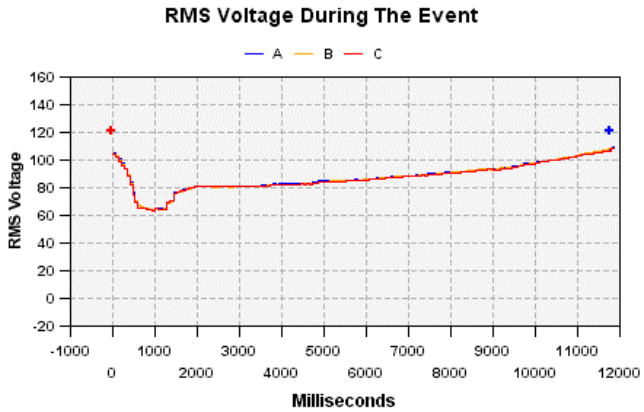

Initial Analysis of August 14th Northeast Blackout

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August 14, 2003

Comments about the Analysis

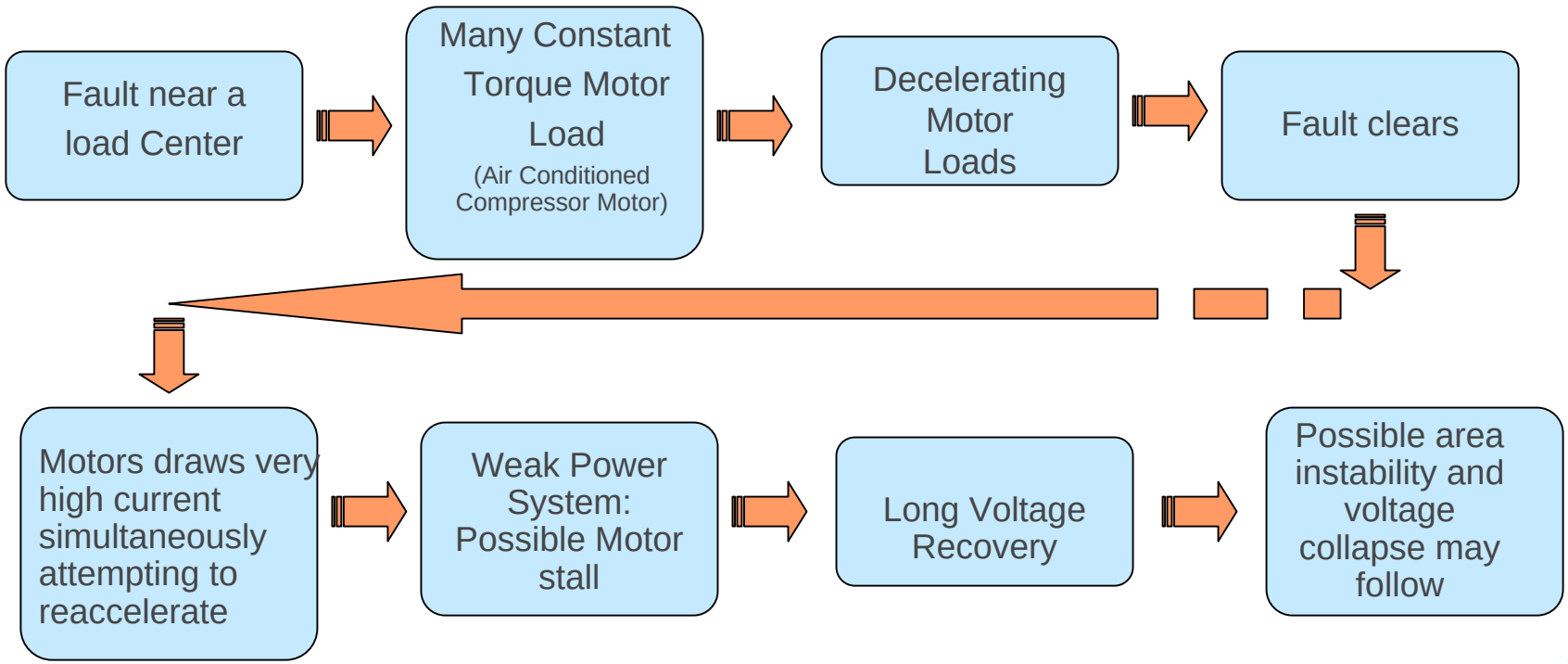
- These were initial thoughts before any significant amount of data were available.
- At this time, we are not sure what role fast voltage collapse may have played in the overall event.
- It is clear that there were power oscillations going on well before the main event that we used for our analysis.

What Happened?

- There is no conclusive explanation of the outage cause as of this time (11:45 pm EST August 14th).
- However, there is one indication that there was a fault in Western Ontario that could have been the initiating event (Carol Murphy – NY ISO)
- The waveforms indicate a phenomena that we have called “fast voltage collapse”.
- This can happen during periods of heavy load, especially when there is a dominance of motor load (e.g. air conditioning and industrial load).
- Recovery from the voltage sag during these conditions can be very slow. The motors draw increased current due to the continuing low voltage and the voltage around the system collapses due to this increased demand following the sag.
- Generators struggle with this increased load.
- Motors will eventually stall and trip. Load goes off and voltage can go very high as a result.
- Within 3 minutes more than 20 generators in NE trip. This is probably caused by frequency variations from the generation/load mismatch.

What is Fast Voltage Collapse?

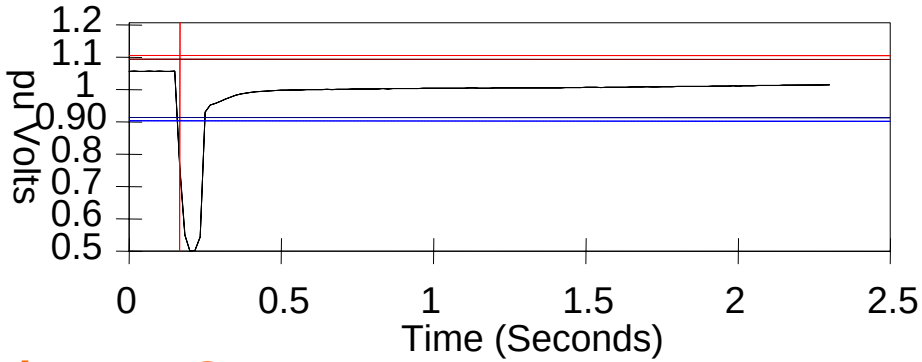
- Fast Voltage Collapse happens in the short-term following a disturbance.
- Short-term voltage instability is an increasing, but often overlooked, industry concern. A plausible scenario of fast voltage collapse (from PQA 2003 presentation by Arshad Mansoor and Mike Ingram)



Example of Voltage and Current Variation During Normal Recovery (United Illuminating)

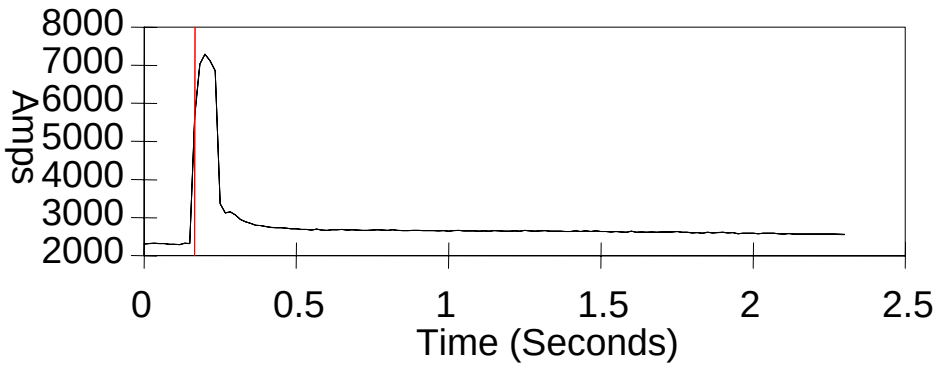
RMS Variation

Phase B Voltage

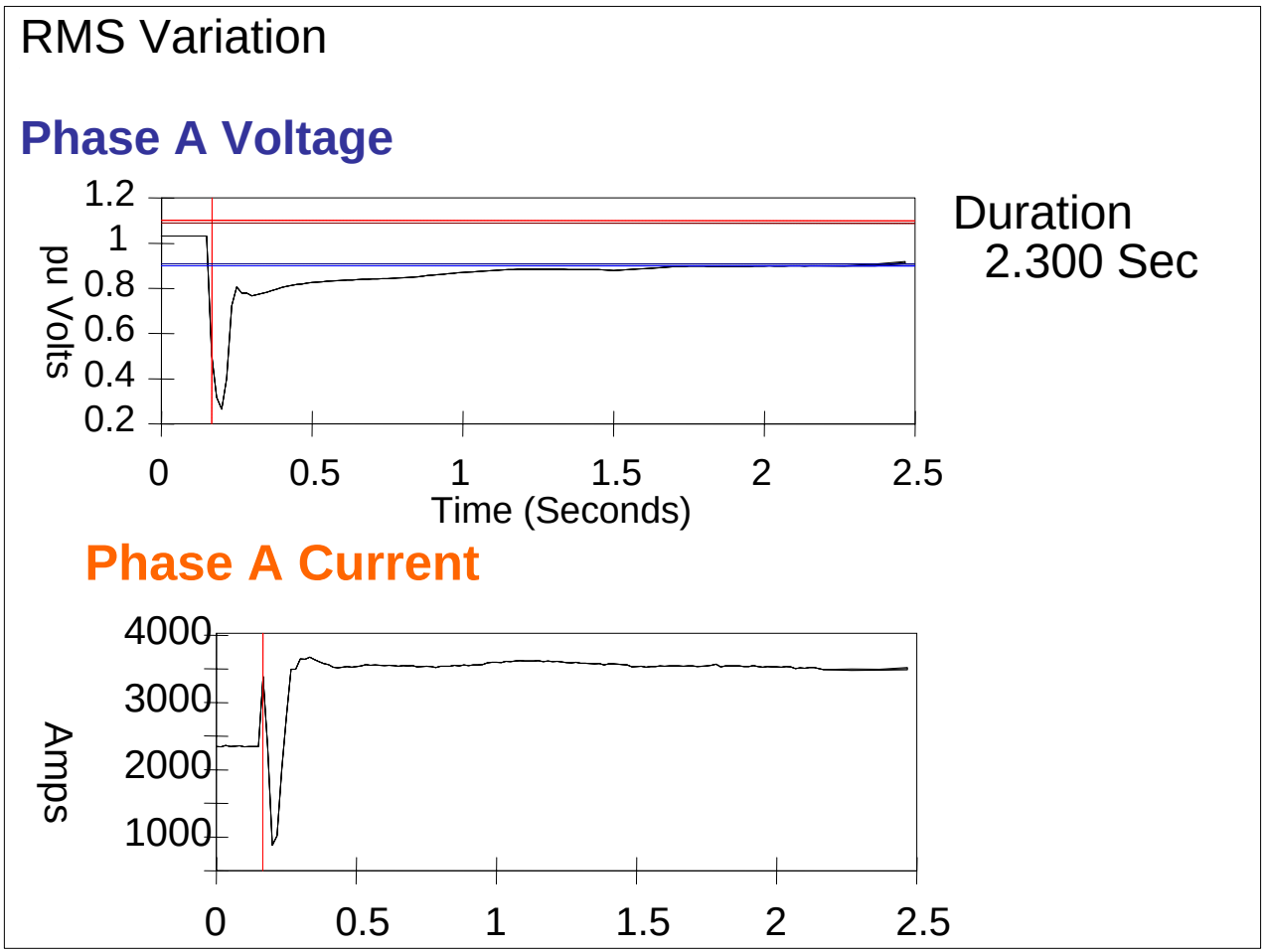


Duration
0.083 Sec

Phase B Current



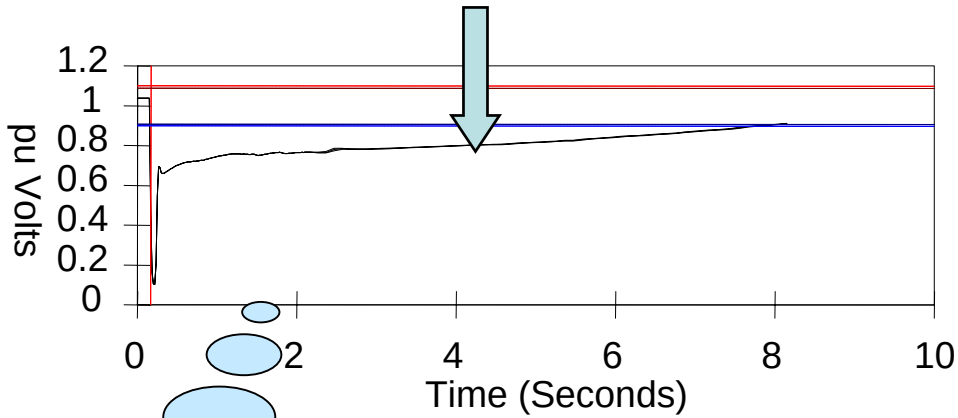
Example of Voltage and Current Variation During a Slow Recovery (United Illuminating)



Example of Very Slow Recovery!! (7.8 sec) (United Illuminating)

RMS Variation

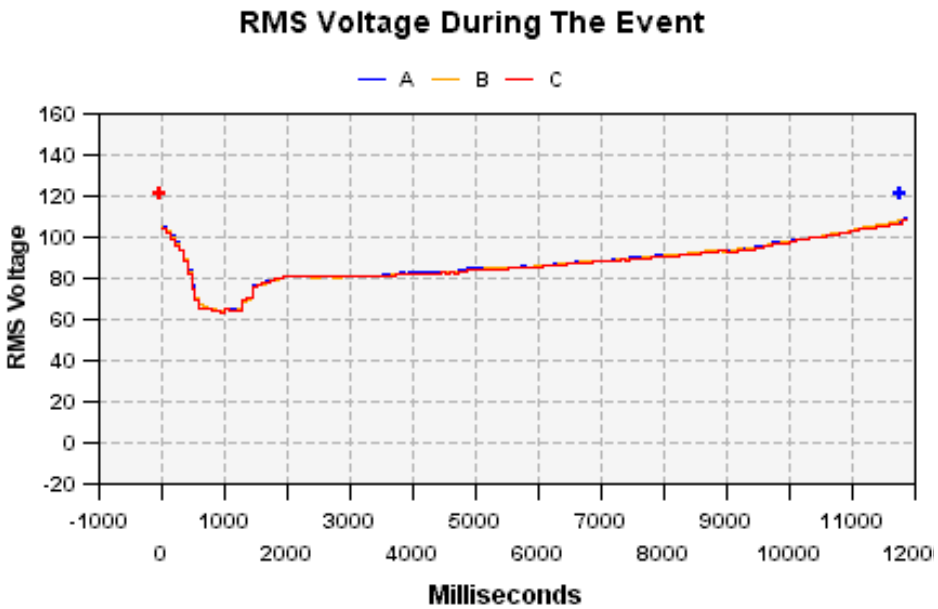
Phase A-B Voltage

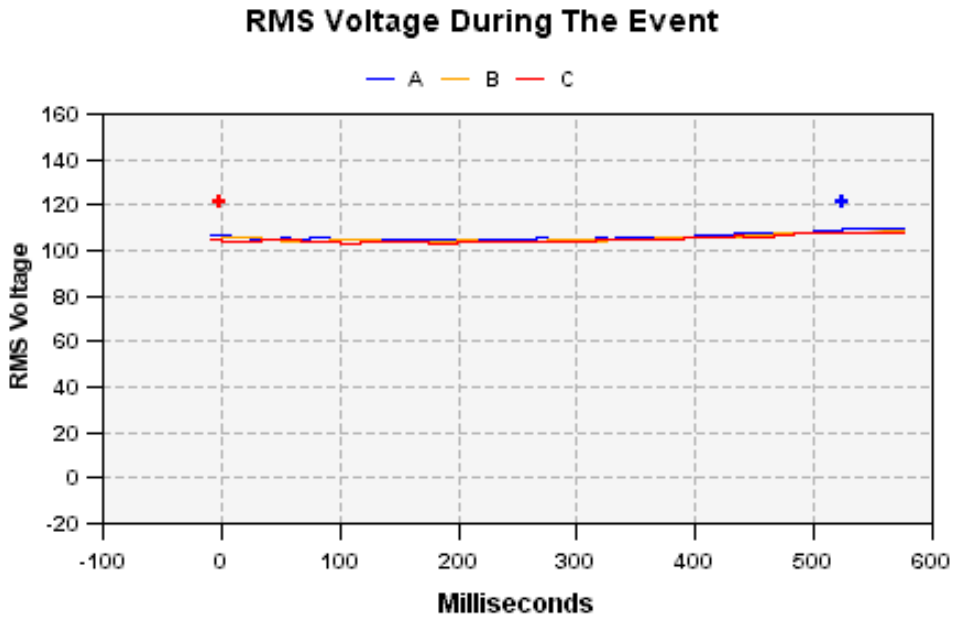


Duration
7.800 Sec

This Site has been considered as a site for possible installation of fast VAR devices

What happened this time?



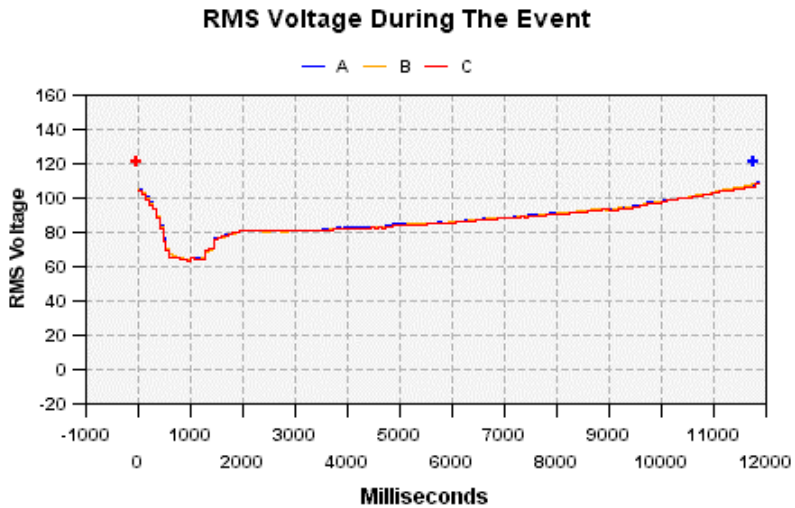


Initiating Event
Aug 14 2003
04:10:43.810 PM EDT 2003
11.6 seconds

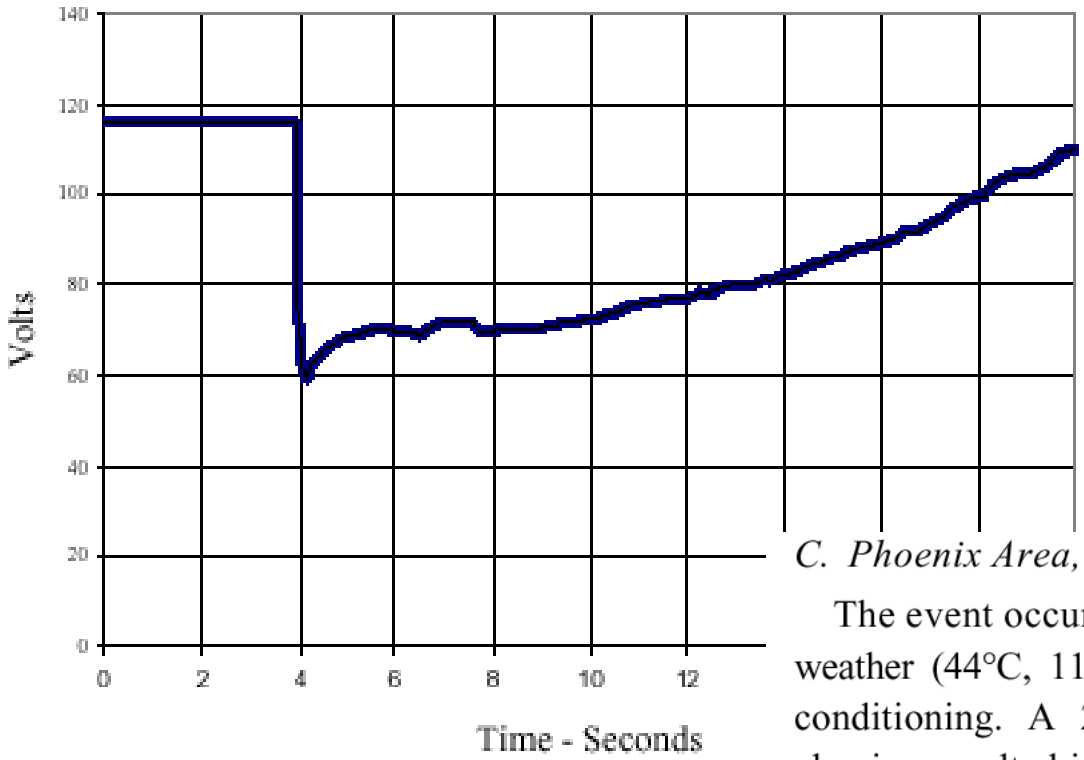
Data from publicly shared data I-Grid™ Monitor in New Jersey

Explanation

- You can see the voltage decaying until it gets down to almost 60% of normal voltage. This is probably the point that load started dropping off.
- However, the recovery is too slow and generators are not able to maintain frequency during this condition.
- Many generators trip, load shedding goes into effect, and then things just shut down due to a lack of generation.



A "Near" Fast Voltage Collapse in Phoenix in 1995



C. Phoenix Area, July 29, 1995 [3]

The event occurred on a Saturday afternoon during very hot weather (44°C, 112°F). Much of the load was residential air conditioning. A 230-kV capacitor bank fault with delayed clearing resulted in loss of five 230-kV lines and two 230/69-kV transformers. About 2100 MW of load was lost. Voltage recovery took up to 20 seconds (Figure 1). Presumably, many residential air conditioners stalled, and then tripped off after some seconds to allow eventual recovery of the remaining power system. Recordings show high reactive power output of area generators during the recovery period. High reactive power output from generators at the nearby Palo Verde nuclear plant was essential for the recovery.

North American Electric Reliability Council, System Disturbances, Review of Selected 1995 Electric System Disturbances in North America, March 1996.

Similarity of Aug 14 2003 Event with July 29, 1995 event

- The voltage collapsed quickly (0.5 sec) to about 60% of nominal – typically where you may see a lot of motor load stalling.
- However, unlike the Phoenix event, several Nuclear power plants and generators tripped off line and were not available to supply load or reactive power.

What are the implications?

- Fast Voltage Collapse is REAL!
- The models and simulation tools we are using do not adequately predict this phenomena – likely due to incorrect load models and their response to disturbances.
- Improved load models and simulation tools that incorporate these load models are needed.
- Monitoring can provide indication of the potential for this problem during even minor voltage sag conditions caused by faults on the system – this information should be assessed for every event and notifications of potential problems provided.