

NERC

NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Pacific Southwest Disturbance

September 8, 2011

NASPI Working Group Meeting – Denver, CO

June 6, 2012

RELIABILITY | ACCOUNTABILITY



Before we knew anything...

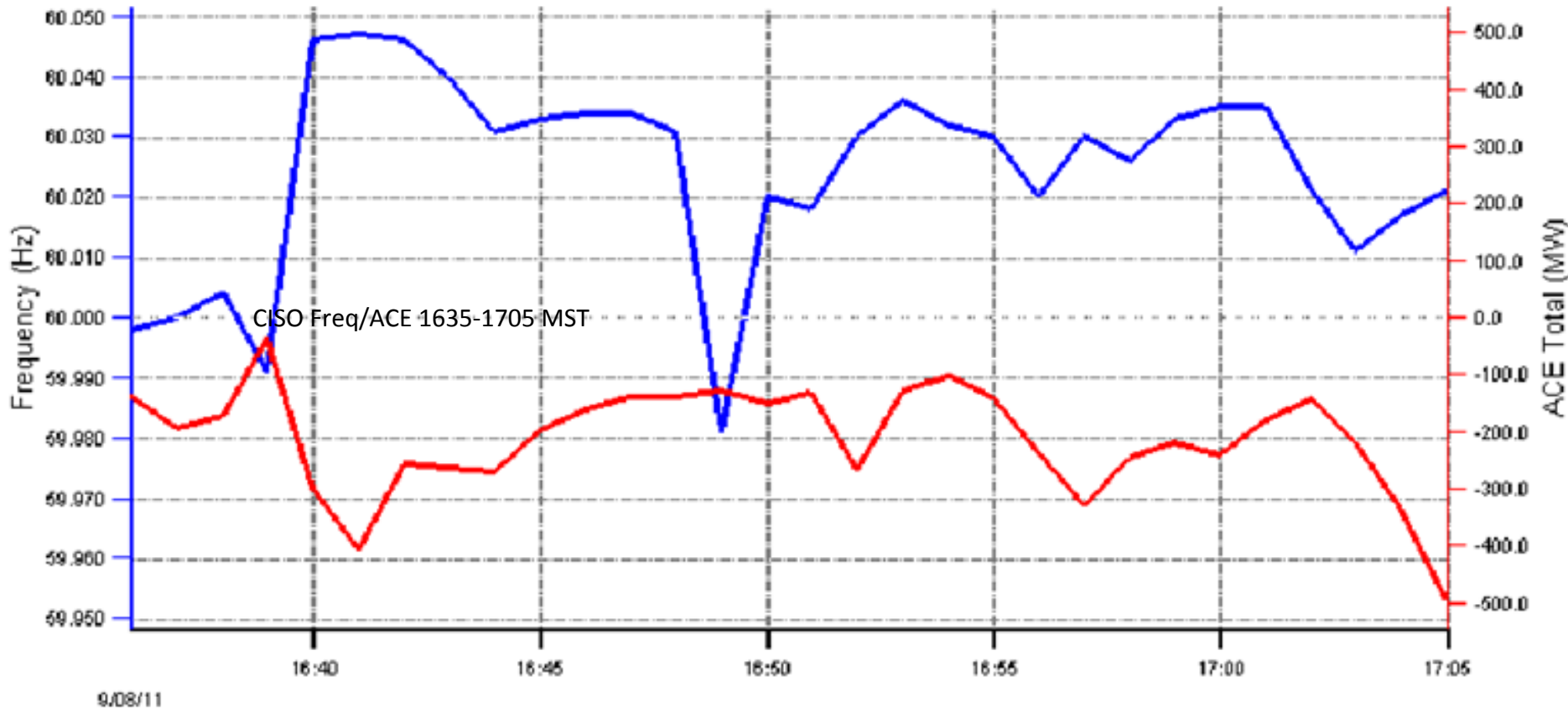
- We heard there was a blackout in Southern California
- ...and that the San Onofre plant was tripped...
- ...and then we heard that a switching error was the cause of the whole thing...
- Of course, we didn't believe it was that simple!

A light blue map of North America is centered on the slide. Overlaid on the map is a semi-transparent image of a nuclear power plant, showing three large cooling towers and a containment dome. The text 'Initial Analysis (overnight)' is written in a dark blue, italicized serif font across the middle of the map.

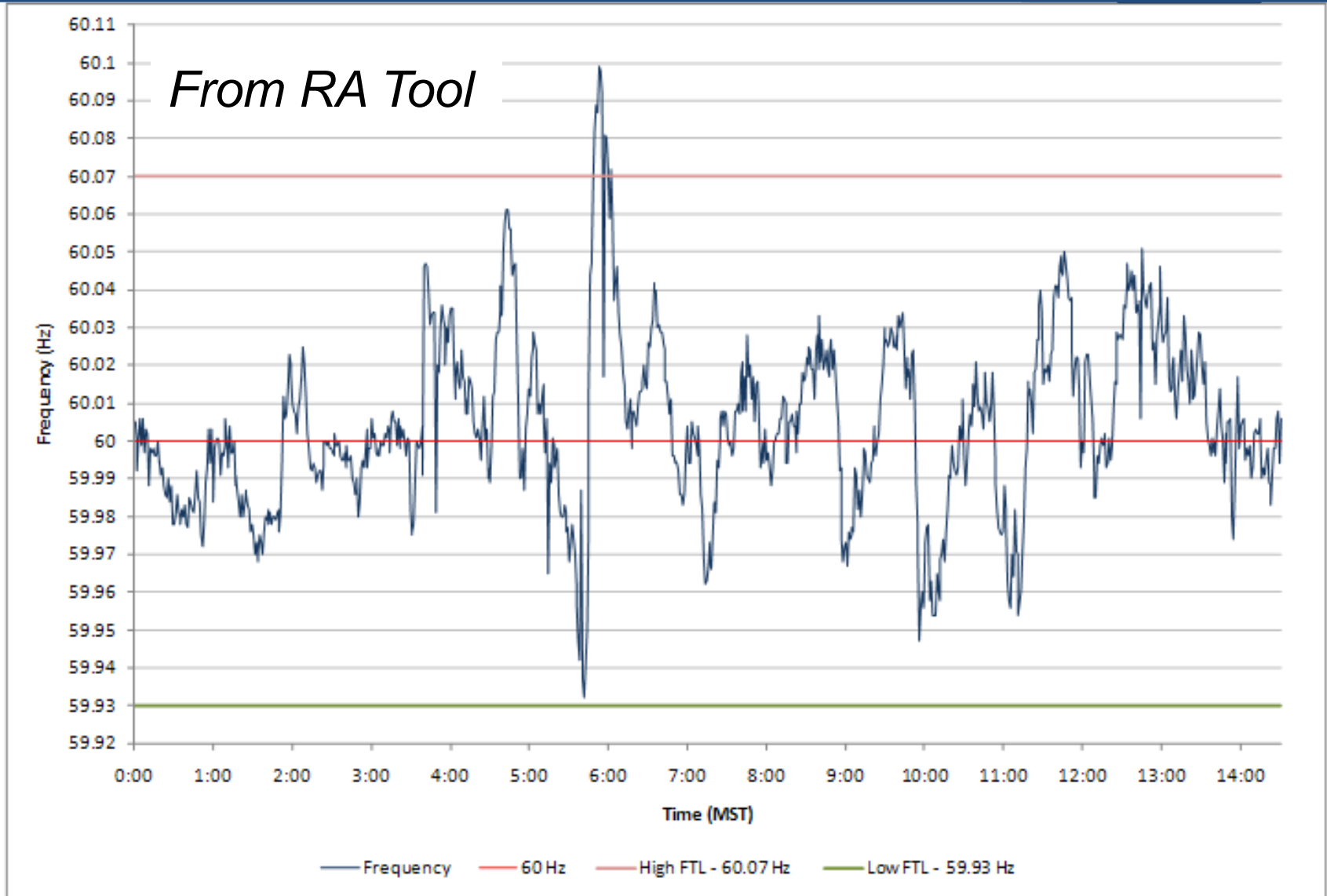
Initial Analysis (overnight)

CAISO Freq/ACE 1635-1705 MST

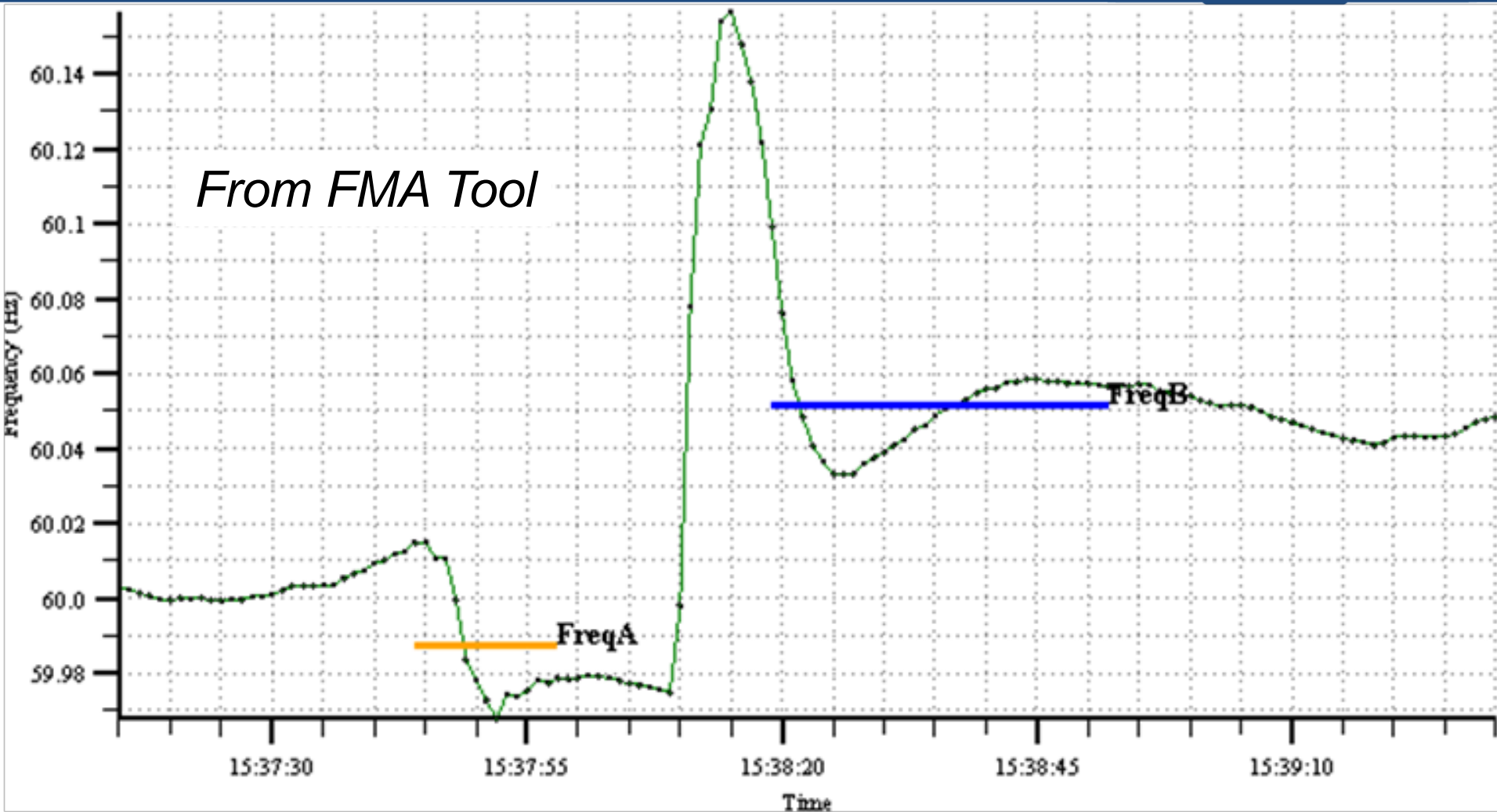
From RA Tool



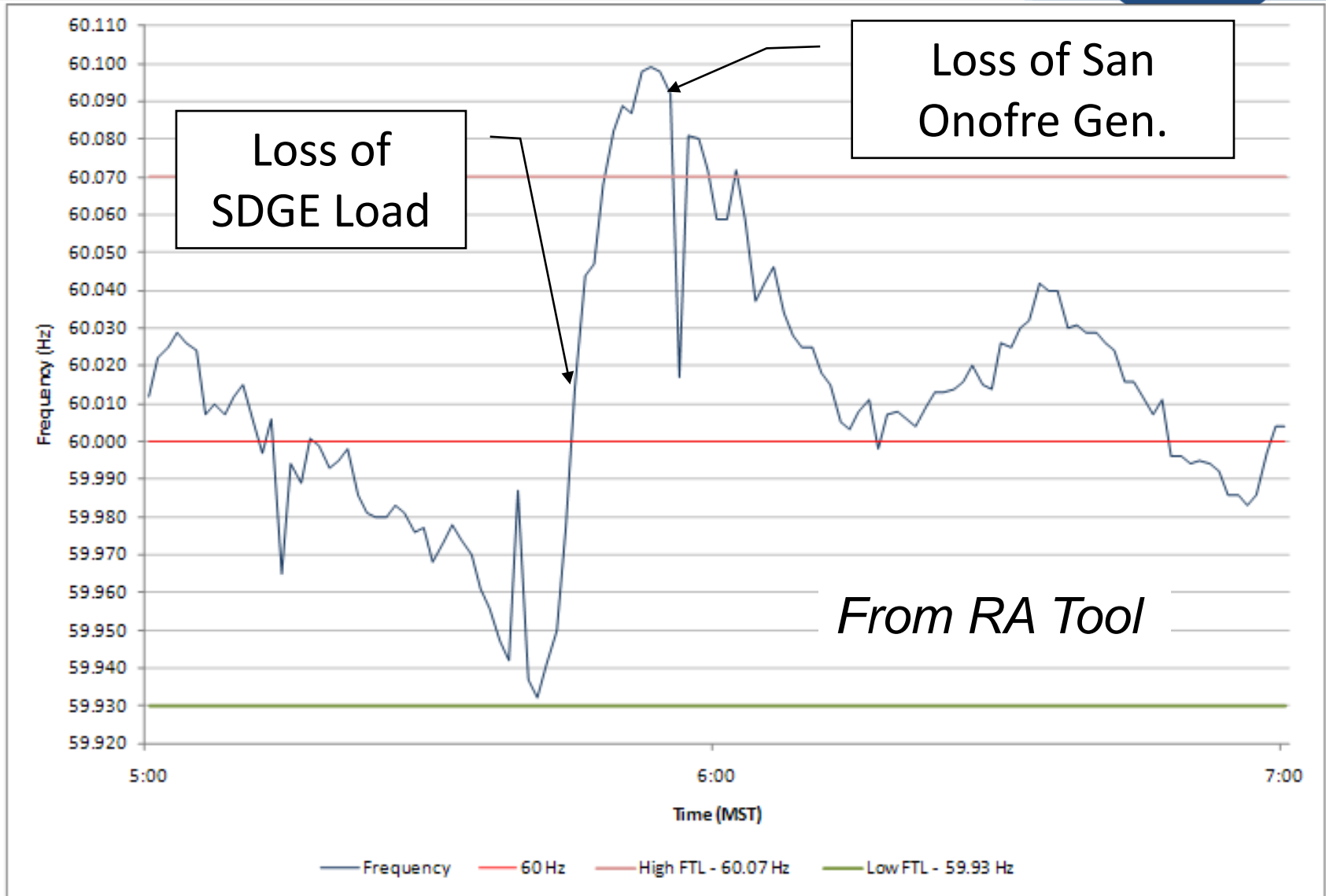
1-Min. CAISO Freq. 1500-0530 MST



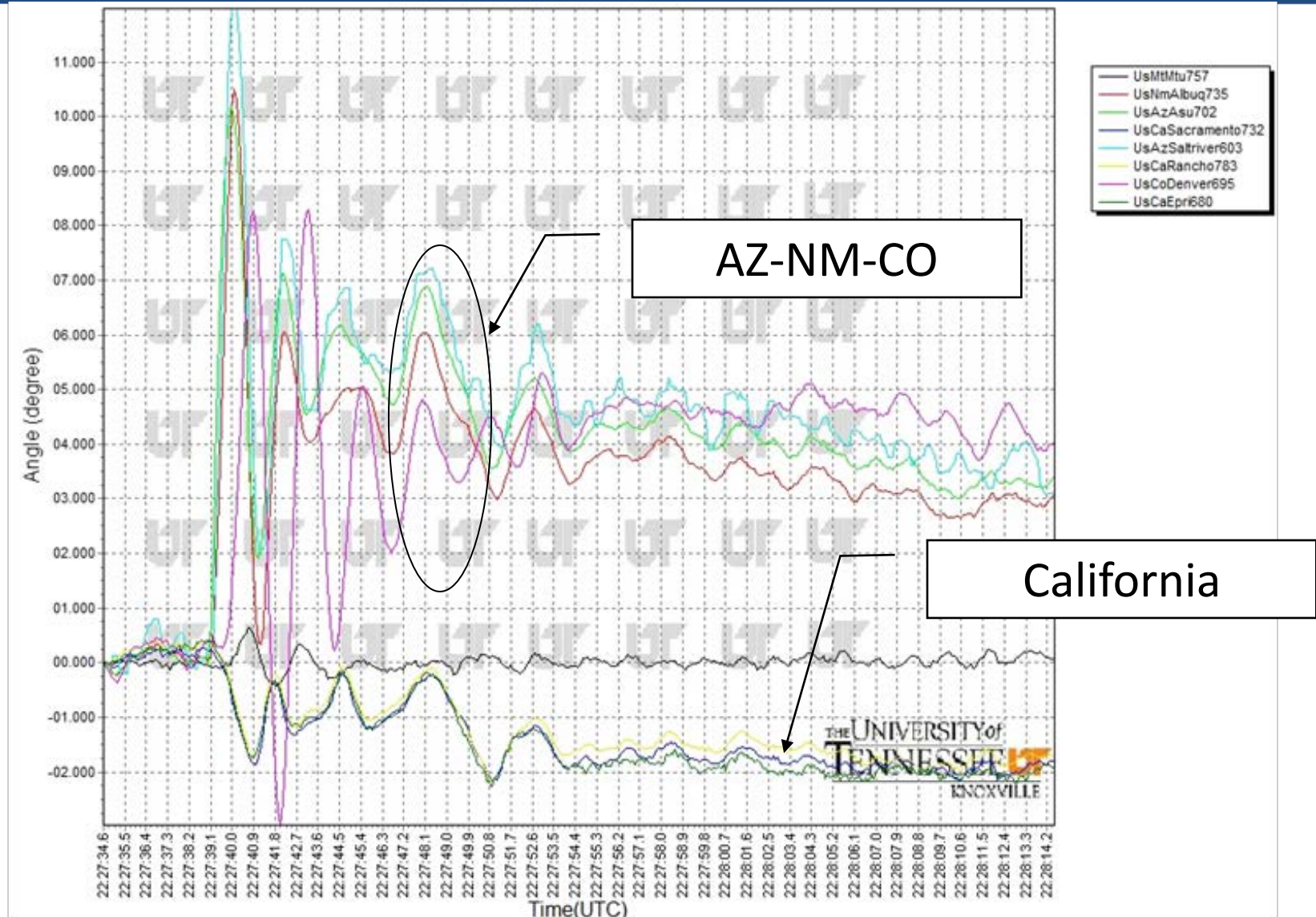
WECC Freq ~1538 – SDGE Sep.



System Separation & SONGS Trip



Initial FNet FDR Angular Plot



A light blue map of North America is centered on the slide. Overlaid on the map is a semi-transparent image of a nuclear power plant, showing two large cooling towers and a containment dome. The title text is superimposed on a dark blue horizontal band across the middle of the map.

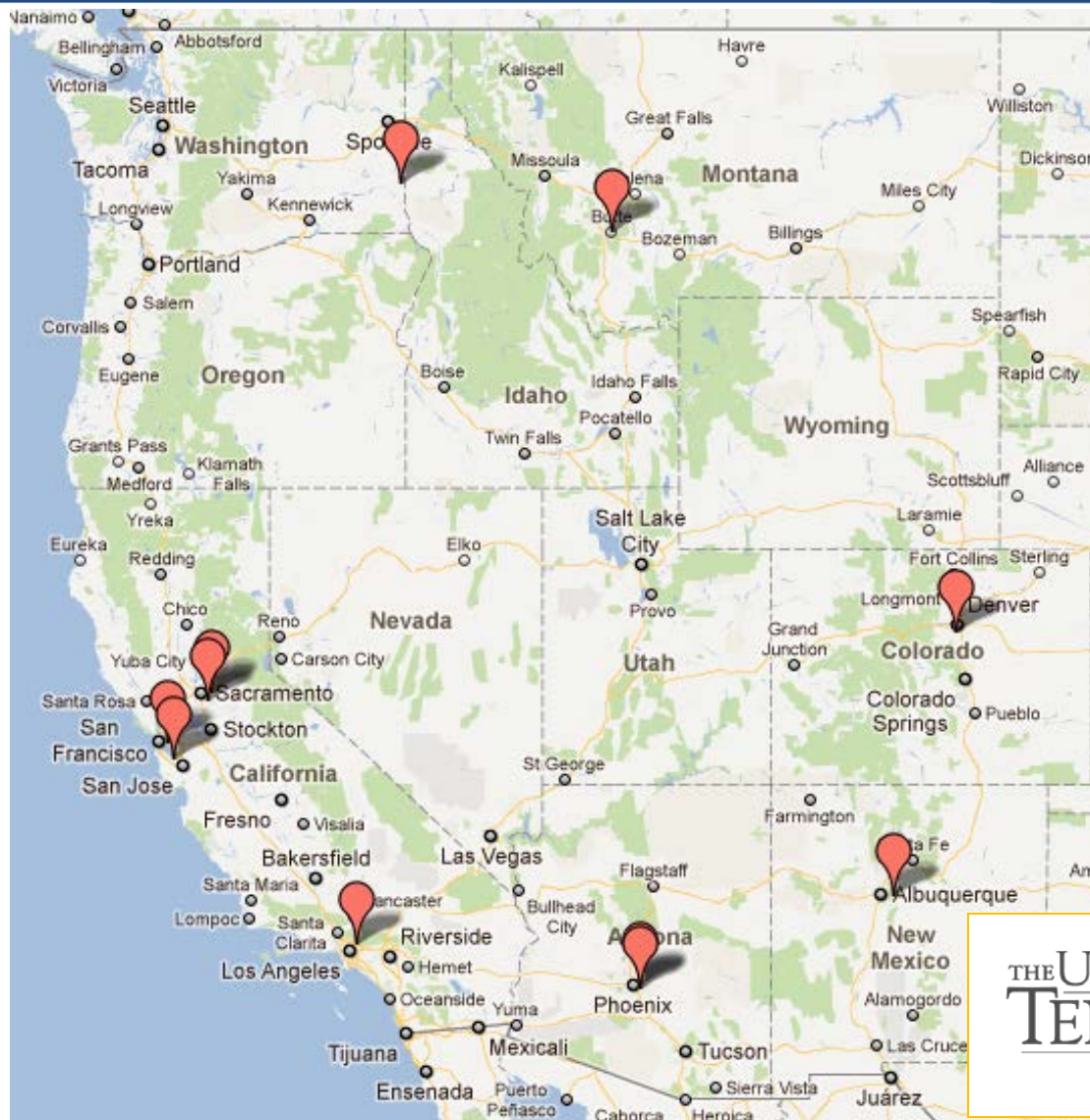
Joint NERC-FERC Event Analysis Inquiry

- Announced September 9, 2012
- Teams formed comprising over 30 senior technical staff of FERC and NERC, plus several NERC contractors and industry subject matter experts
- Multiple meetings and exchanges with affected entities to gather facts
- Team products combined into final report
- Outreach sessions to gain feedback on draft findings and recommendations

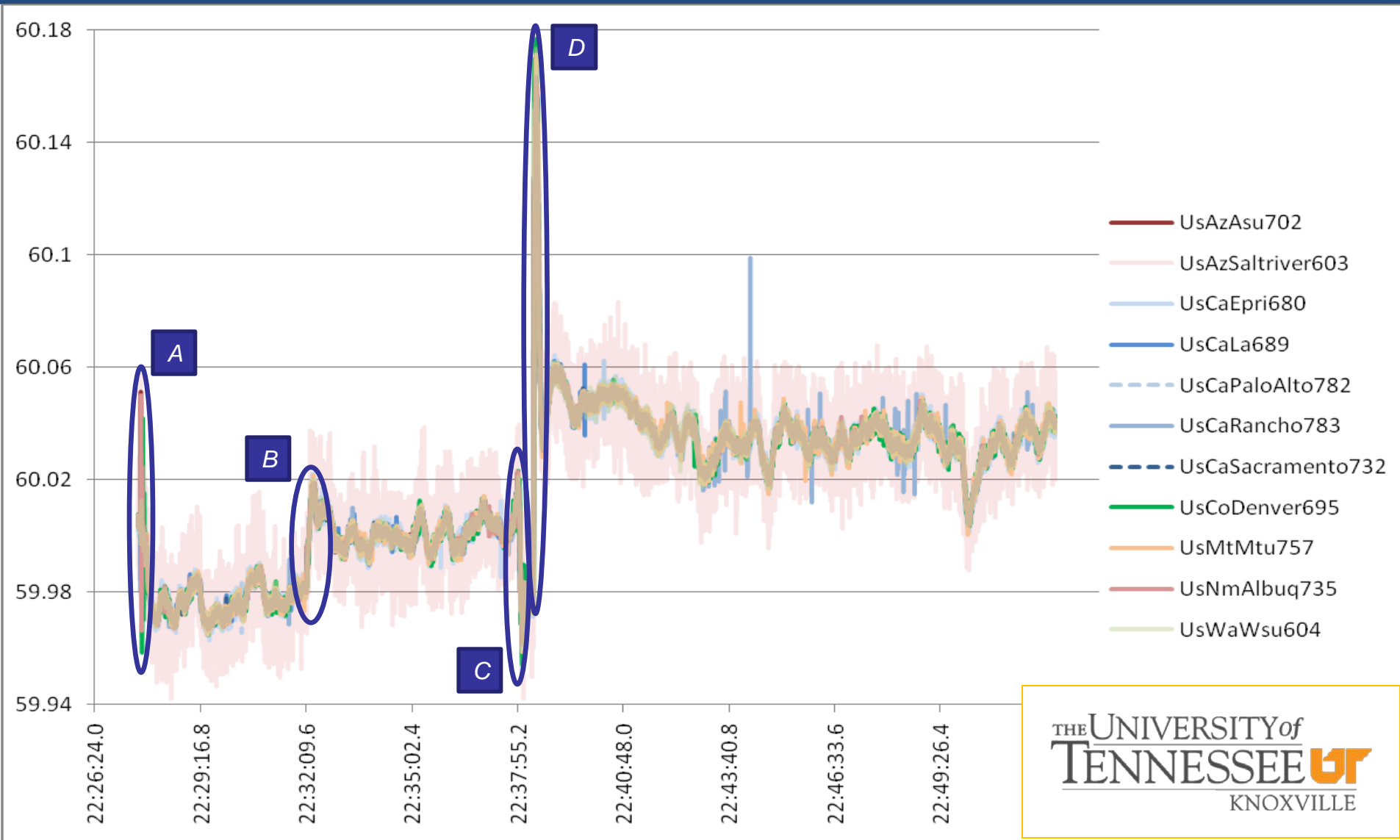
- Data Requests/Management
- Sequence of Events
- Modeling/Simulation
- Cause Analysis/Human Performance
- Operations Tools/ SCADA/EMS
- Frequency Analysis
- System Planning/Design
- Equipment Performance/System Protection
- Restoration

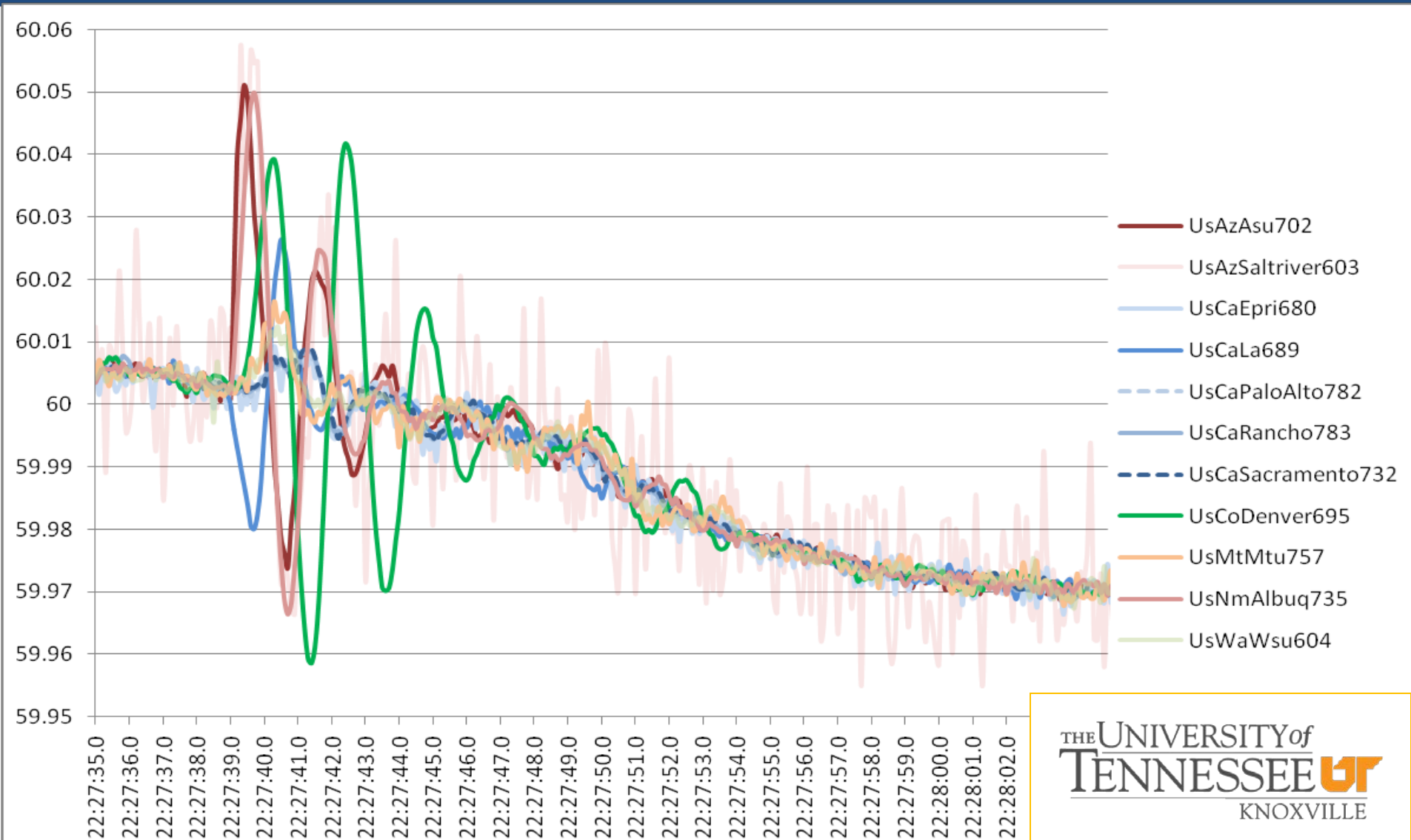
A light blue map of North America is centered on the slide. Overlaid on the map is a semi-transparent image of a nuclear power plant, showing two large cooling towers and a containment dome. A dark blue horizontal band is positioned across the middle of the map, containing the title text.

Initial FNet Analysis

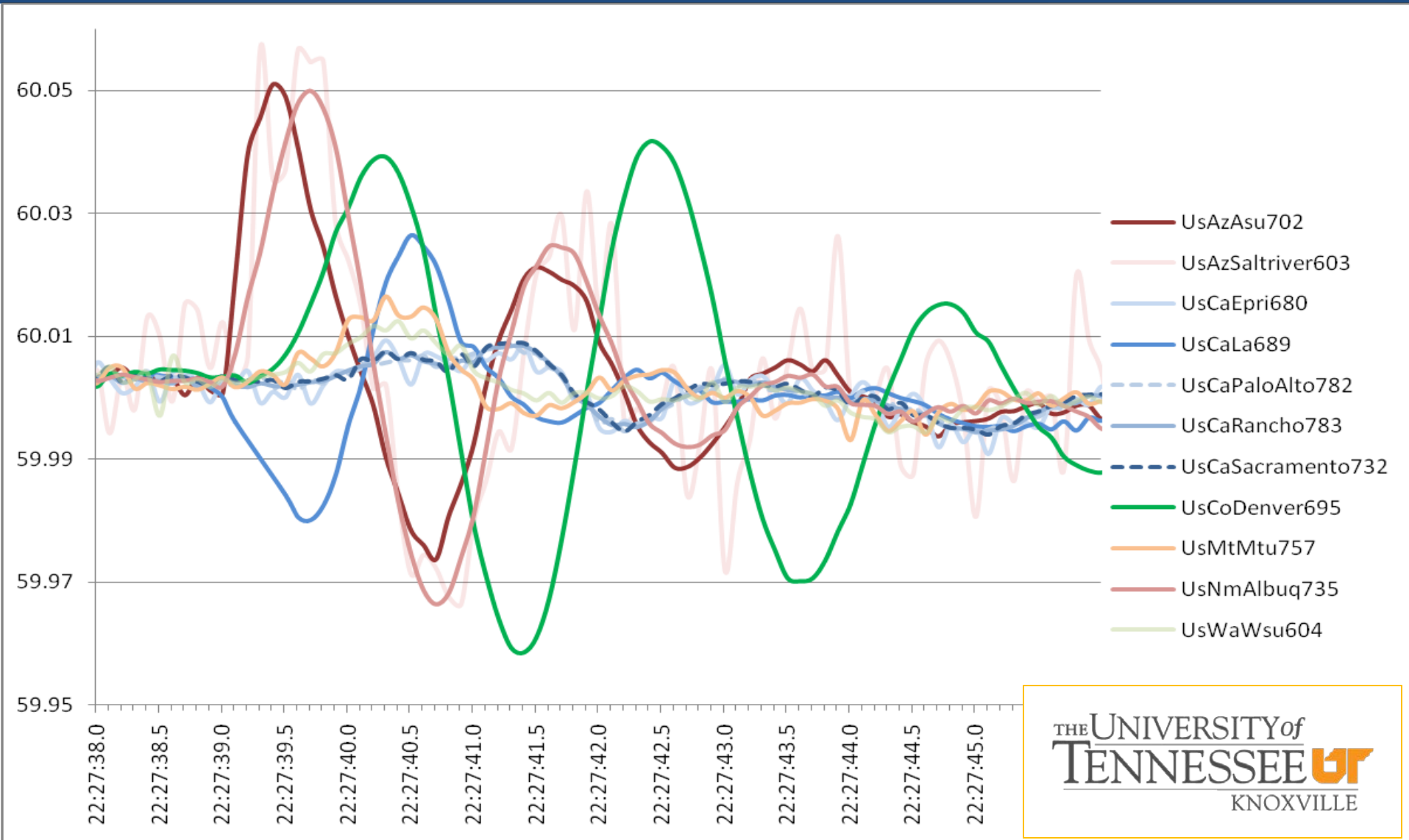


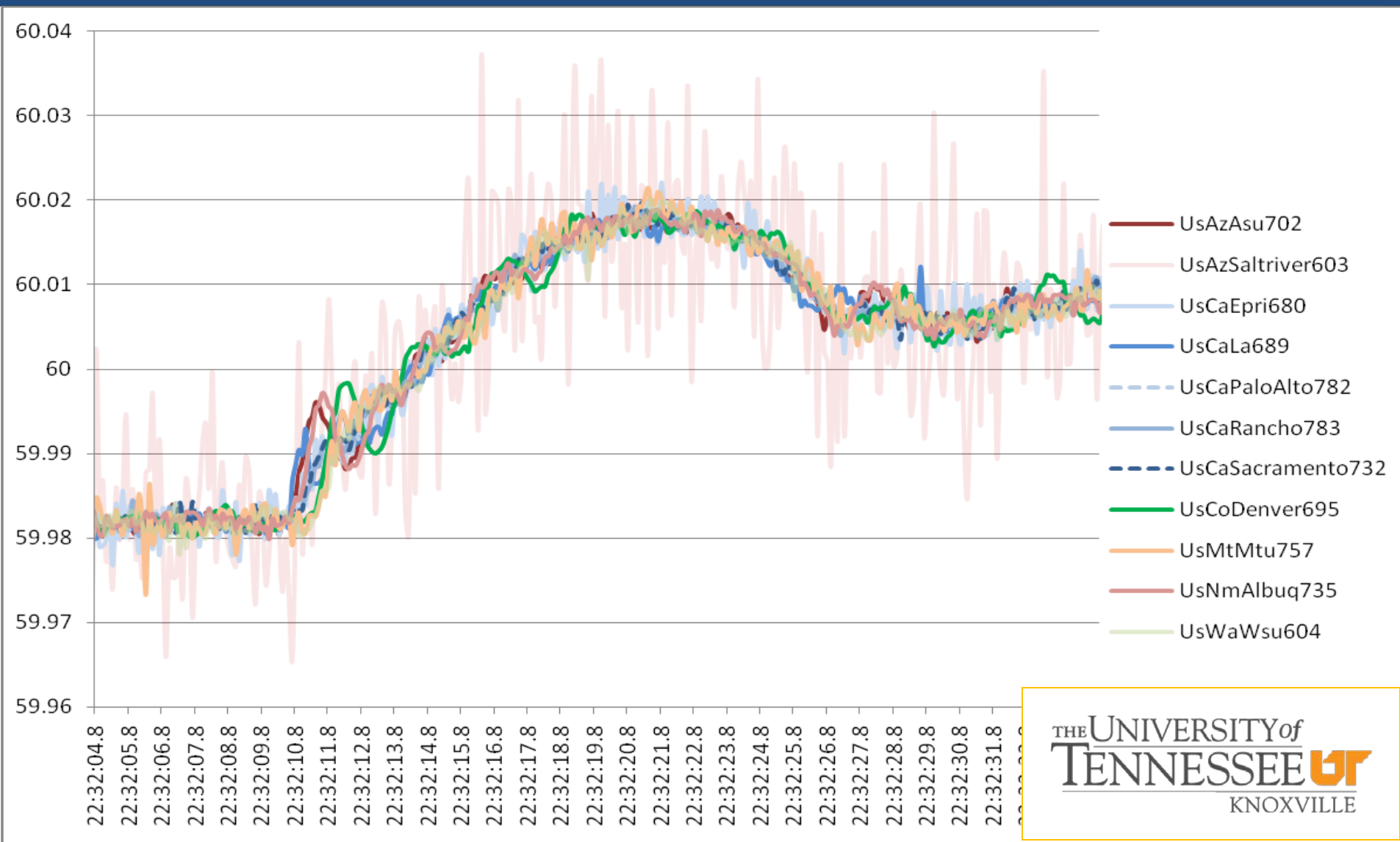
25 Minutes of Frequency

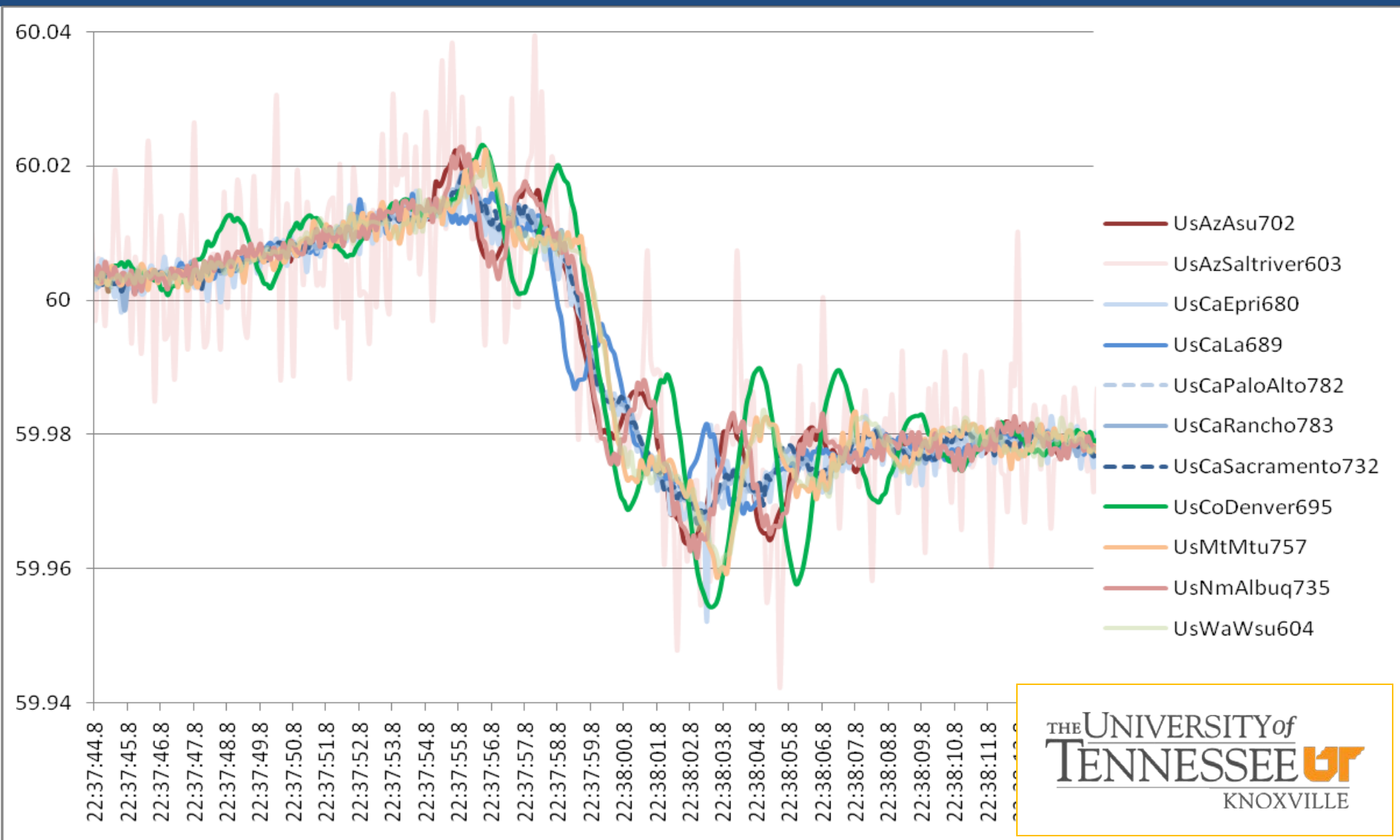


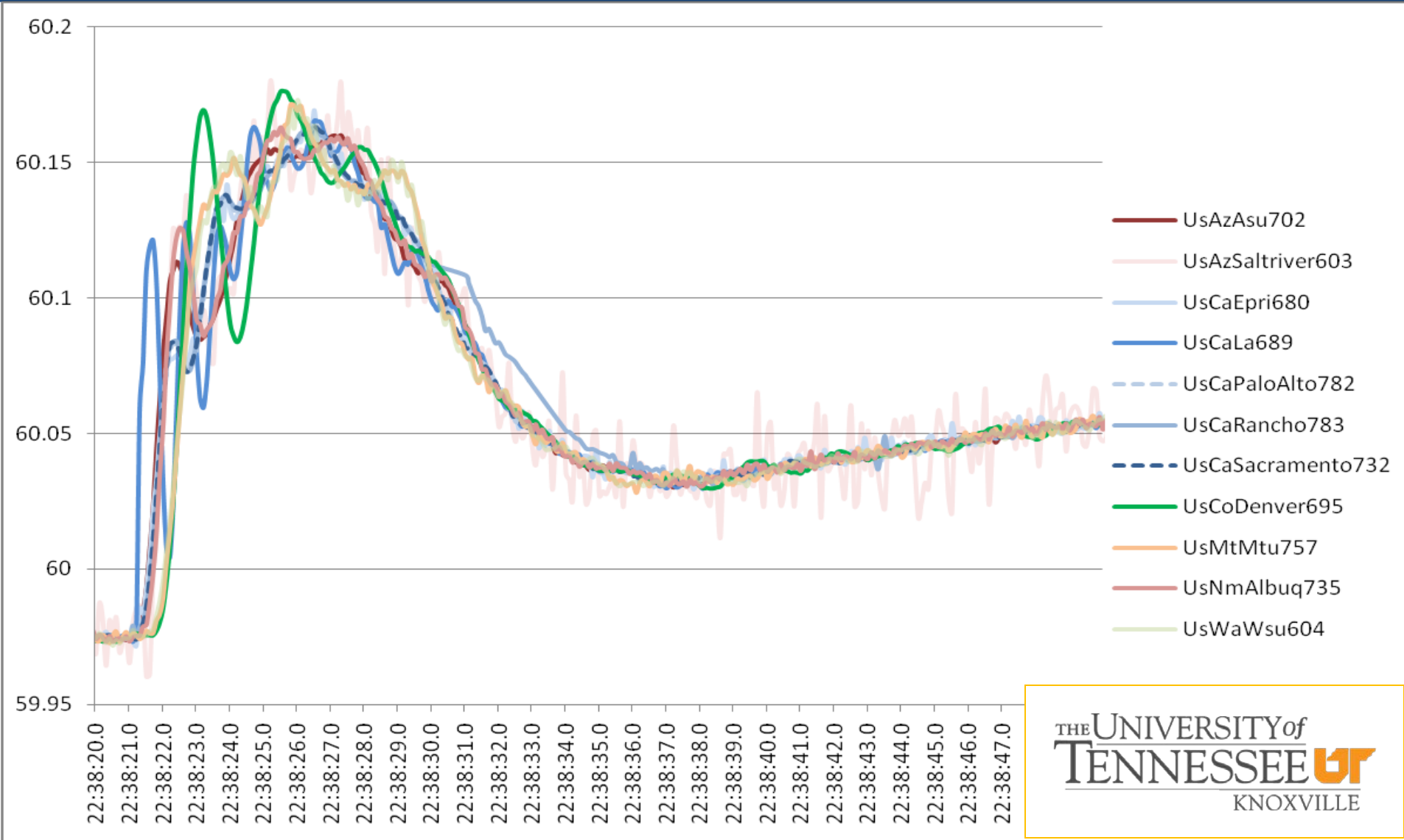


Event A Detail









- The frequency shows four main events
 - A. The initial **separation** around **22:27:39 (UTC)**, with a 'slow' frequency dip of about -30 mHz over about 25 seconds
 - B. A frequency **ramp** beginning around **22:32:10** increasing frequency +30 mHz over about 15 seconds
 - C. A frequency **drop** around **22:37:55** of over -40 mHz (B-A) over about 12 seconds
 - D. A frequency **jump** around **22:38:21** of over +150 mHz (C-A) in less than 5 seconds, settling at around +80 mHz (B-A) in about 20 seconds



Sequence of Events

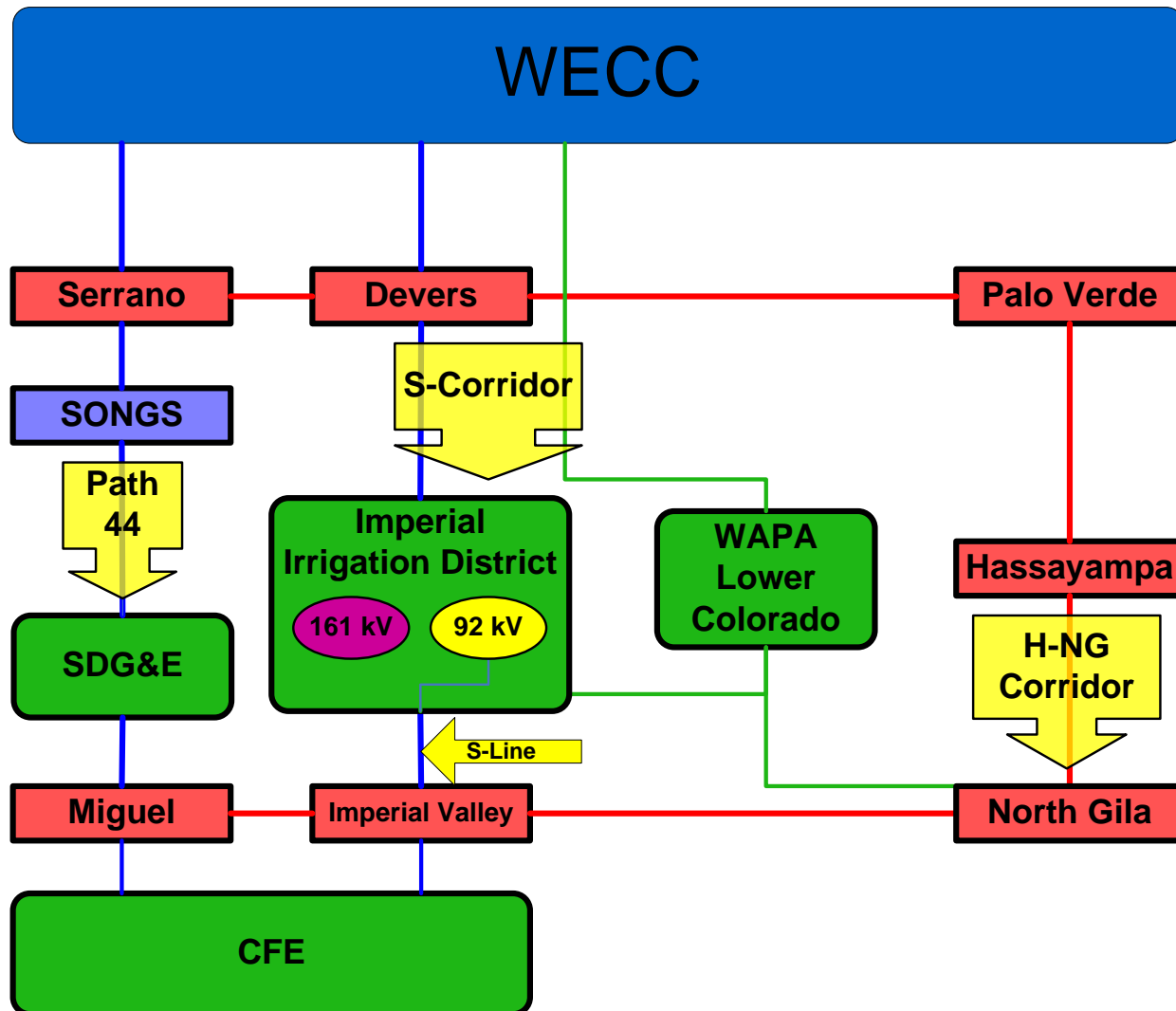
- Over 30 ‘major’ element operations over the course of 11 minutes
 - Line and transformer trips
 - Generator trips and runback
 - Load shedding
 - Over 50 additional ‘minor’ operations such as capacitor and reactor switching
- Over 6 GB of data of different qualities and resolution
 - Operator logs, PI historian, SCADA, PMU, DFR, relay

- Reported event times were entered in a database
 - Facilitated slicing & dicing by event and element type
 - Tracked reported time vs. verified time and status
- Event were categorized
 - Unqualified
 - Non-essential
 - Information
 - Event
 - Minor Event
 - Human Action
 - System Condition
 - Restoration

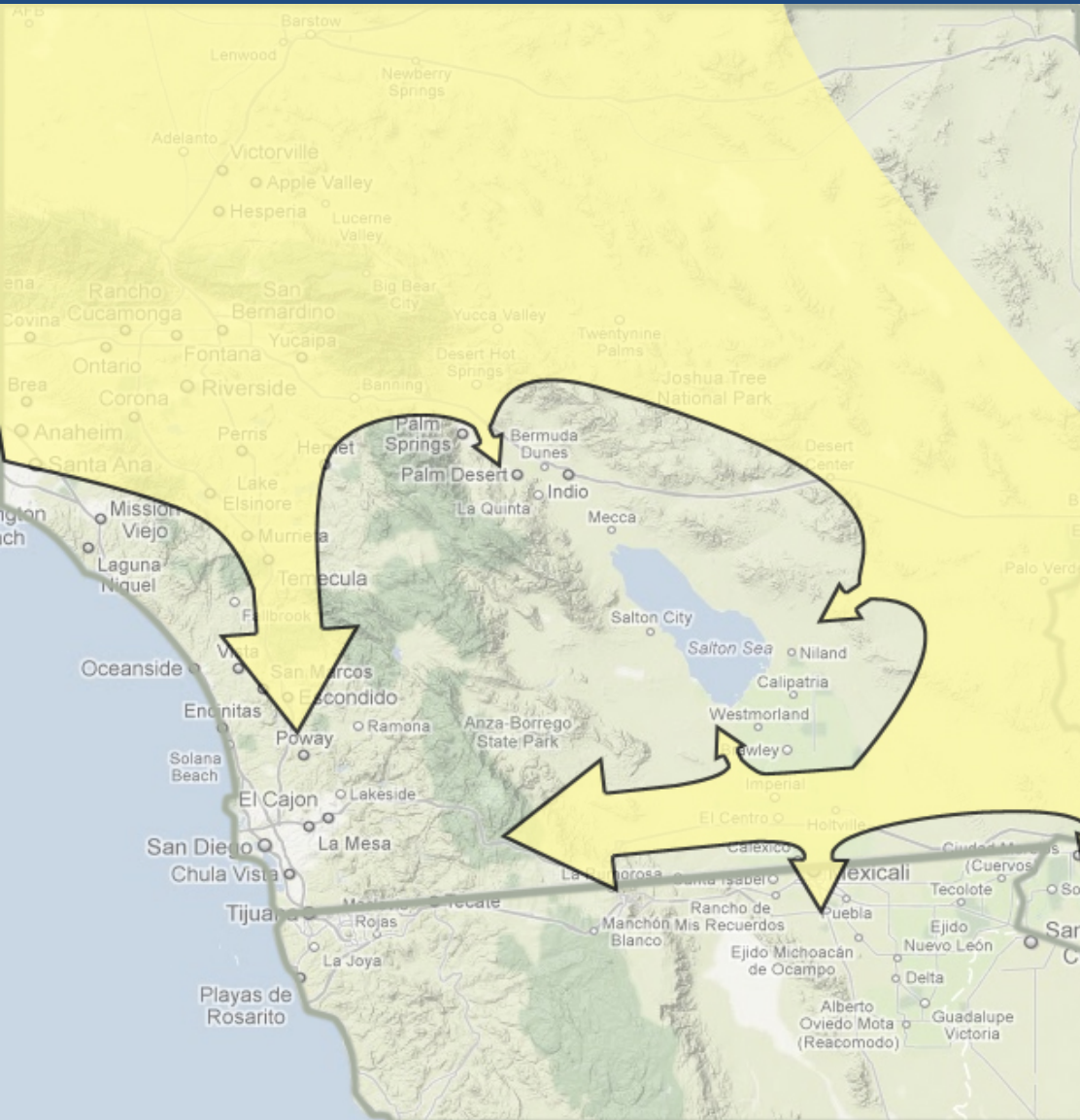
ID	Source	SourceFileName	Event Time
85	IID	Disturbance Data Form Sep08-2011-IID.	15:28:17.265
Event			
Coachella Valley 230/92kV Bank #1 No Longer Carrying Load			
<input checked="" type="checkbox"/> Phase-Initiating Event? InfoLevel 3 EventType Transform			
DetailedEvent			
Coachella Valley 230kV KSNO breaker open. This breaker is a High side breaker on the 230kV Ring Bus arrangement. The other high side H1O breaker was opened at 15:28:17.264, resulting in the disconnection of Bank #1. The overcurrent tripping relay (51) recorded 843 A on the 230 kV winding at the time of trip.			
	Start	Stop	Time Zone
Raw	15:28:17		PDT
Agreed	15:28:17		PDT
	Agreed ms		
	265	TimeQuality	NIST
<input checked="" type="checkbox"/> Reconciled?			
HowDateWasReconciled			
Confirmed within 0.1 seconds by Devers 230kV PMU voltage and frequency.			
Notes Comments			
From Bus #	21007	To Bus #	21008
	COACHELV		COACHELV
	230		92
Station	Coachella Valle	Circuit #	1
		MVAR	

- The database was reviewed collectively by the SOE team
 - What caused the event?
 - Does the sequence make sense?
 - Does the data support the cause?
 - Can the timing be verified?
- These questions may be difficult to answer when multiple events occur near-simultaneously
- Using PMU data, we were able to verify the SOE in 6 total meeting days

Simplified System Diagram



Phase 1 – Pre-Disturbance



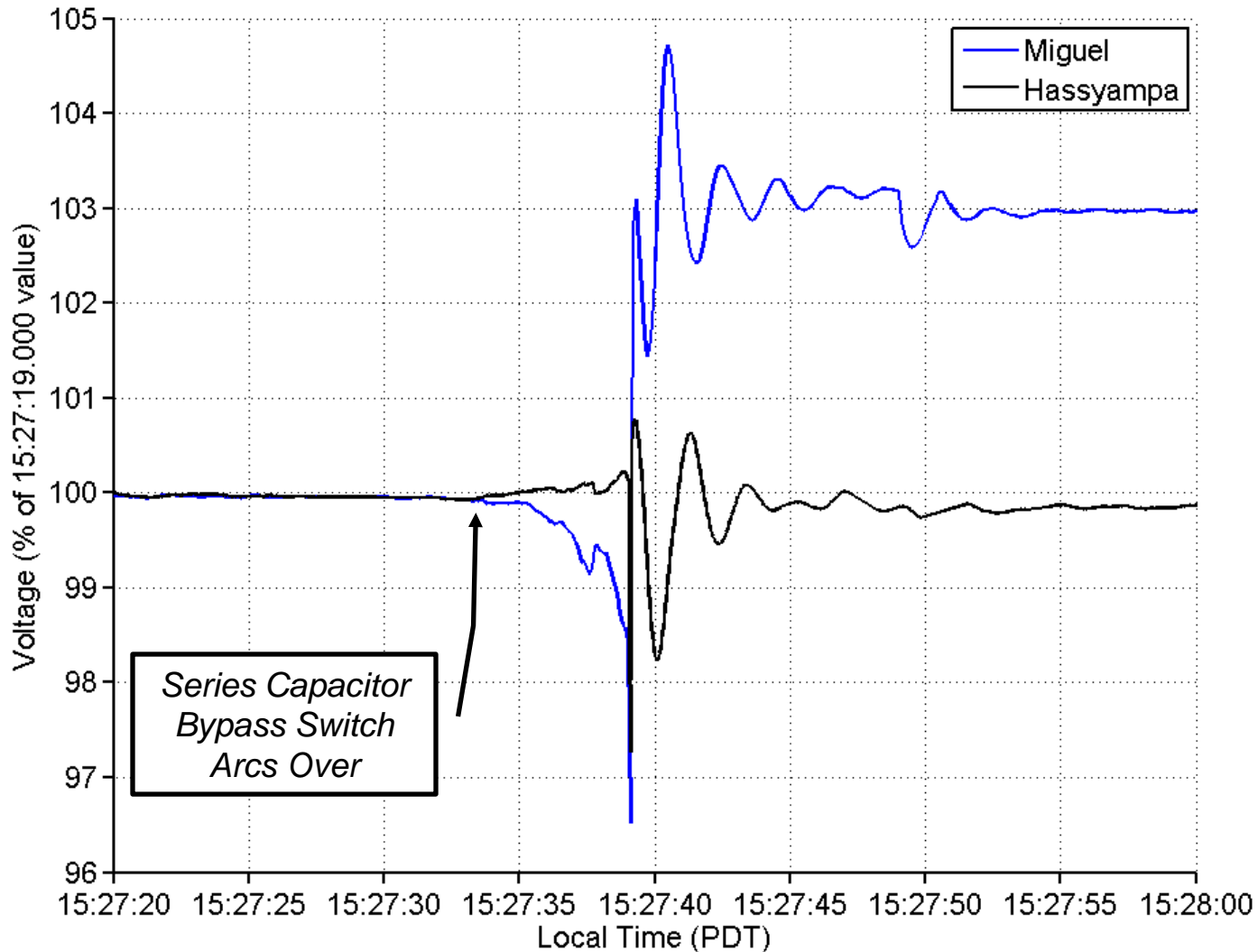
- *Hot, shoulder season day; some generation and transmission outages*
- *High loading on some key facilities: H-NG at 78% of normal rating; CV transformers at 83%*
- *44 minutes before loss of H-NG, IID's RTCA results showed loss of CV-1 transformer would load CV-2 transformer above its relay trip point*
- *15:27:39: APS technician skipped a critical step in isolating the series capacitor bank at North Gila substation; H-NG trips*

Phase 2 – Trip of H-NG 500 kV

15:27:39 – 15:28:16

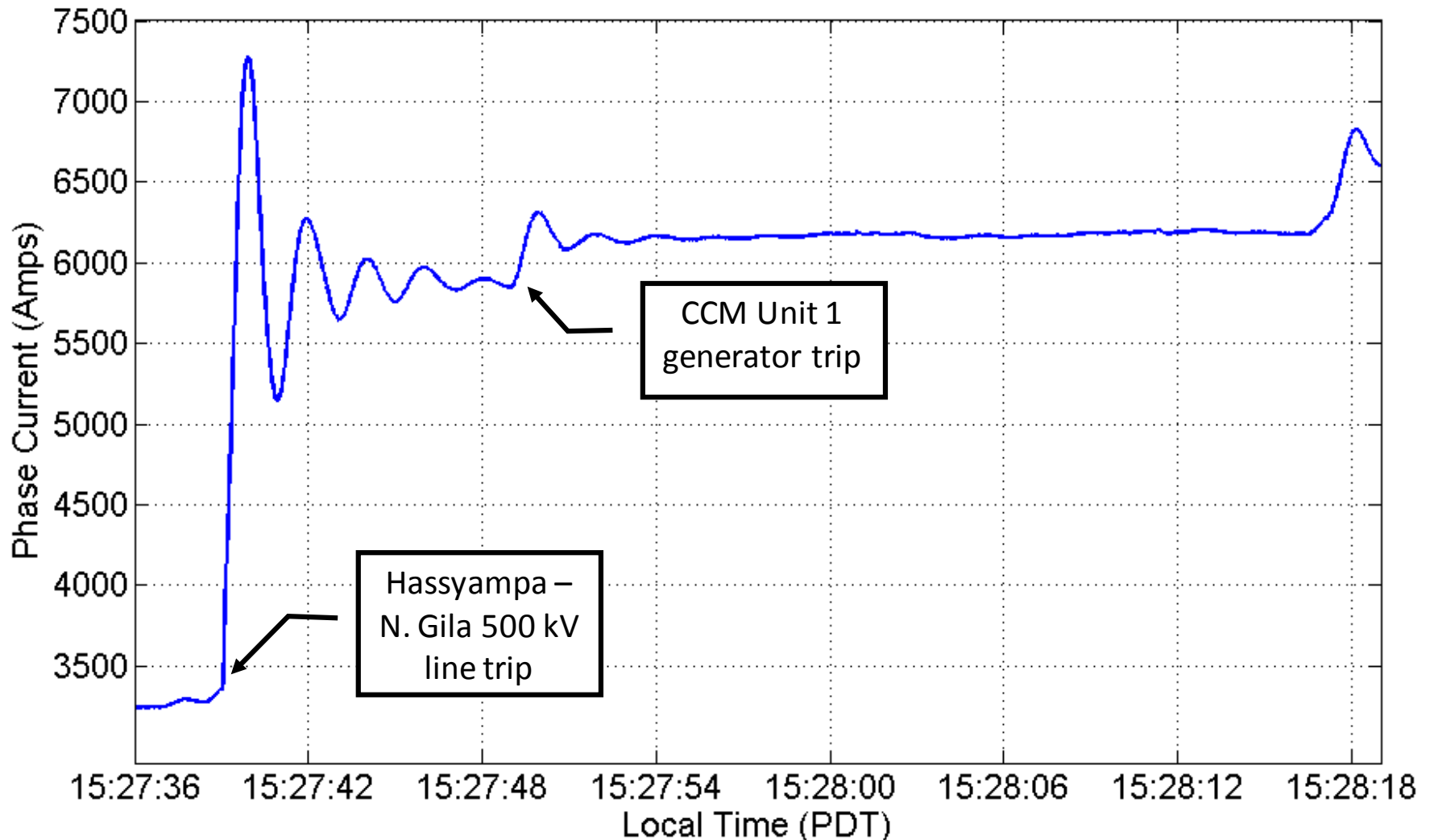
- *H-NG 500 kV trips at 15:27:39*
- *APS tells WECC RC line expected to be restored quickly*
- *H-NG flow redistributes: 77% to SCE-SDGE (Path 44); remainder to IID, and WALC*
- *CV transformers immediately overloaded above relay settings*
- *Path 44 at 5,900 amps; 8,000 amp limit on SONGS separation scheme*

Initiating Event – Voltage Divergence Hassayampa – North Gila 500 kV Trip



Hass. – N. Gila 500 kV Line Trip

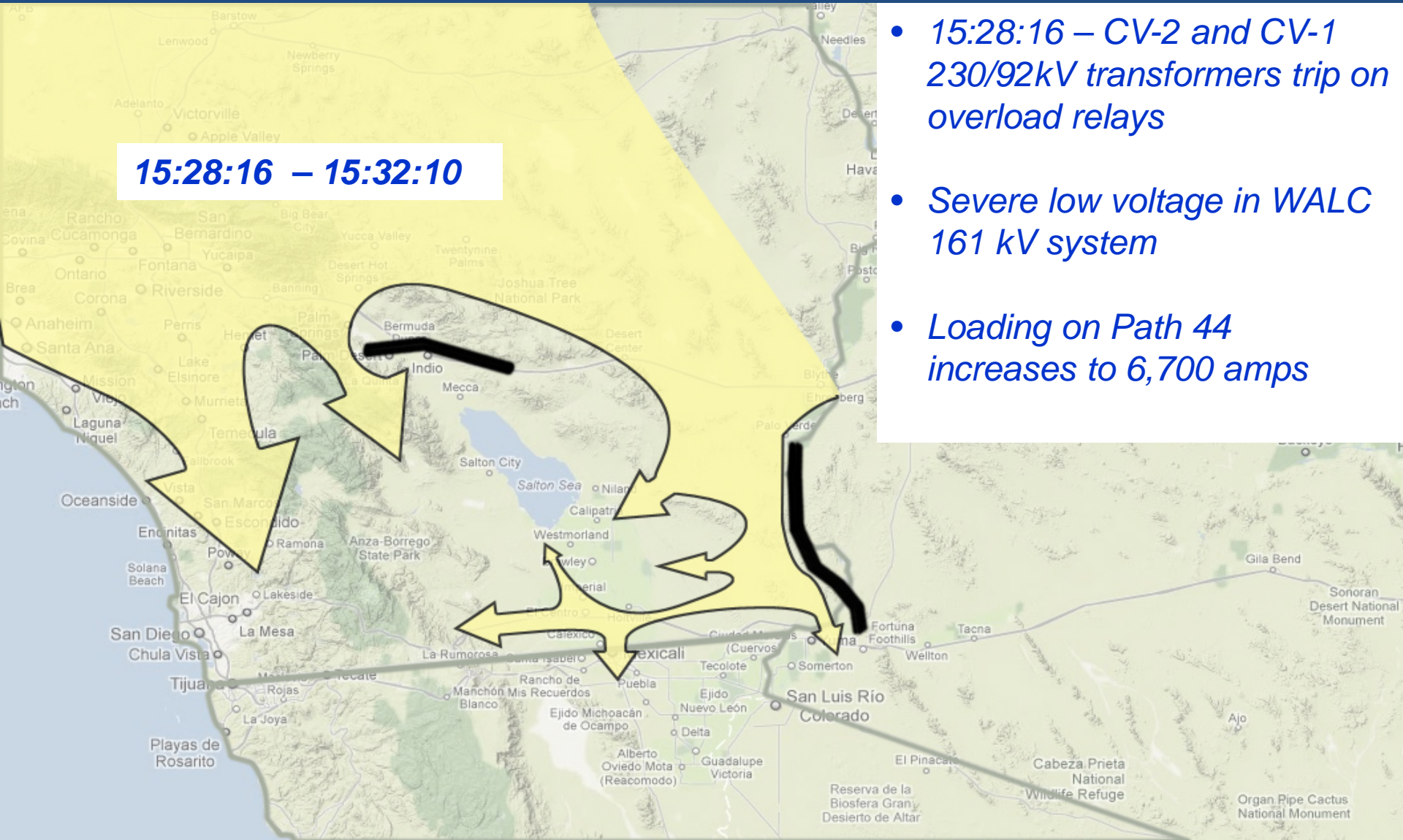
South of SONGS Current



Phase 3 – Trip of CV Transformers

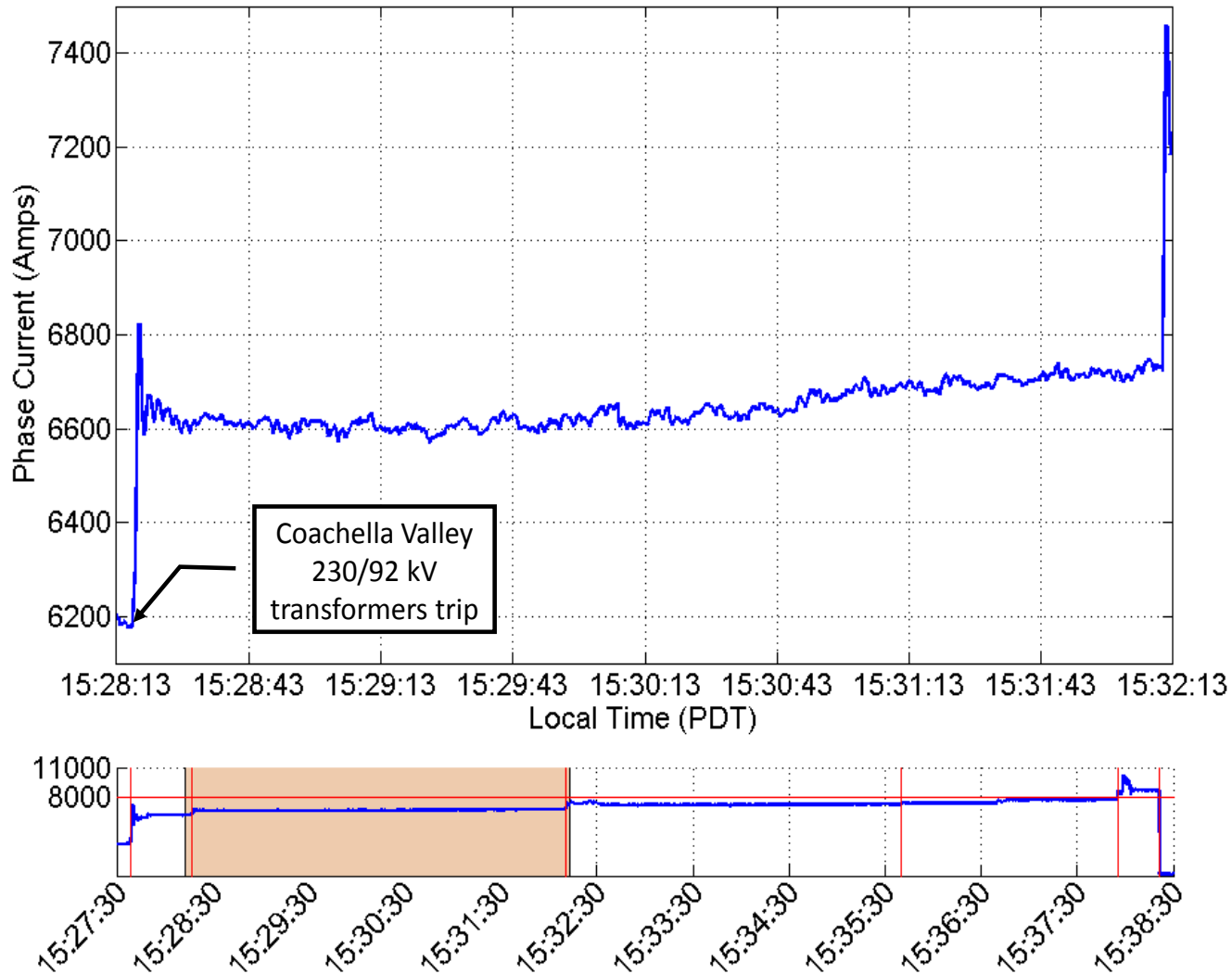
15:28:16 – 15:32:10

- 15:28:16 – CV-2 and CV-1 230/92kV transformers trip on overload relays
- Severe low voltage in WALC 161 kV system
- Loading on Path 44 increases to 6,700 amps



Coachella Valley Transf. Trip

South of SONGS Current



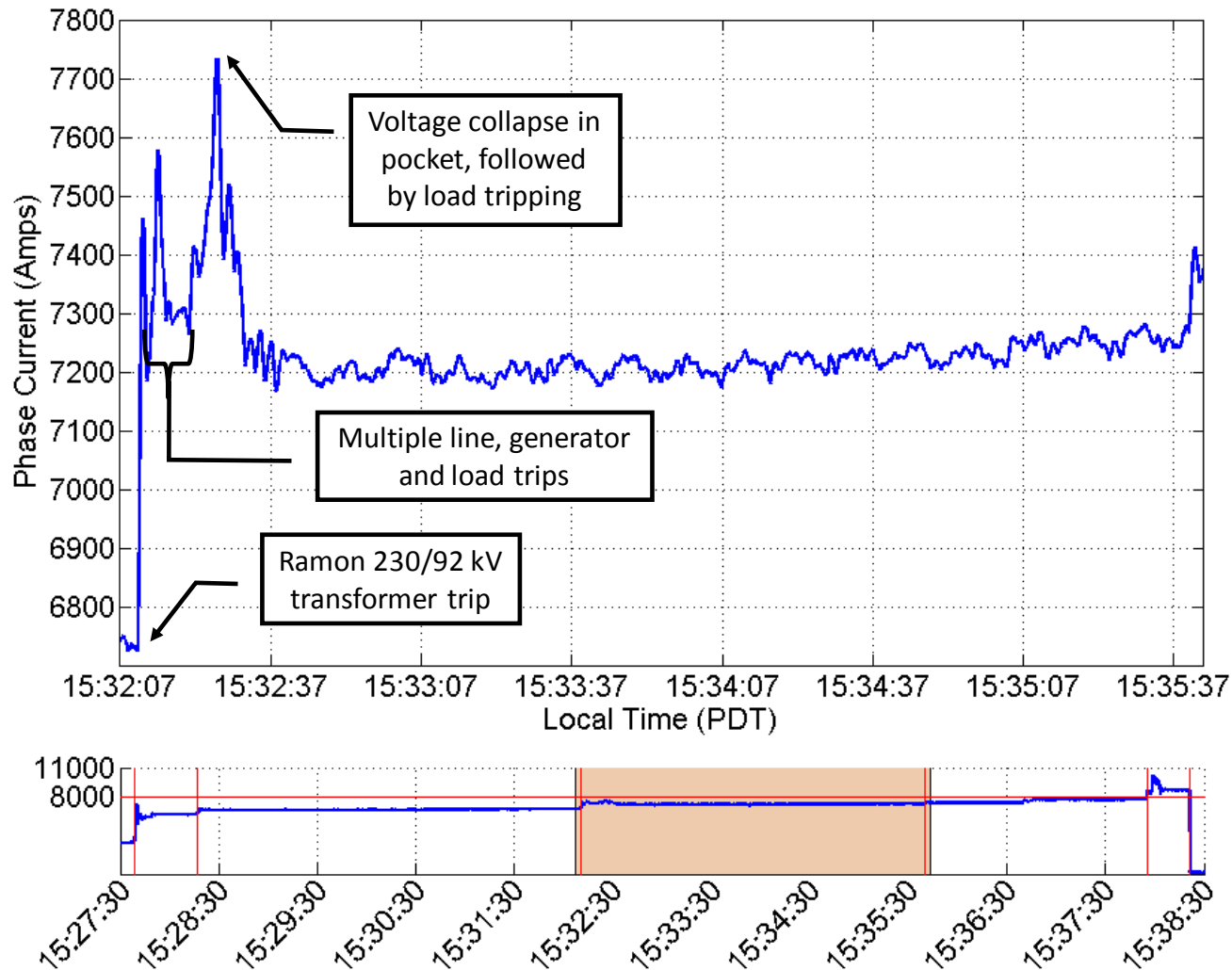
Phase 4 – Ramon Xfmr Trip

15:32:10 – 15:35:40

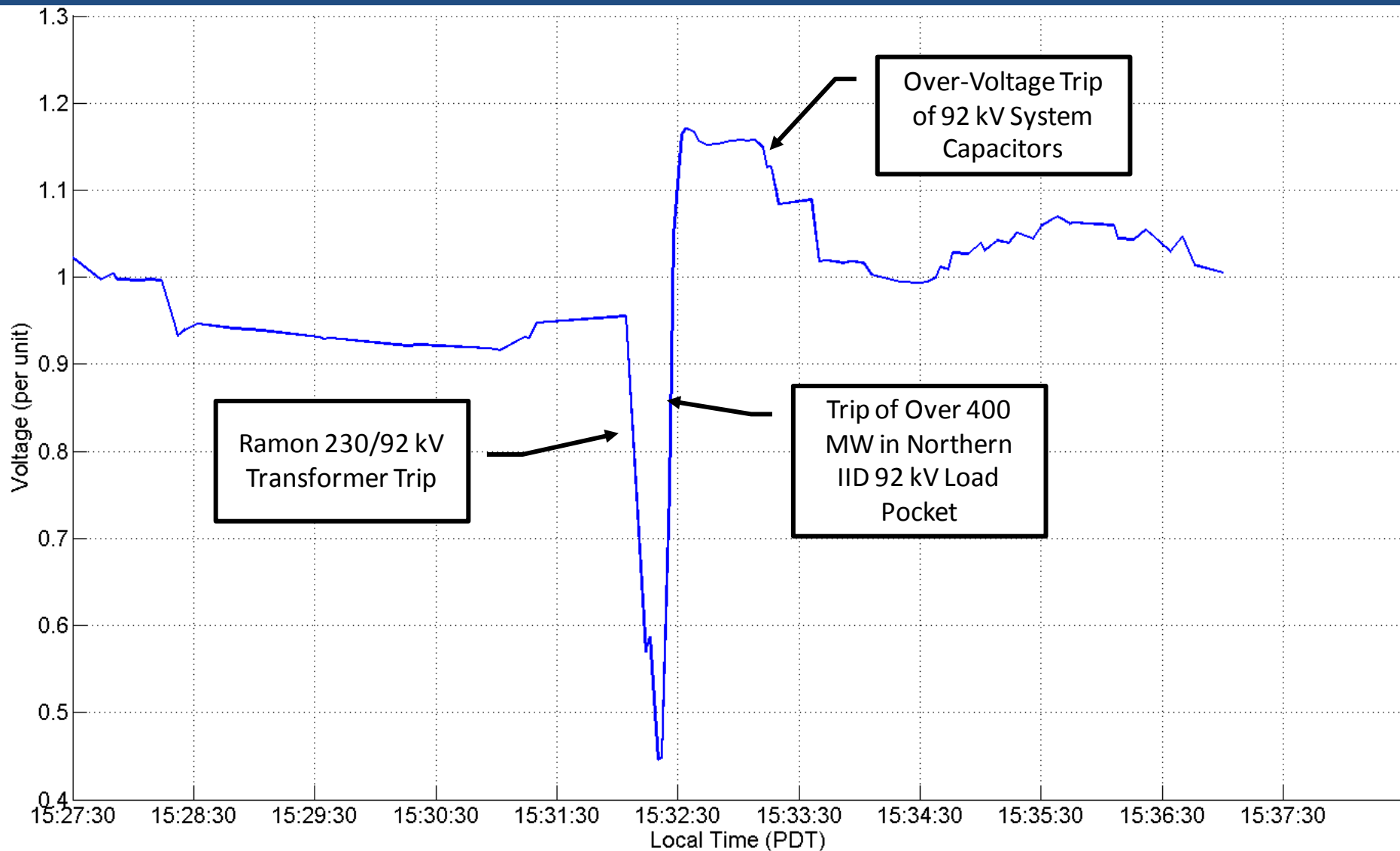
- 15:32:10 Ramon 230/92kV transformer trips on overload relay
- 15:32:13 Blythe-Niland 161kV line trips
- 15:32:15 Niland – CV 161kV line trips
- IID undervoltage load shedding; loss of generation and 92 kV transmission lines
- Severe low voltage in WALC 161 kV system
- Loading on Path 44 increases to 7,800 amps; settles at 7,200 amps

Ramon Transformer Trip

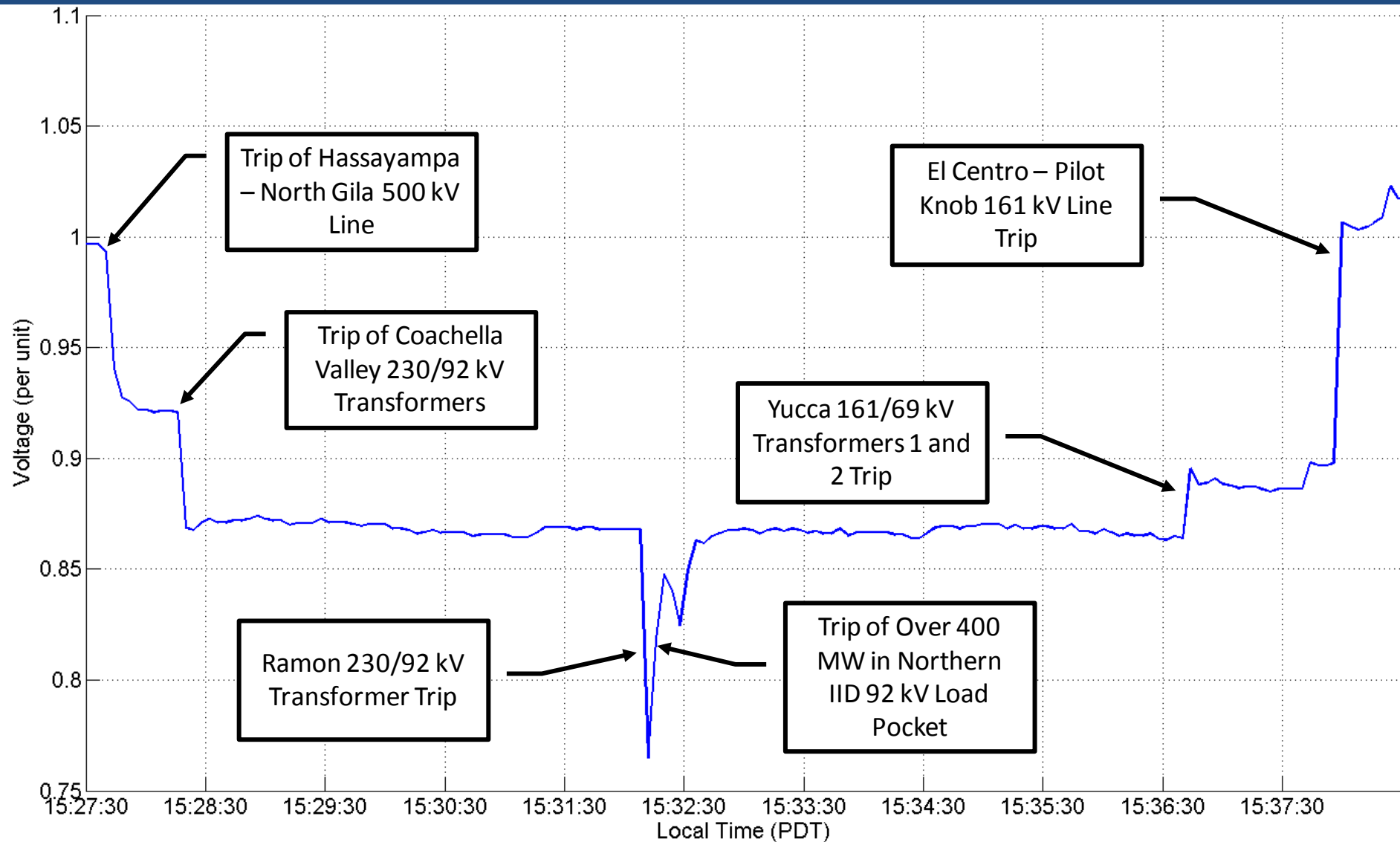
South of SONGS Current



Voltage in Northern IID 92 kV System



Blythe 161 kV Voltage

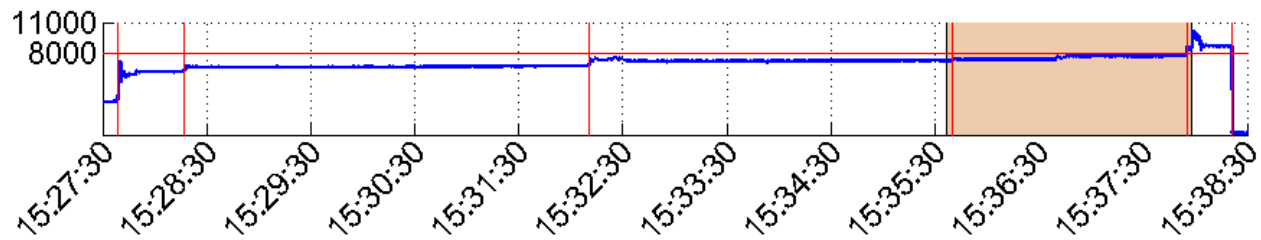
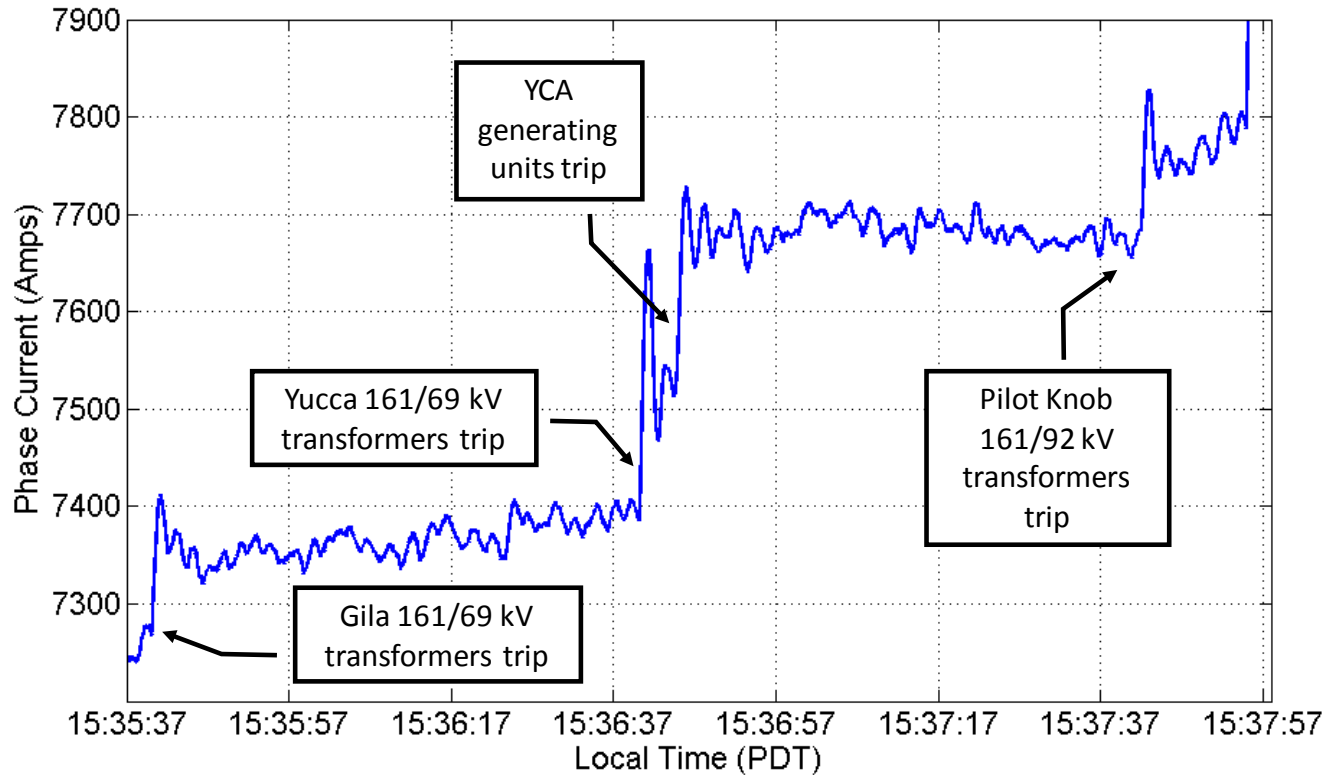


Phase 5 – Yuma Separates

15:35:40 – 15:37:55

- *Yuma AZ Separates from IID and WALC when Gila and Yucca transformers trip*
- *Yuma load pocket isolated on single tie to SDG&E*
- *Loading on Path 44 increases to 7,400 amps after Gila transformer trip; to 7,800 amps after Yucca transformers and generator trip*

South of SONGS Current



Phase 6 – High-Speed Cascade

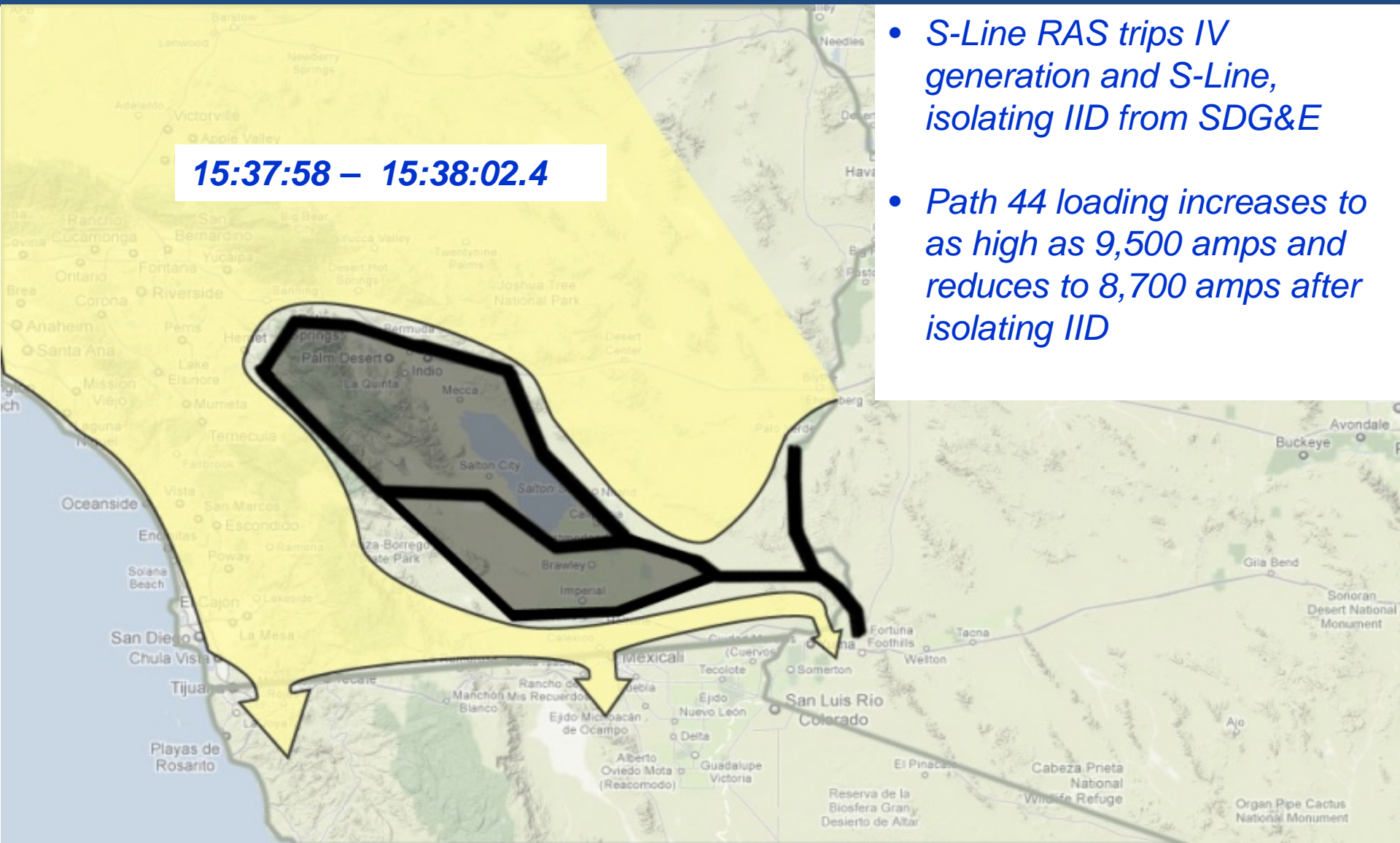
15:37:55

- *El Centro – Pilot Knob 161kV line trips; all IID 92 kV system radial from SDG&E via S-Line*
- *WALC 161 kV system voltage returns to normal*
- *Path 44 exceeds 8,000 amp setting and timer starts*

Phase 6 – High-Speed Cascade

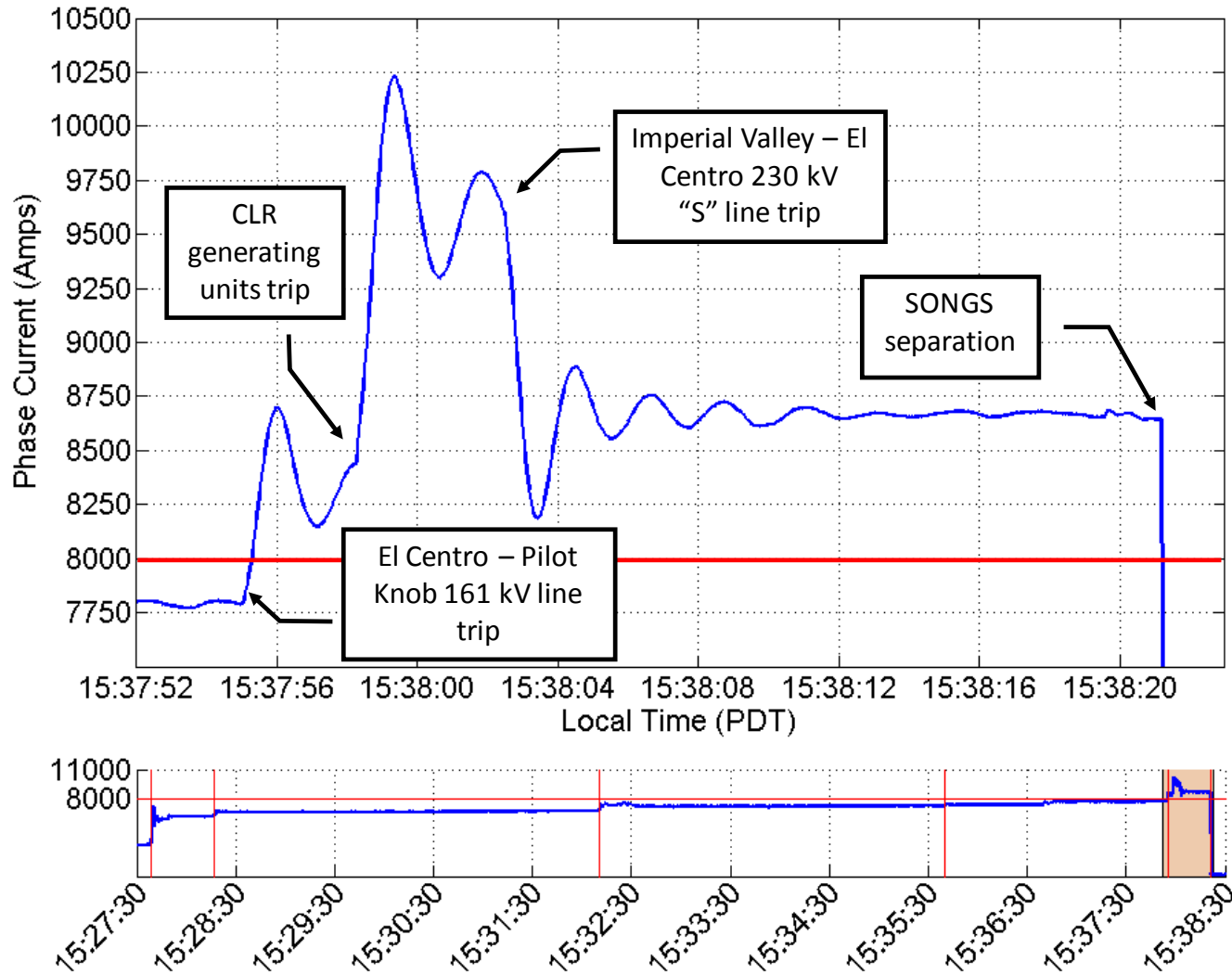
15:37:58 – 15:38:02.4

- *S-Line RAS trips IV generation and S-Line, isolating IID from SDG&E*
- *Path 44 loading increases to as high as 9,500 amps and reduces to 8,700 amps after isolating IID*

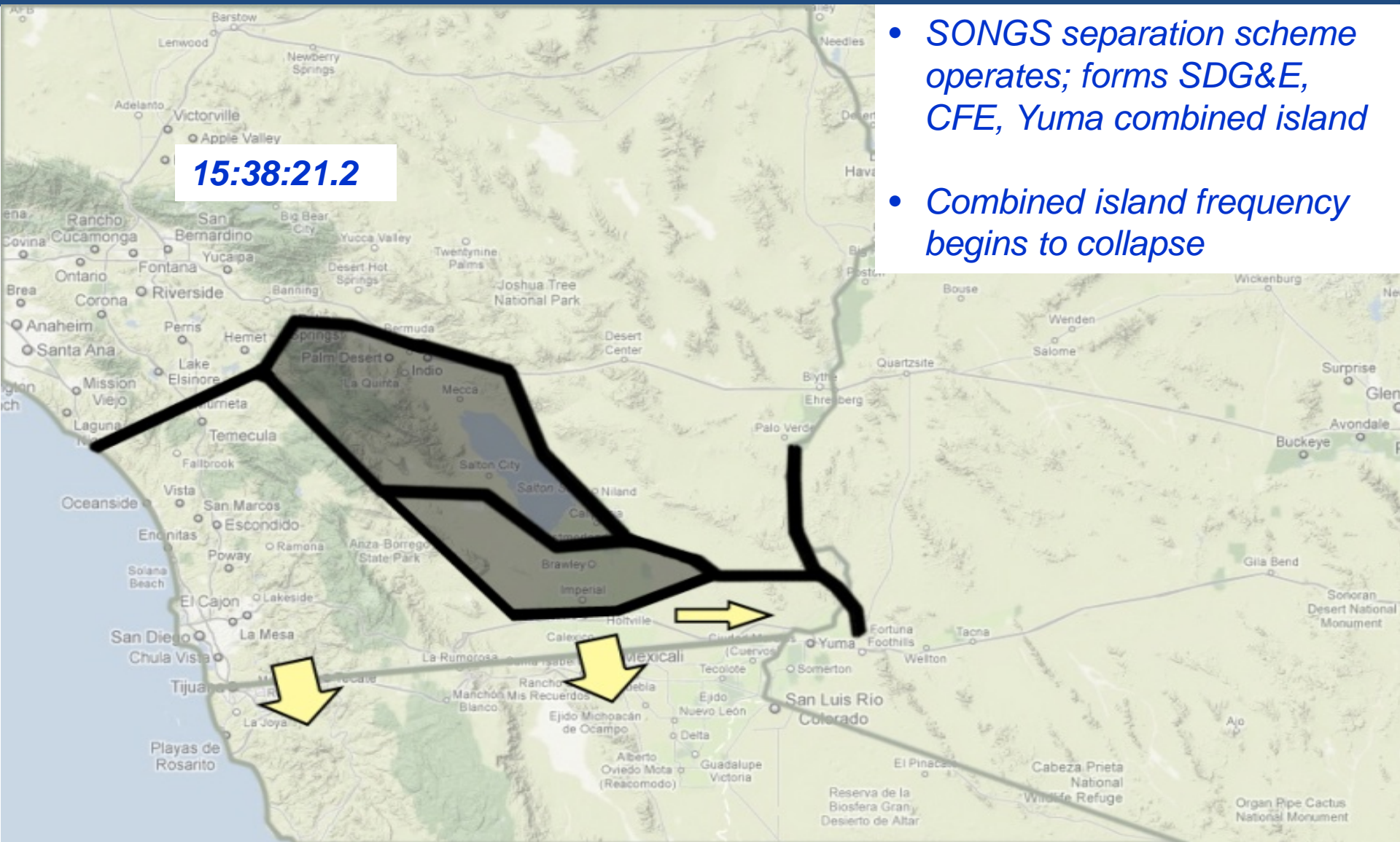


Phase 6 – High-Speed Cascade

South of SONGS Current

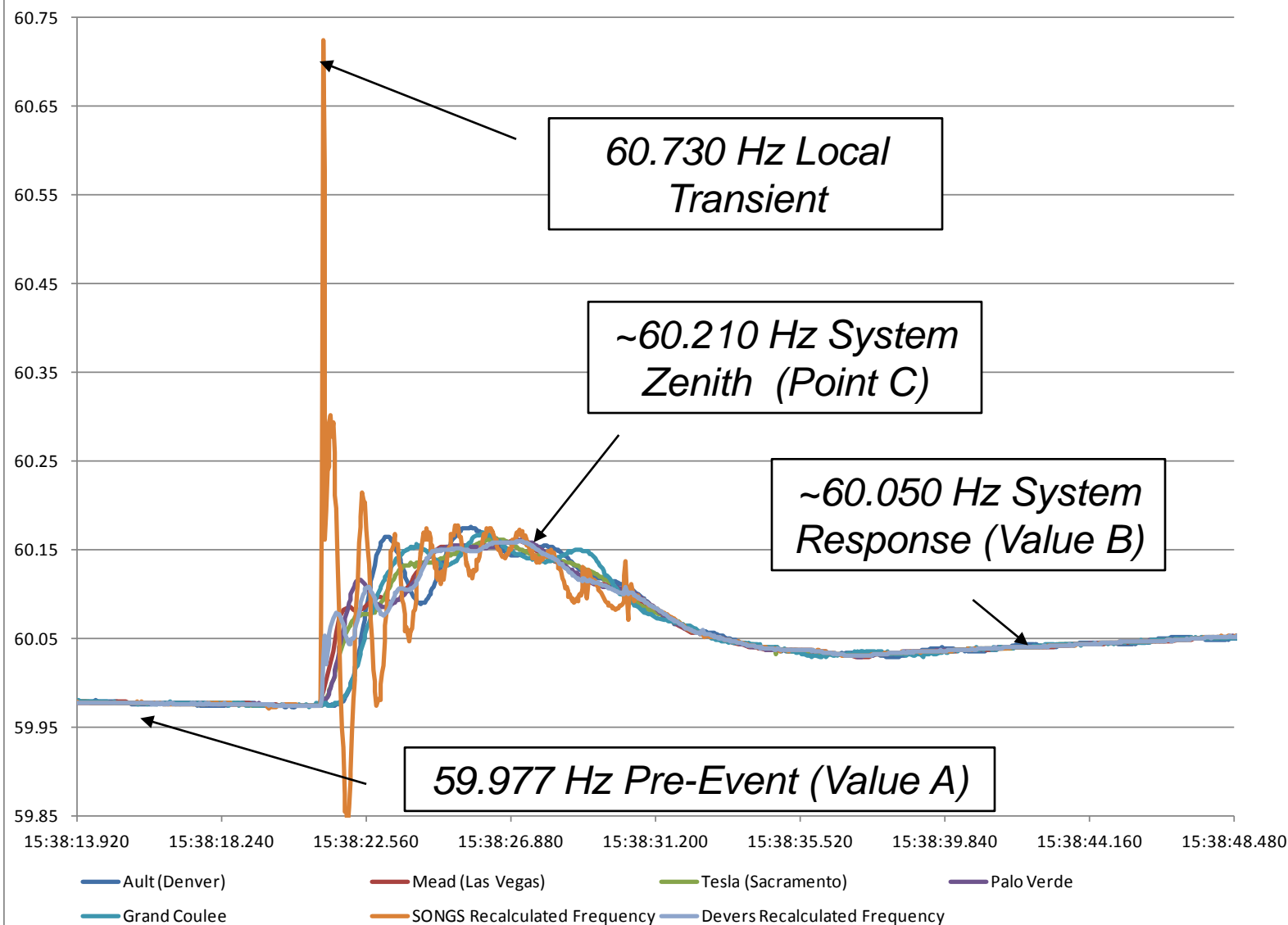


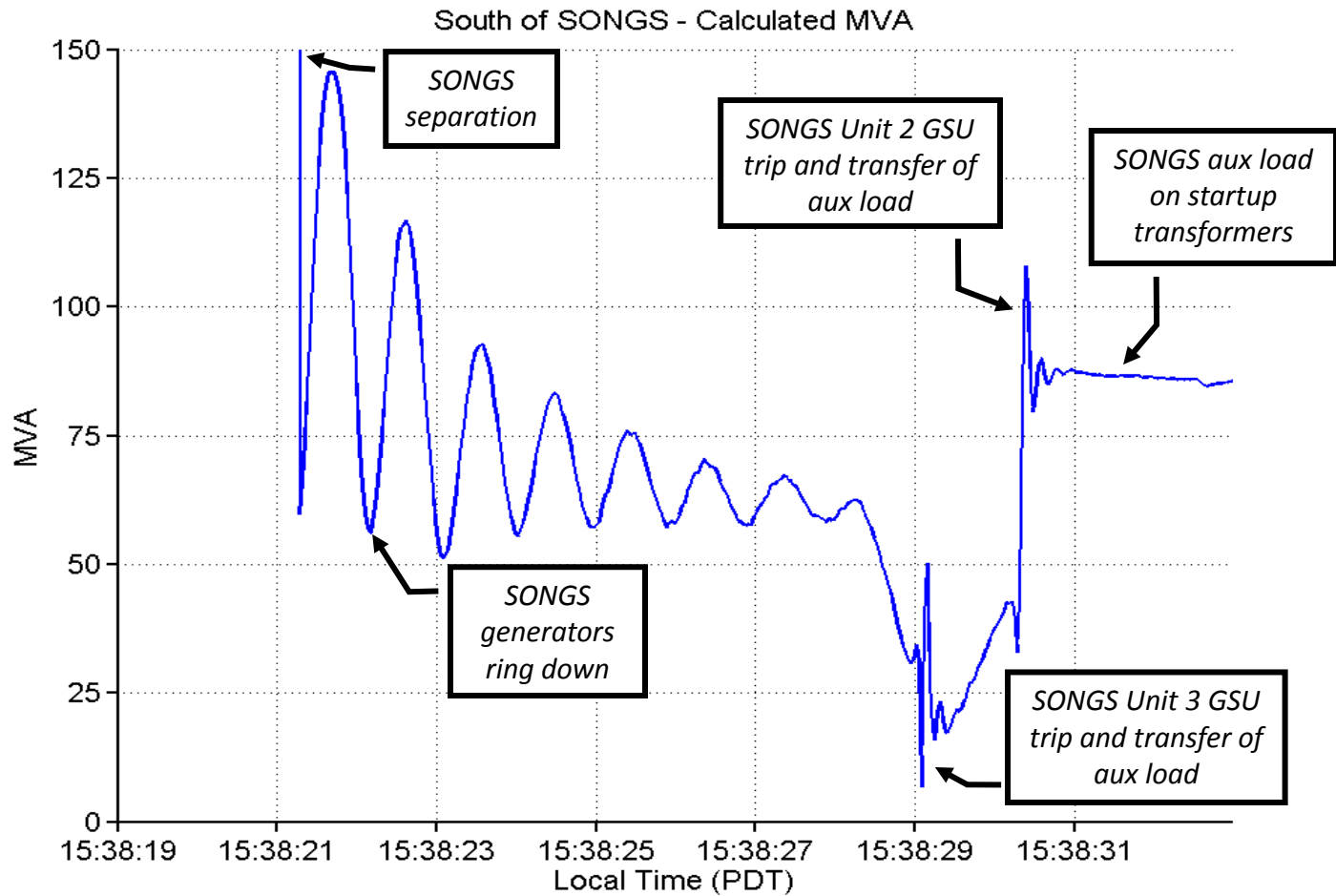
Phase 6 – High-Speed Cascade



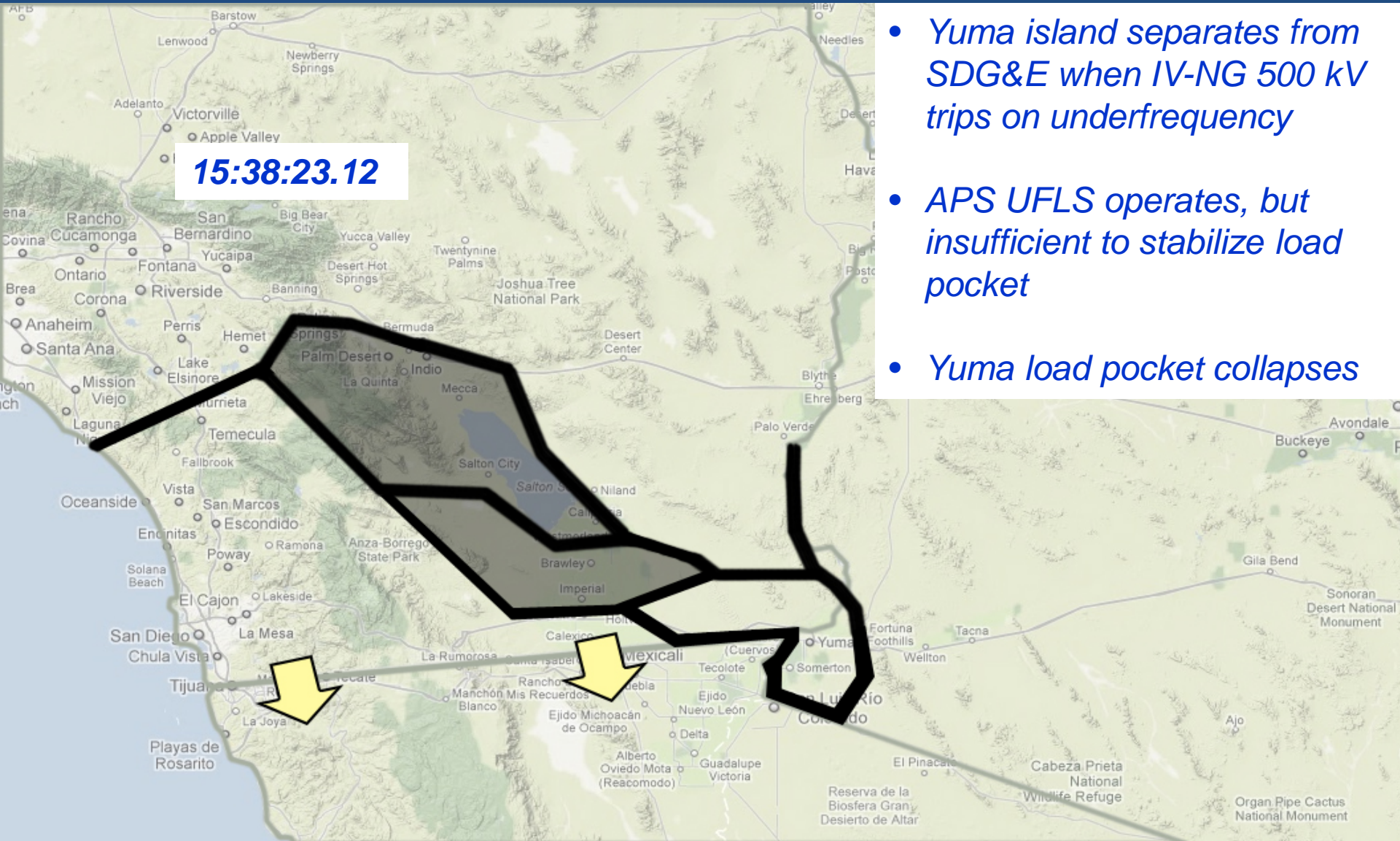
- *SONGS separation scheme operates; forms SDG&E, CFE, Yuma combined island*
- *Combined island frequency begins to collapse*

SONGS Sep. Frequency Impacts

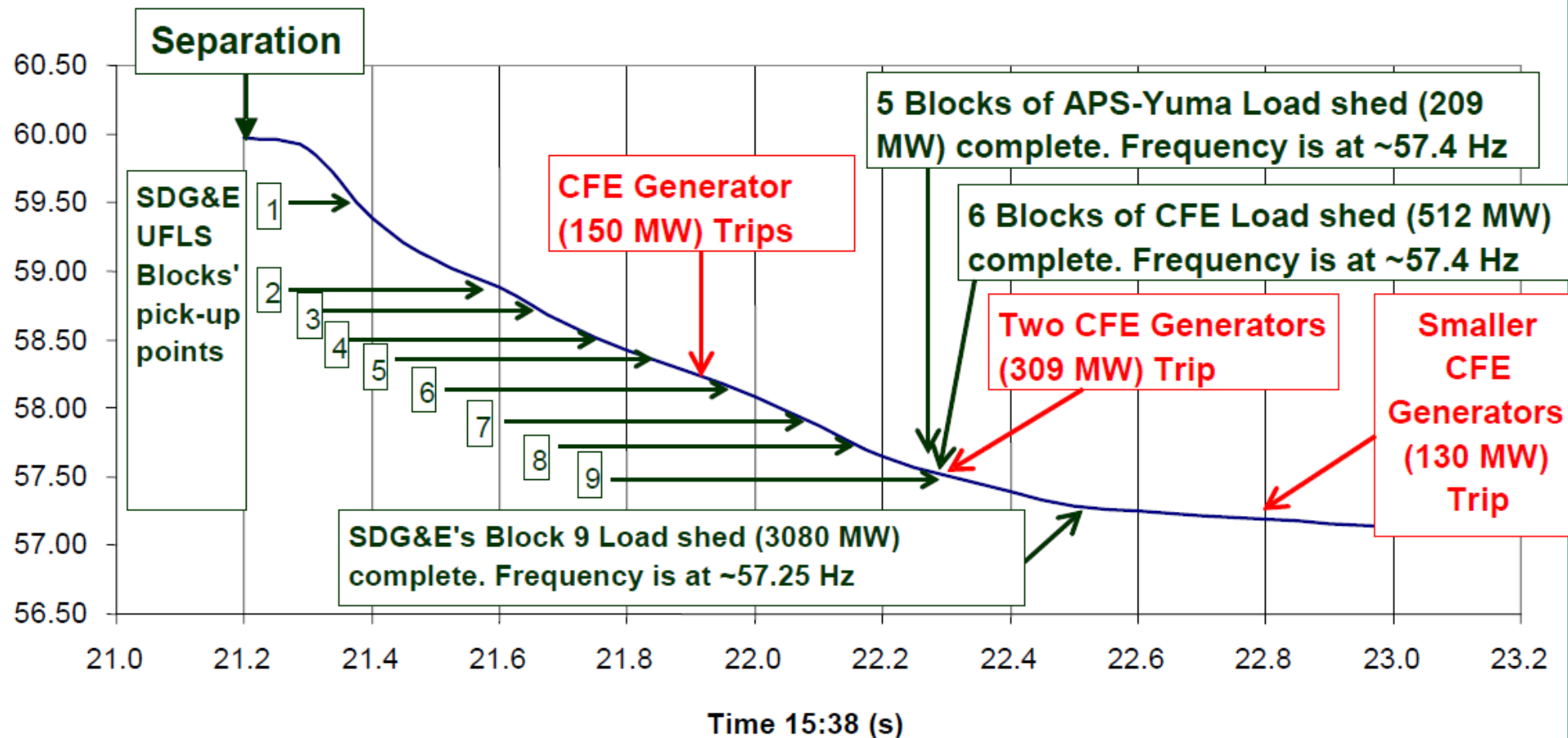




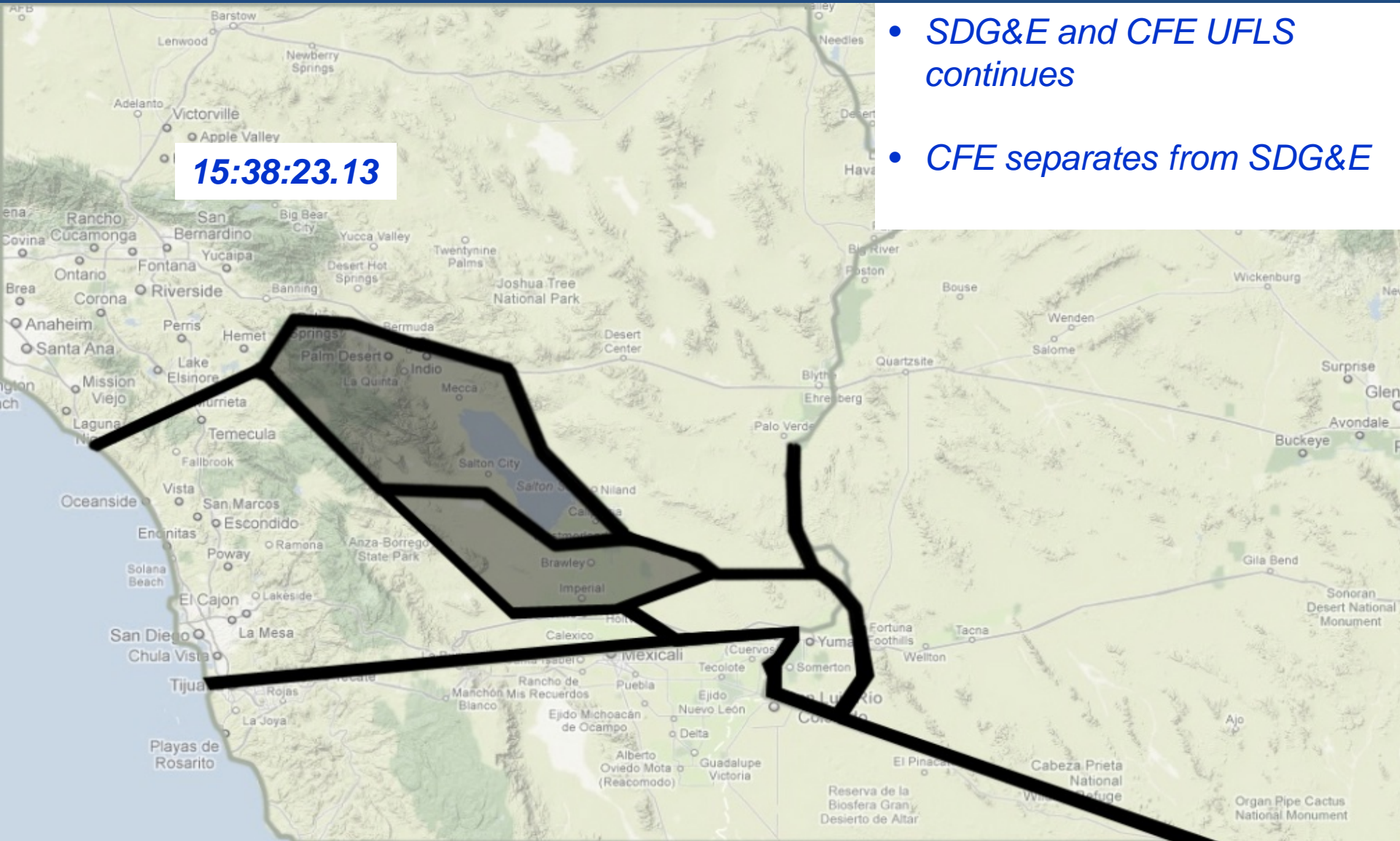
Phase 7 – S CA Separates



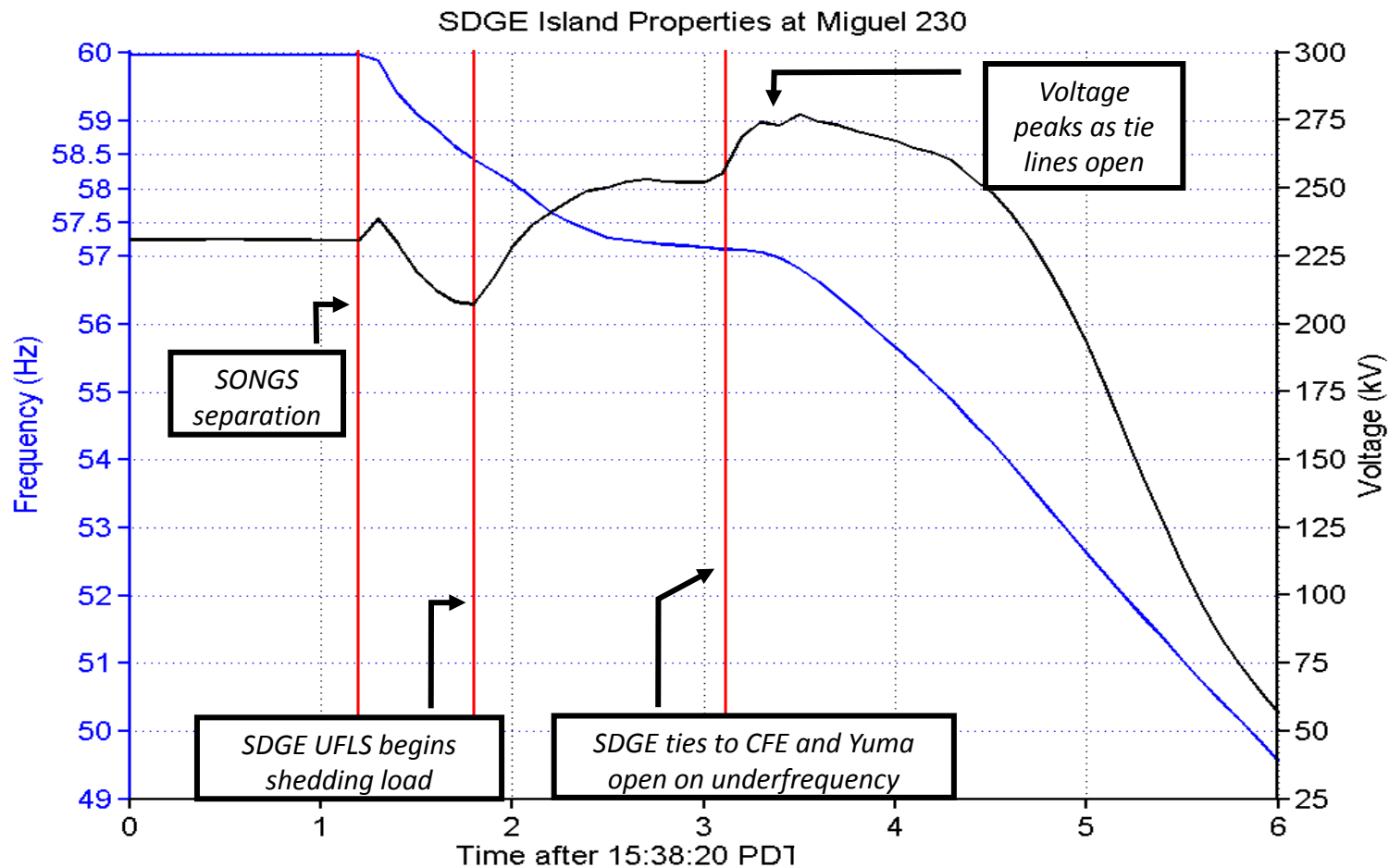
UFLS Operations in the Island



Phase 7 – CFE Separates



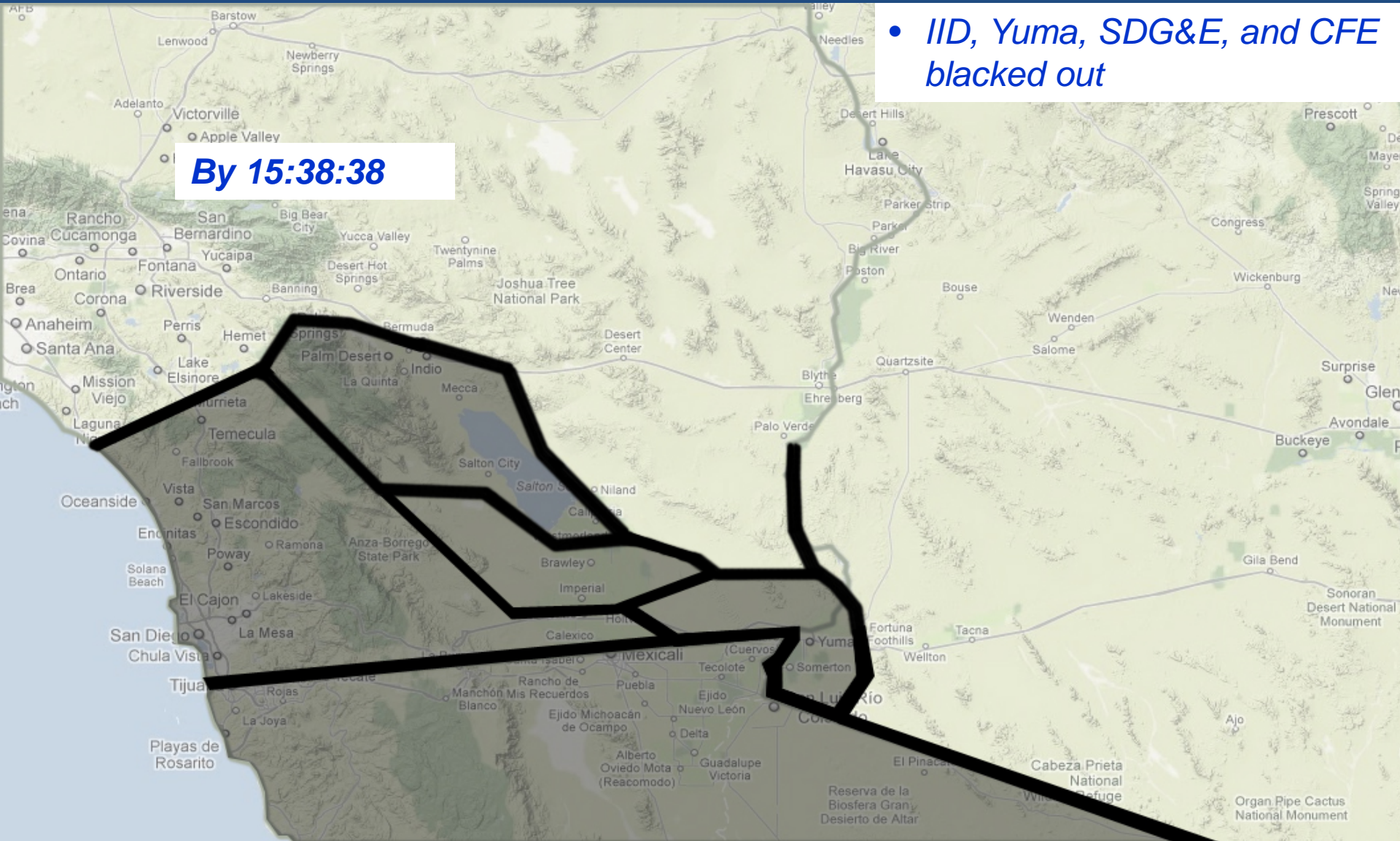
- *SDG&E and CFE UFLS continues*
- *CFE separates from SDG&E*



Phase 7 – Complete Blackout

- IID, Yuma, SDG&E, and CFE blacked out*

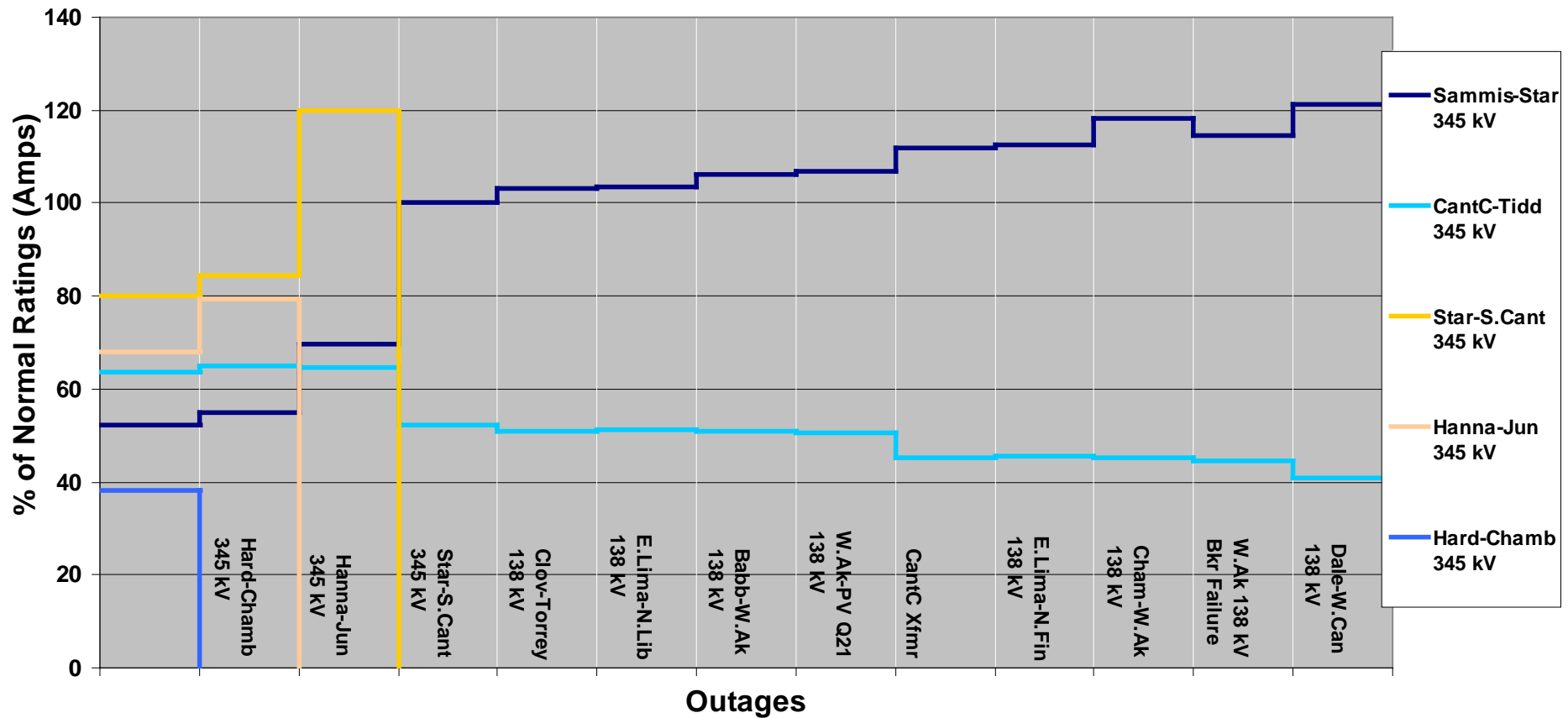
By 15:38:38

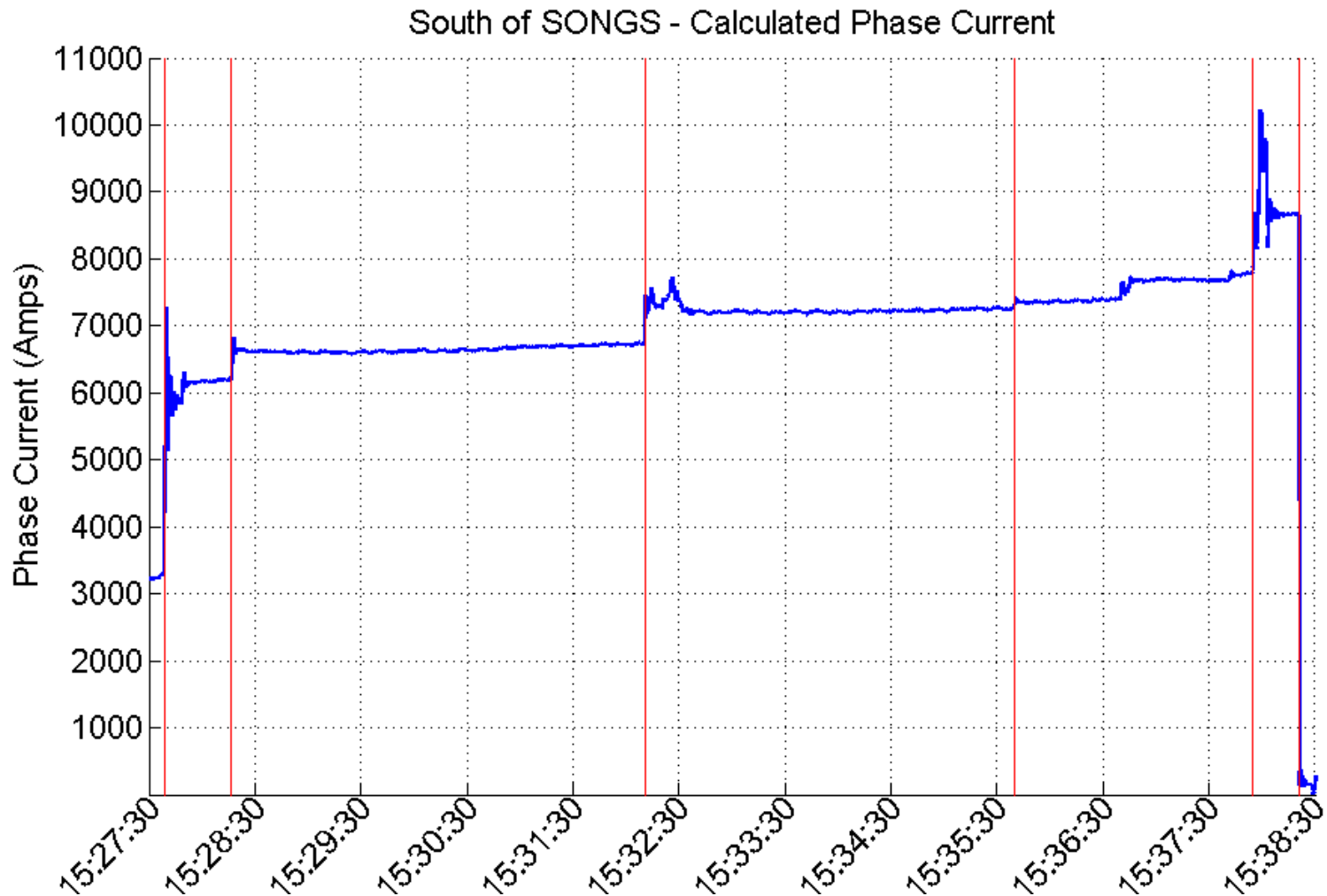


A light blue map of North America is centered on the slide. Overlaid on the map is a photograph of a nuclear power plant, showing several large, white, hourglass-shaped containment domes and a smaller, blue, dome-shaped structure in the background. The image is semi-transparent, allowing the map to be seen through it.

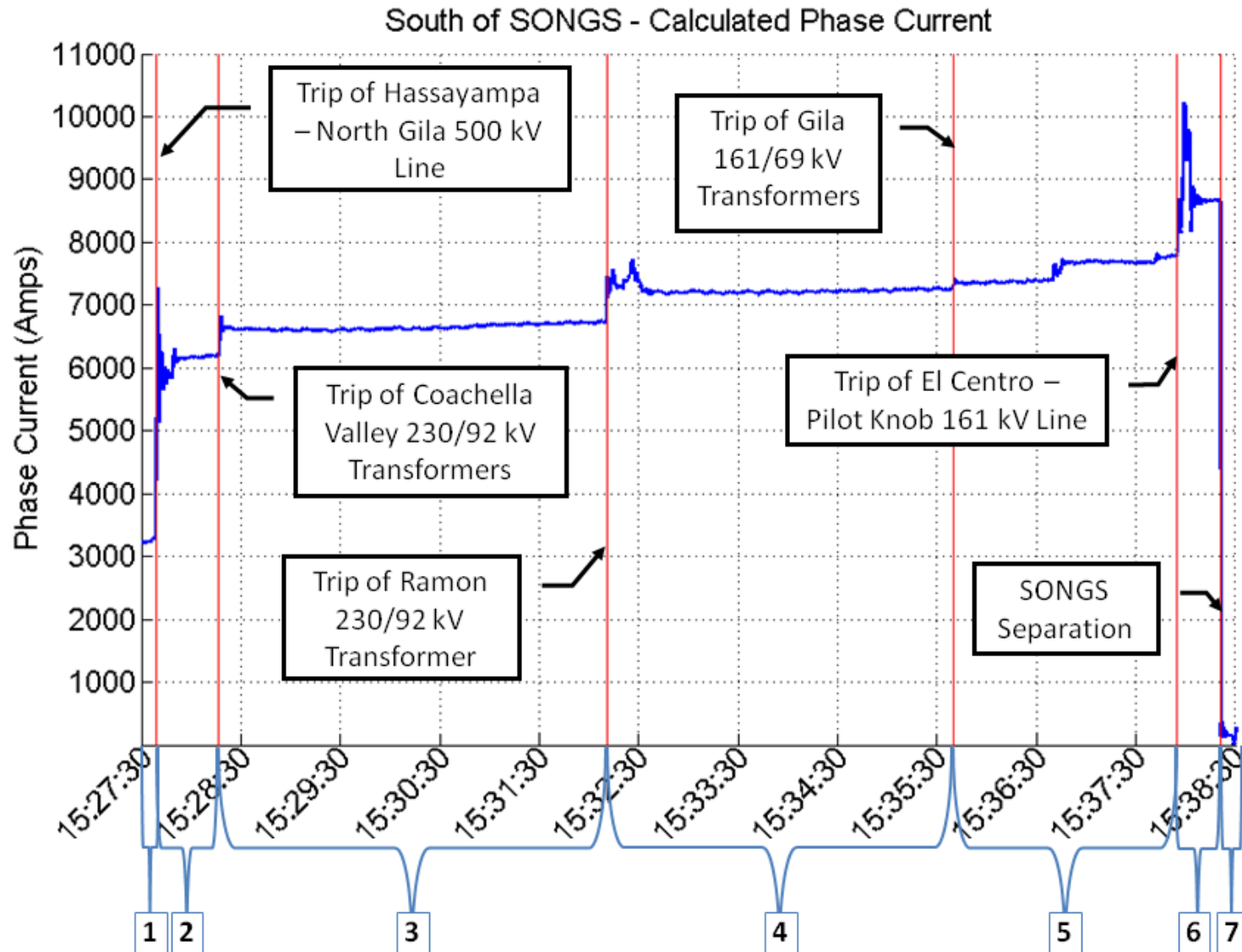
Use of PMUs in EA

2003 Blackout Simulations





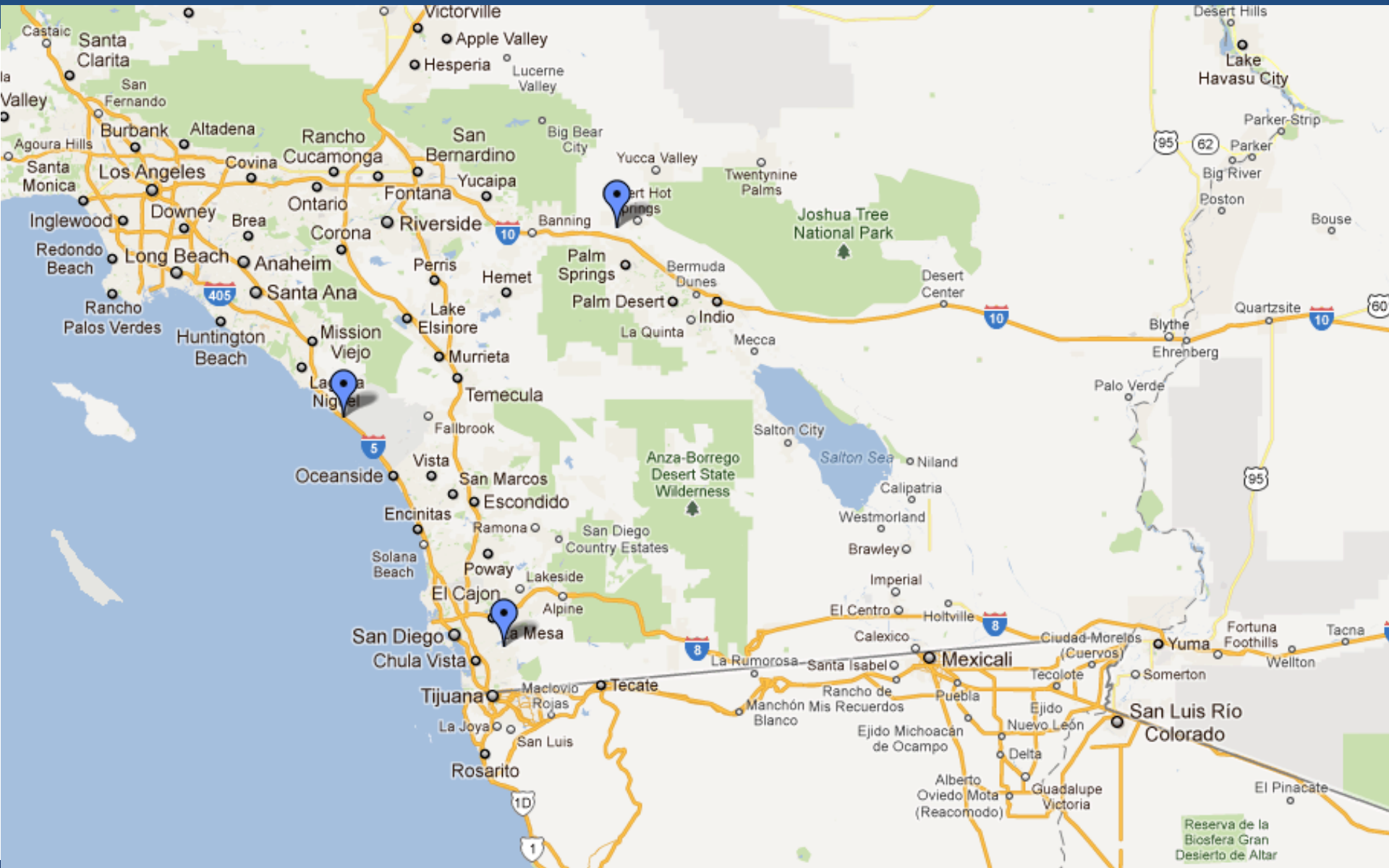
7 Phases of Event



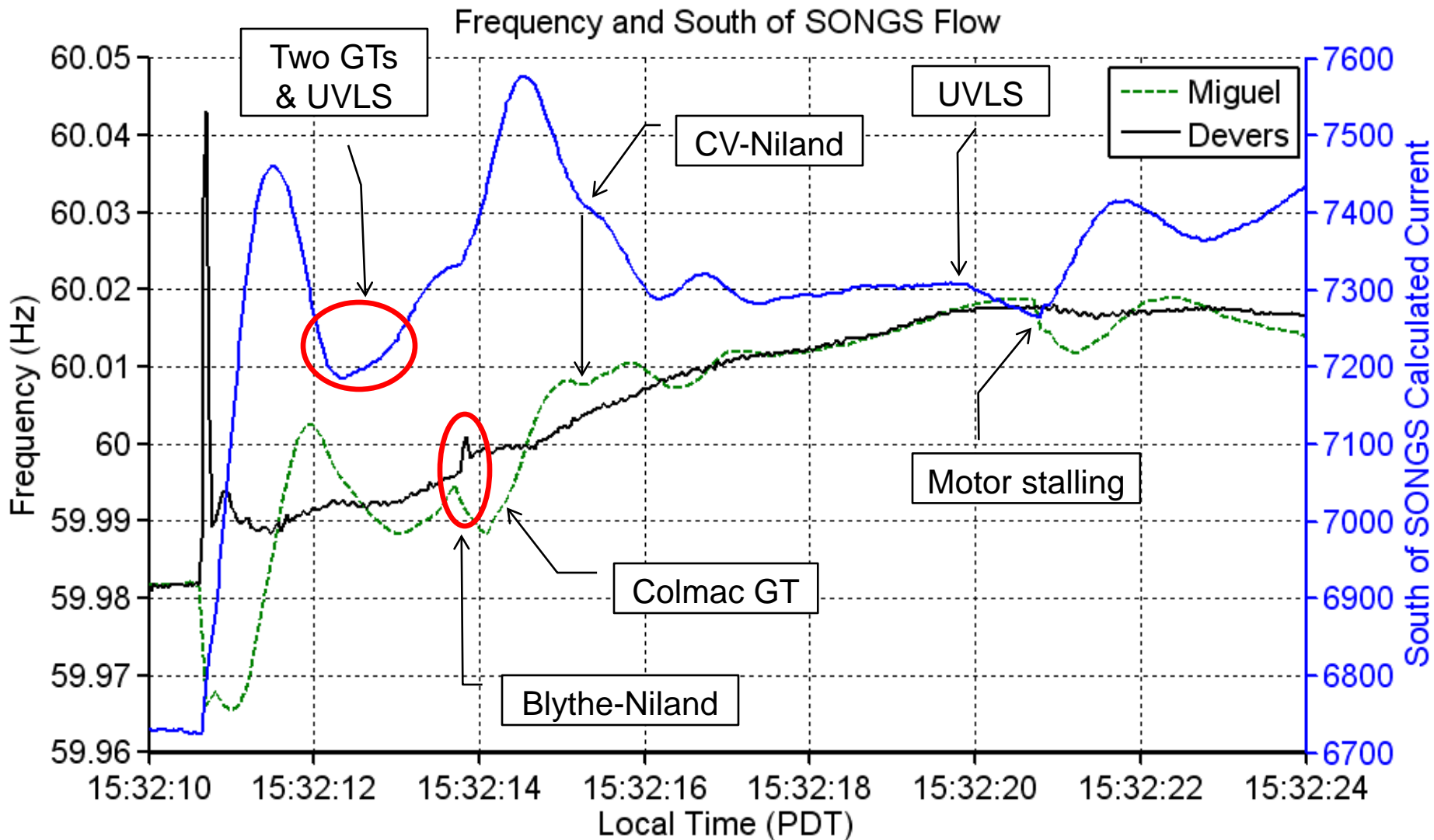


Sequence of Events Analysis with PMUs

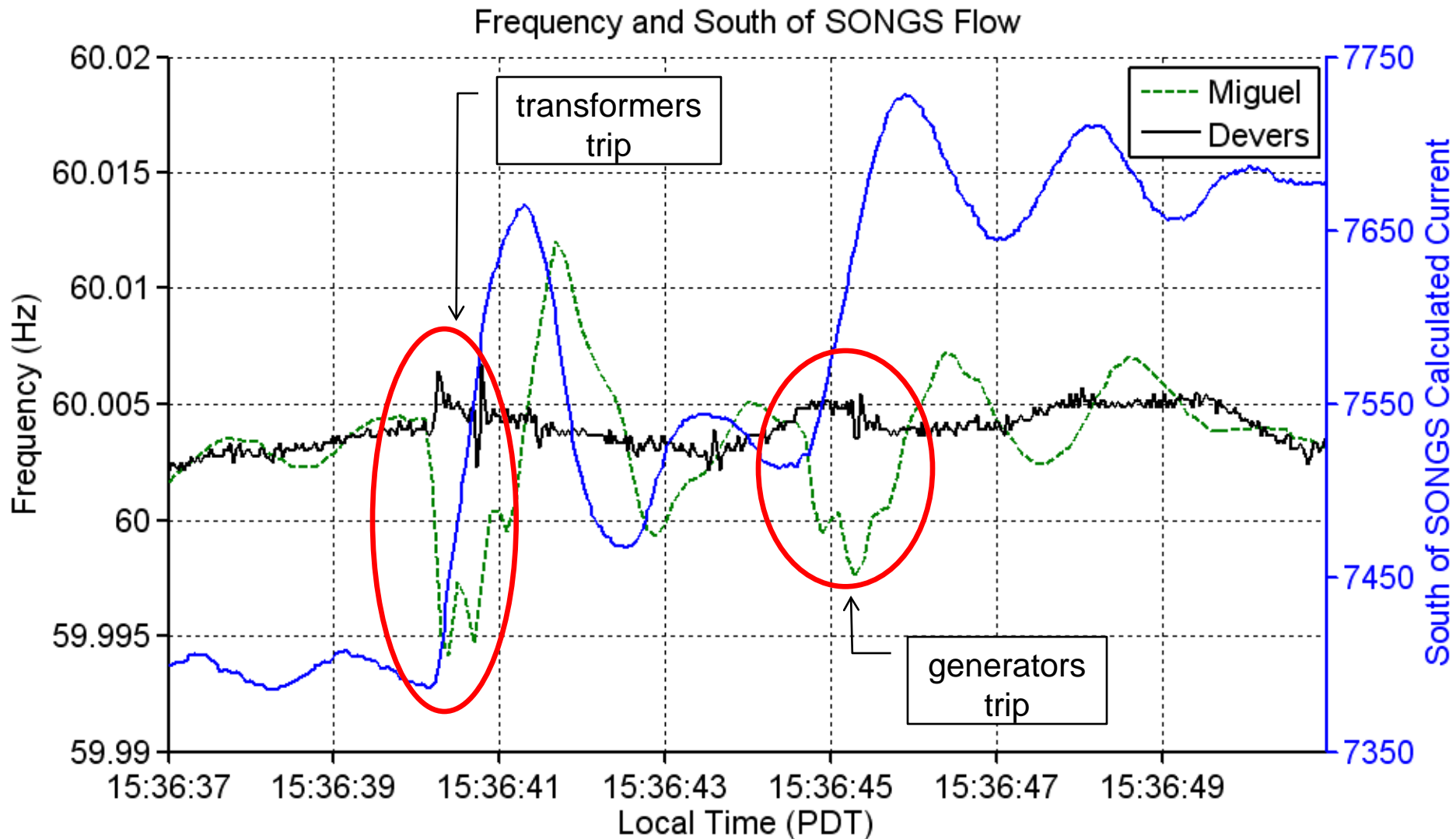
Critical PMU Locations



Phase 4 Example

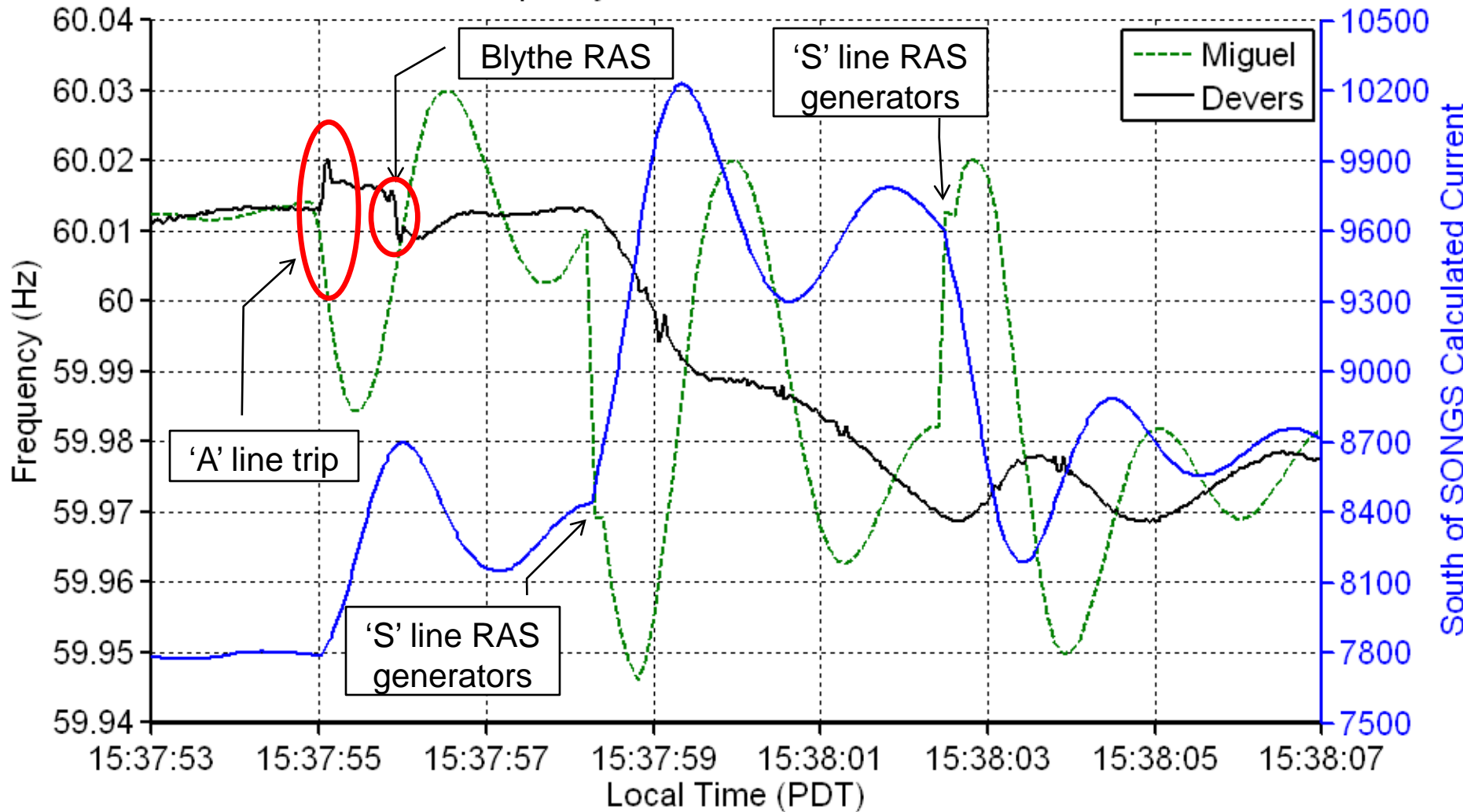


Phase 5 Example

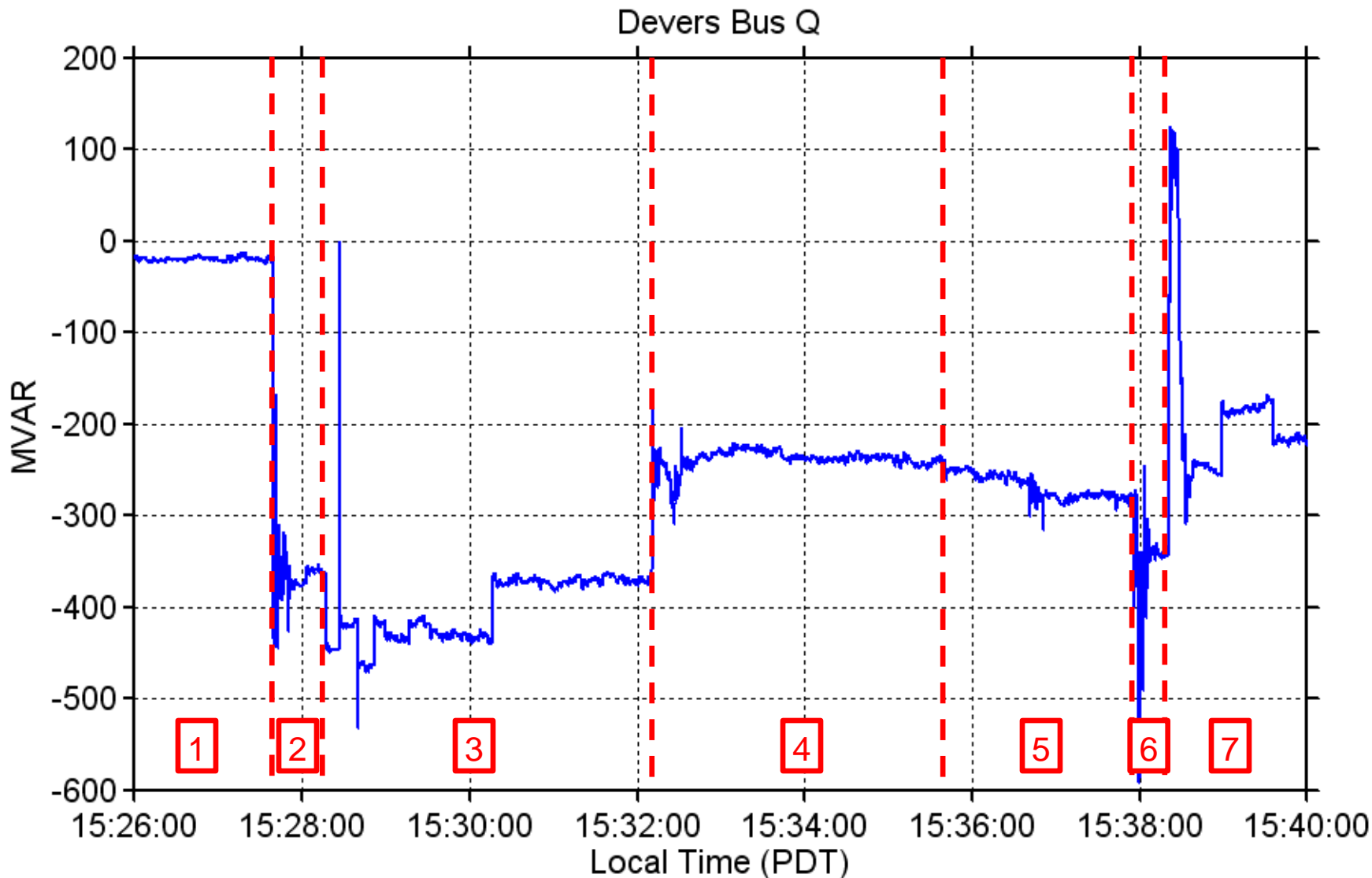


Phase 6 Example

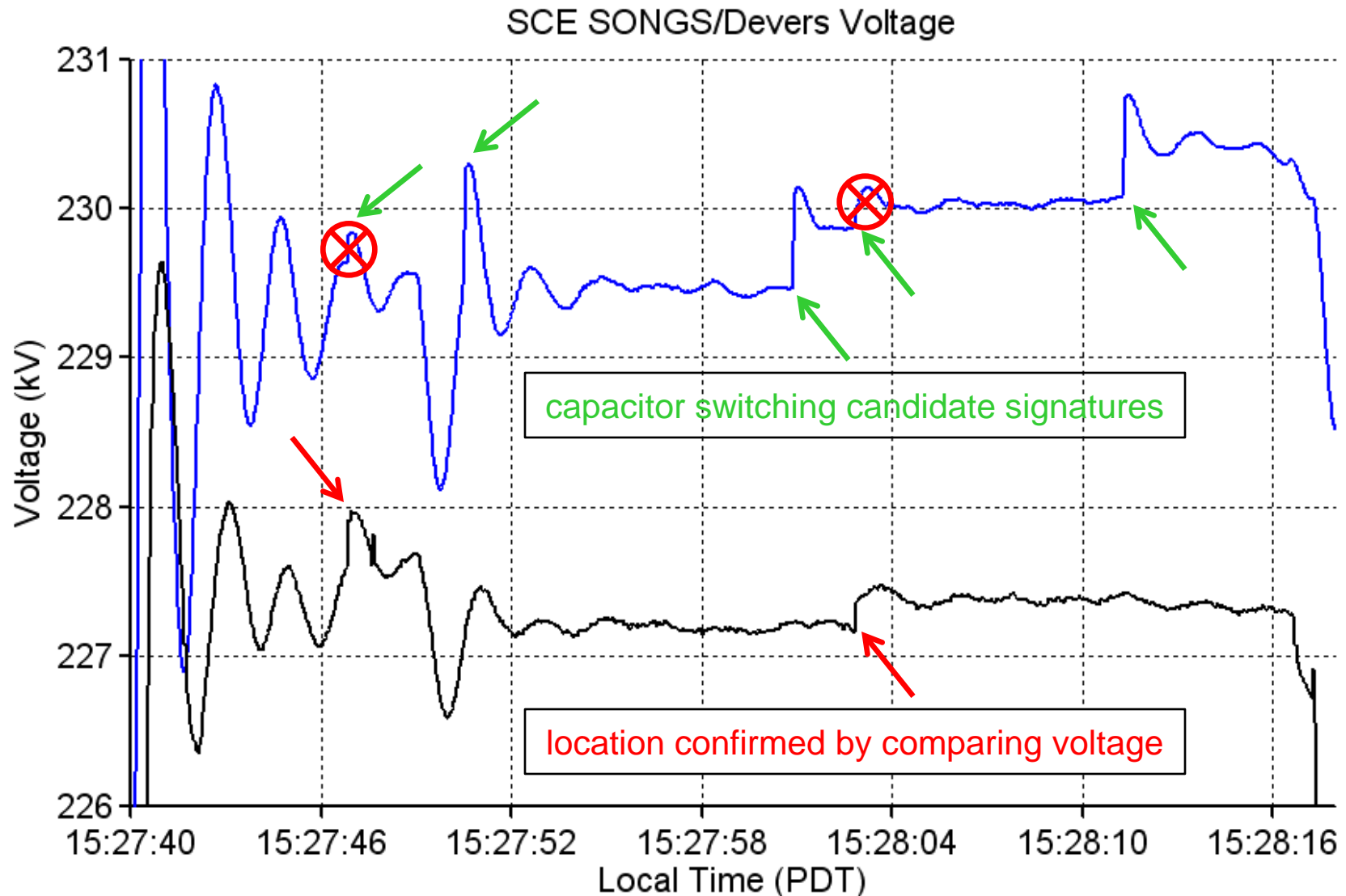
Frequency and South of SONGS Flow



Devers SVC Output



Capacitor Switching

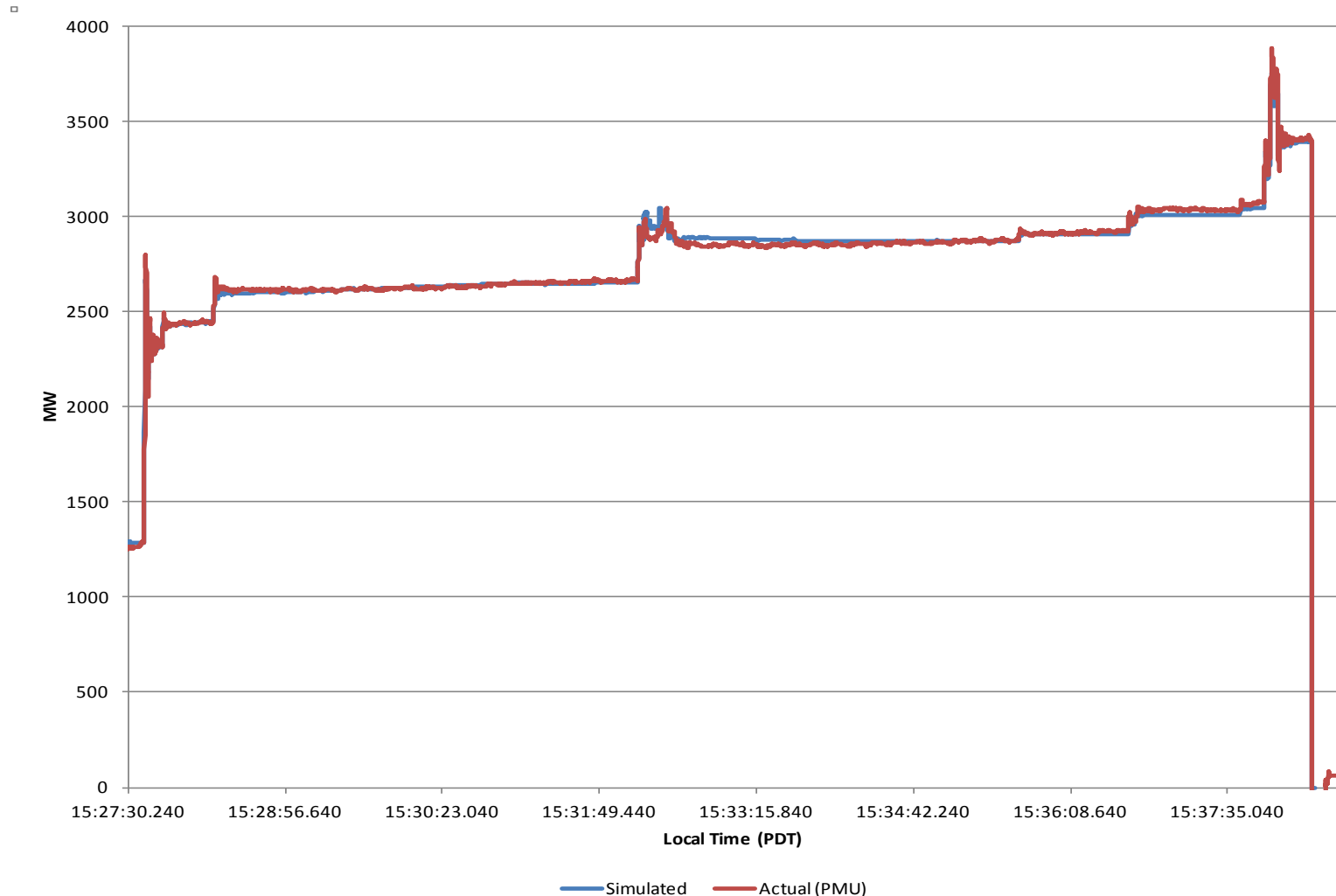


A light blue map of North America is centered on the slide. Overlaid on the map is a semi-transparent image of a nuclear power plant, showing two large cooling towers and a containment dome. The text "EA Modeling" is written in a dark blue, italicized serif font across the middle of the map.

EA Modeling

Simulation vs. Actual Flows

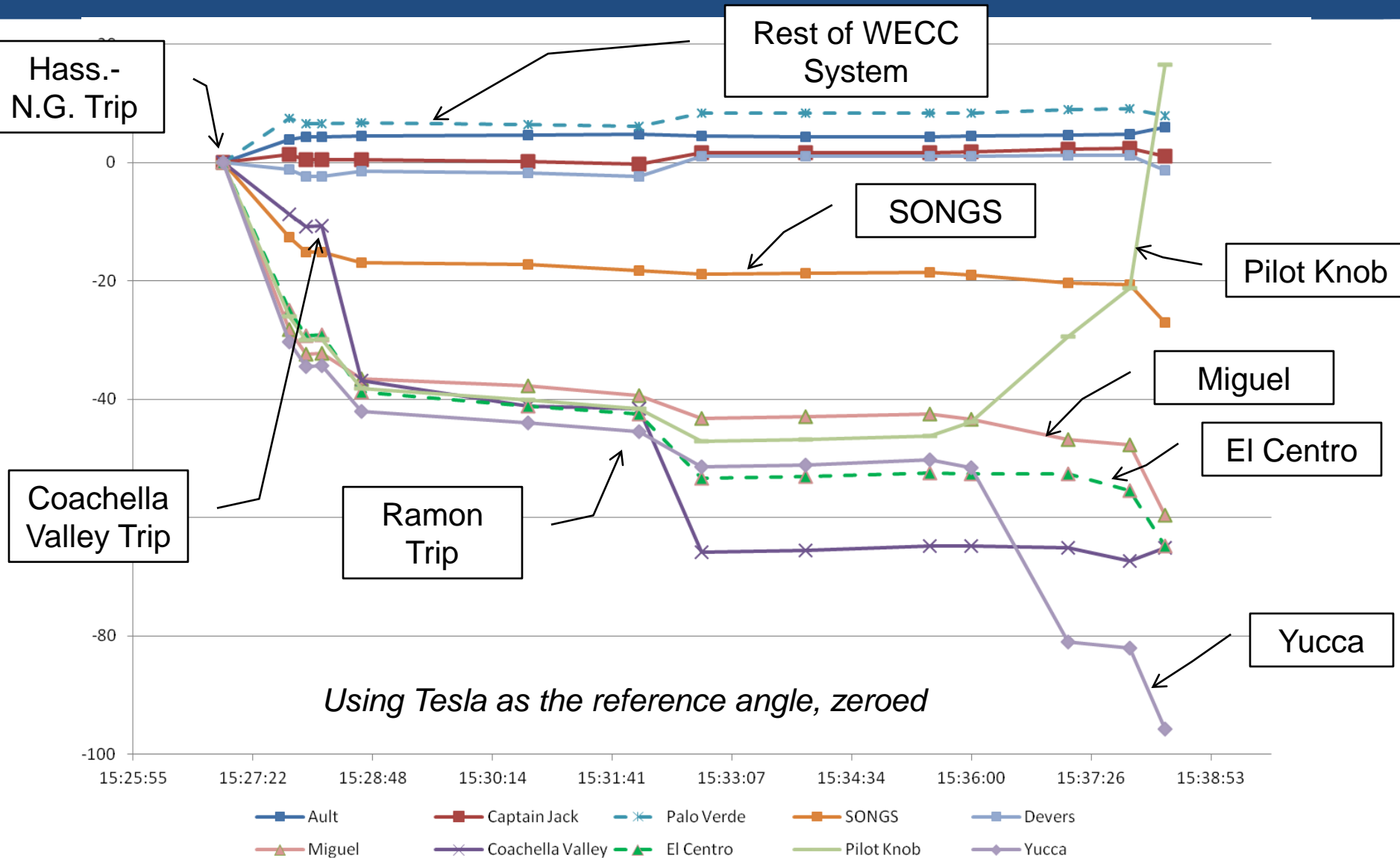
South of SONGS Flows



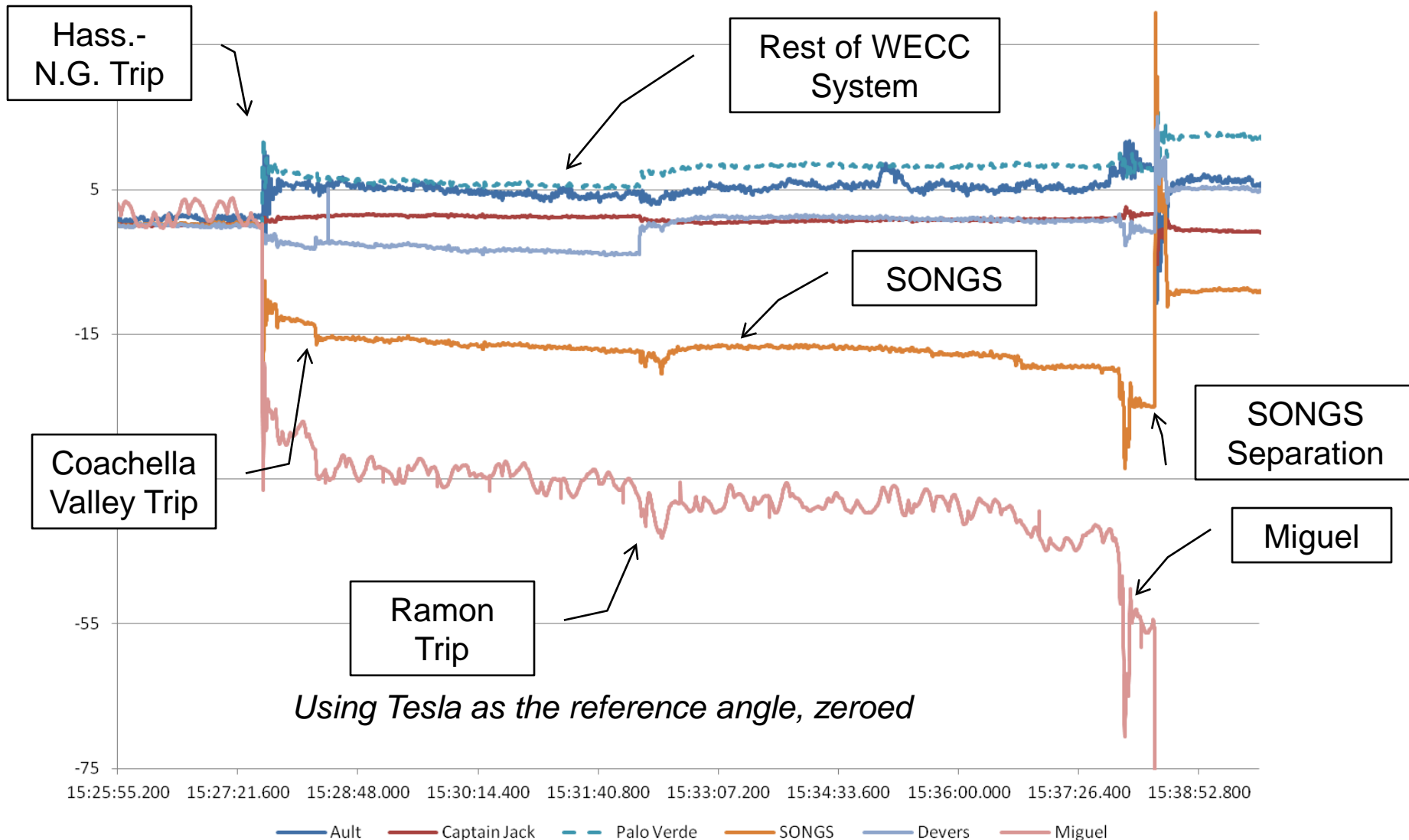


Angular Separation Teaser

Simulated Phase Angles



PMU Measured Phase Angles





Questions?