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NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Pacific Southwest Disturbance

September 8, 2011

Event Analysis Overview Presented to IEEE PSRC
May 17, 2012 – Main Committee Meeting

RELIABILITY | ACCOUNTABILITY




September 8, 2011 Event

- 11 minute cascading outage in Pacific Southwest
- 2.7 million customers out in AZ, S.CA, MX, some up to 12 hours
- Initiated when single 500 kV line tripped, but not sole cause
- Power redistributed, increasing flows through underlying systems, causing voltage drops and equipment overloads
- Ripple effect led to tripping of lines and generators, automatic load shedding, and operation of a Remedial Action Scheme and an intertie separation scheme
- Restoration process generally effective

Customer Impacts

Entity	Load Lost (MW)	Customers
SDGE	4,293	1.4 million
CFE	2,150	1.1 million
IID	929	146 thousand
APS	389	70 thousand
WALC	74	Note

Note: 64 MWs of WALC's load loss affected APS's customers

Joint FERC/NERC Inquiry

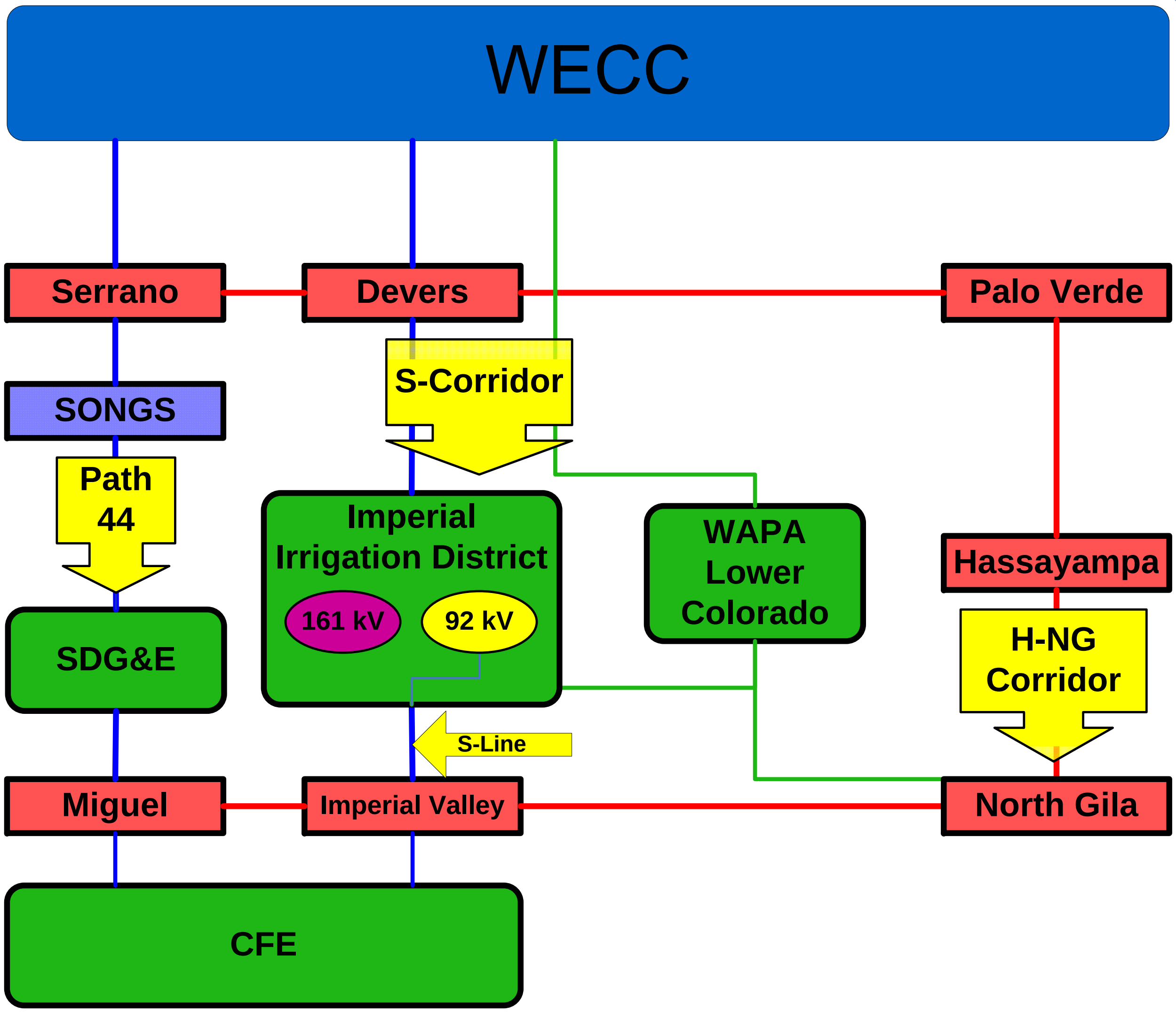
- Announced September 9, 2012
- Teams formed comprising over 30 senior technical staff of FERC and NERC, plus several NERC contractors and industry subject matter experts
- Multiple meetings and exchanges with affected entities to gather facts
- Team products combined into final report
- Outreach sessions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

Inquiry Teams

- 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

Sequence of Events

Simplified System Diagram



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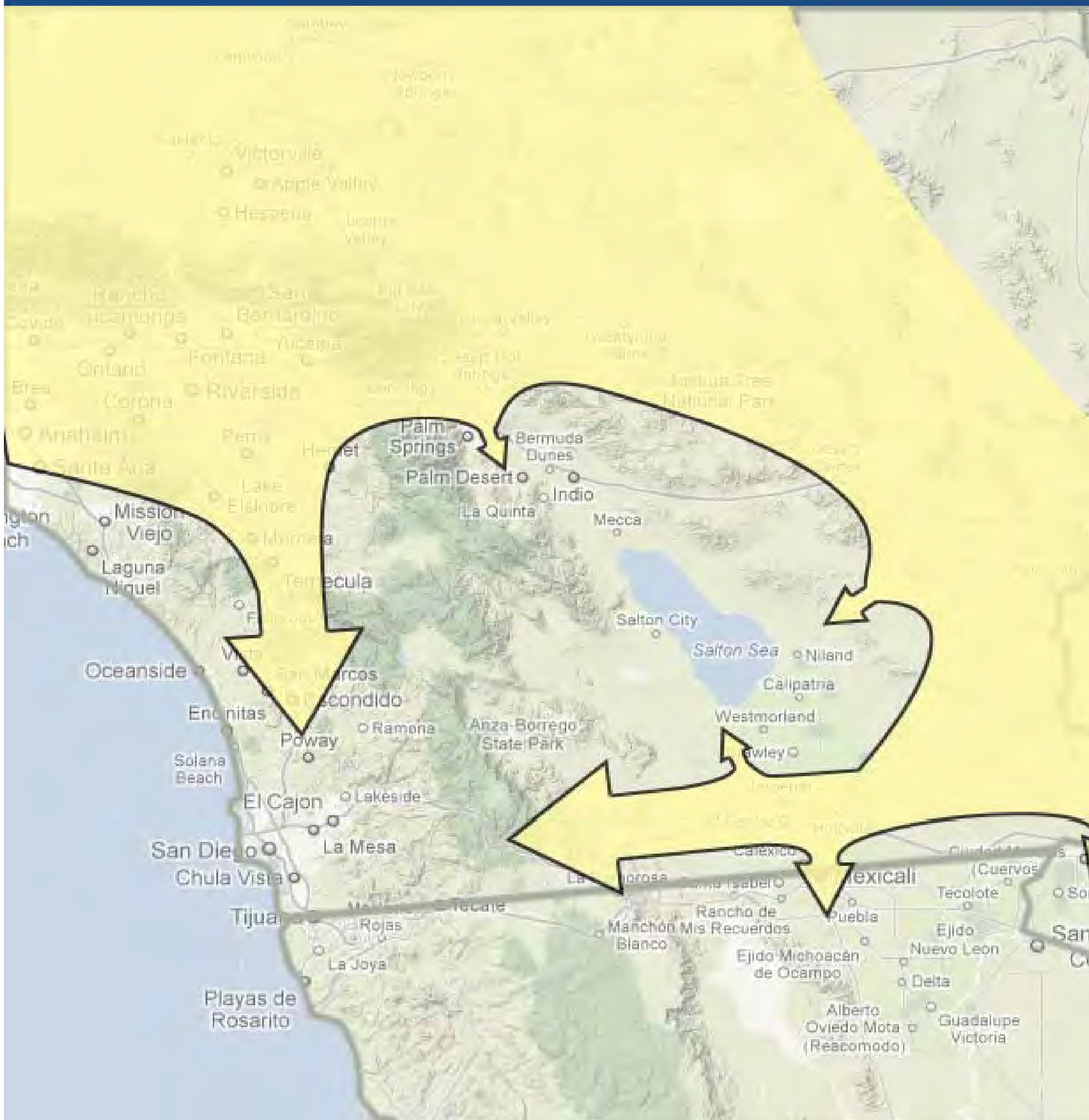
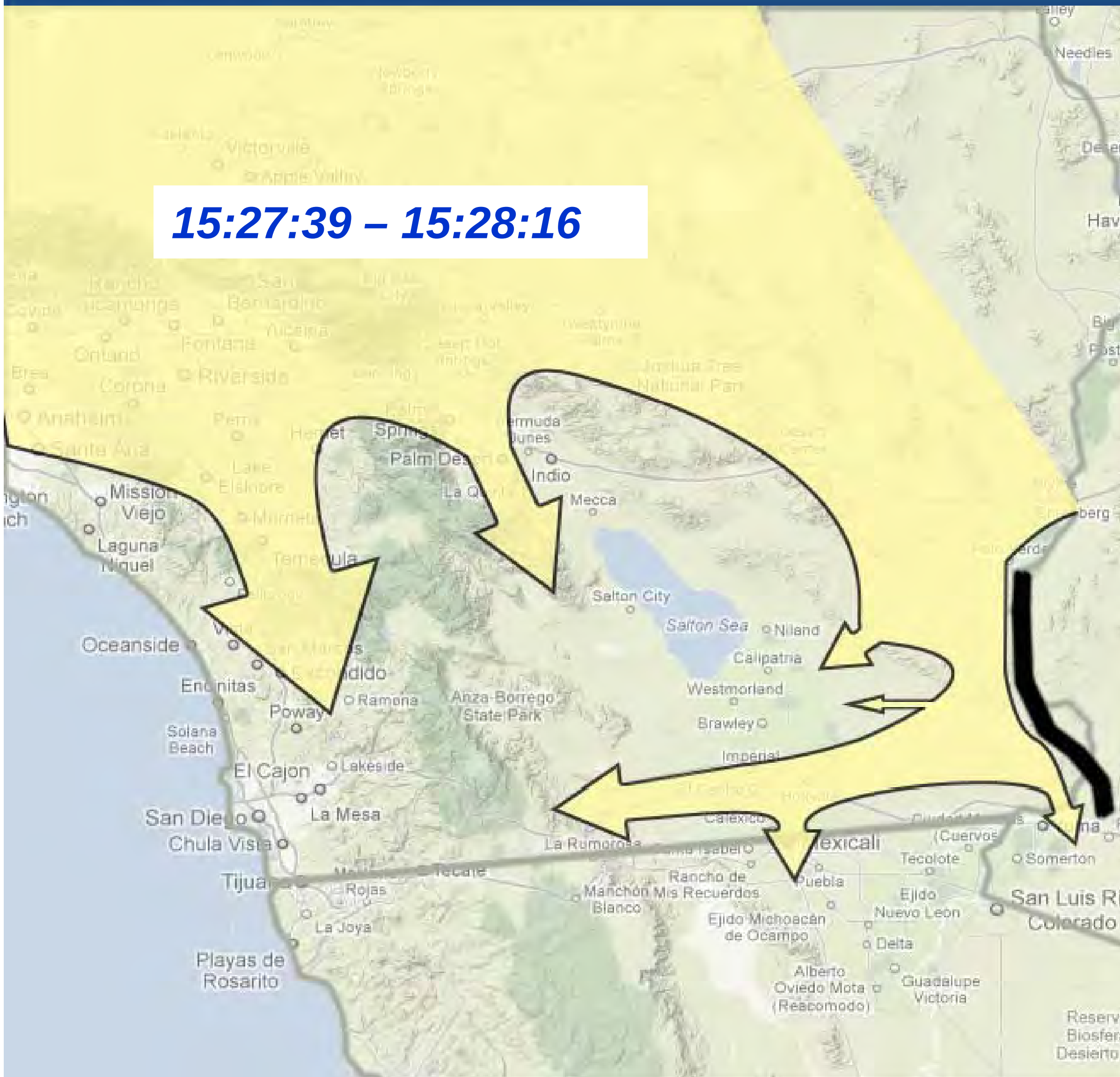
Phase 1 – Pre-Disturbance



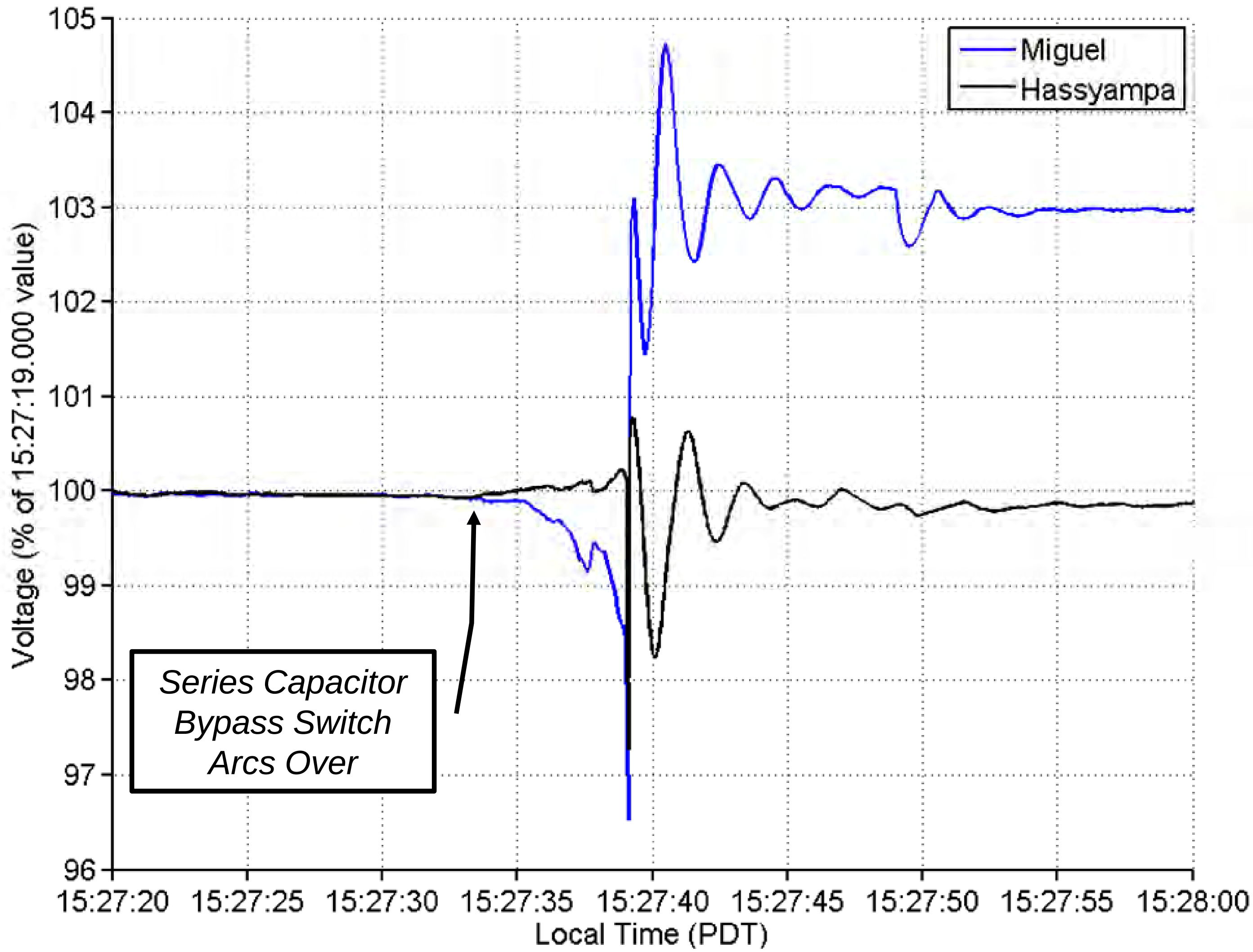
- *Hot, shoulder season day; some generation and transmission outages*
- *High loading on some key facilities: H-NG at 78% of normal rating; CV transformers at 83%*
- *44 minutes before loss of H-NG, IID's RTCA results showed loss of CV-1 transformer would load CV-2 transformer above its relay trip point*
- *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

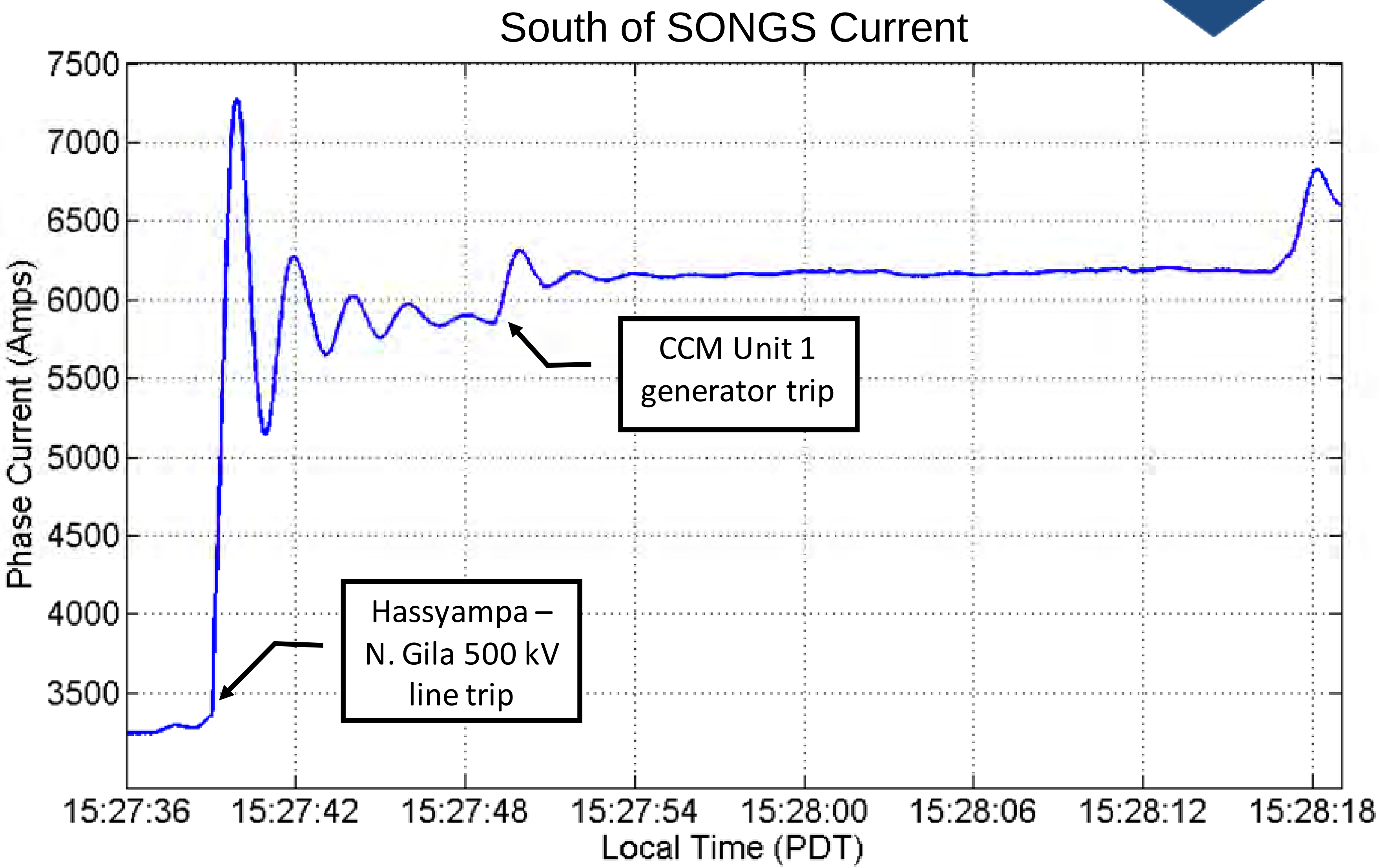


- *H-NG 500 kV trips at 15:27:39*
- *APS tells WECC RC line expected to be restored quickly*
- *H-NG flow redistributes: 77% to SCE-SDGE (Path 44); remainder to IID, and WALC*
- *CV transformers immediately overloaded above relay settings*
- *Path 44 at 5,900 amps; 8,000 amp limit on SONGS separation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

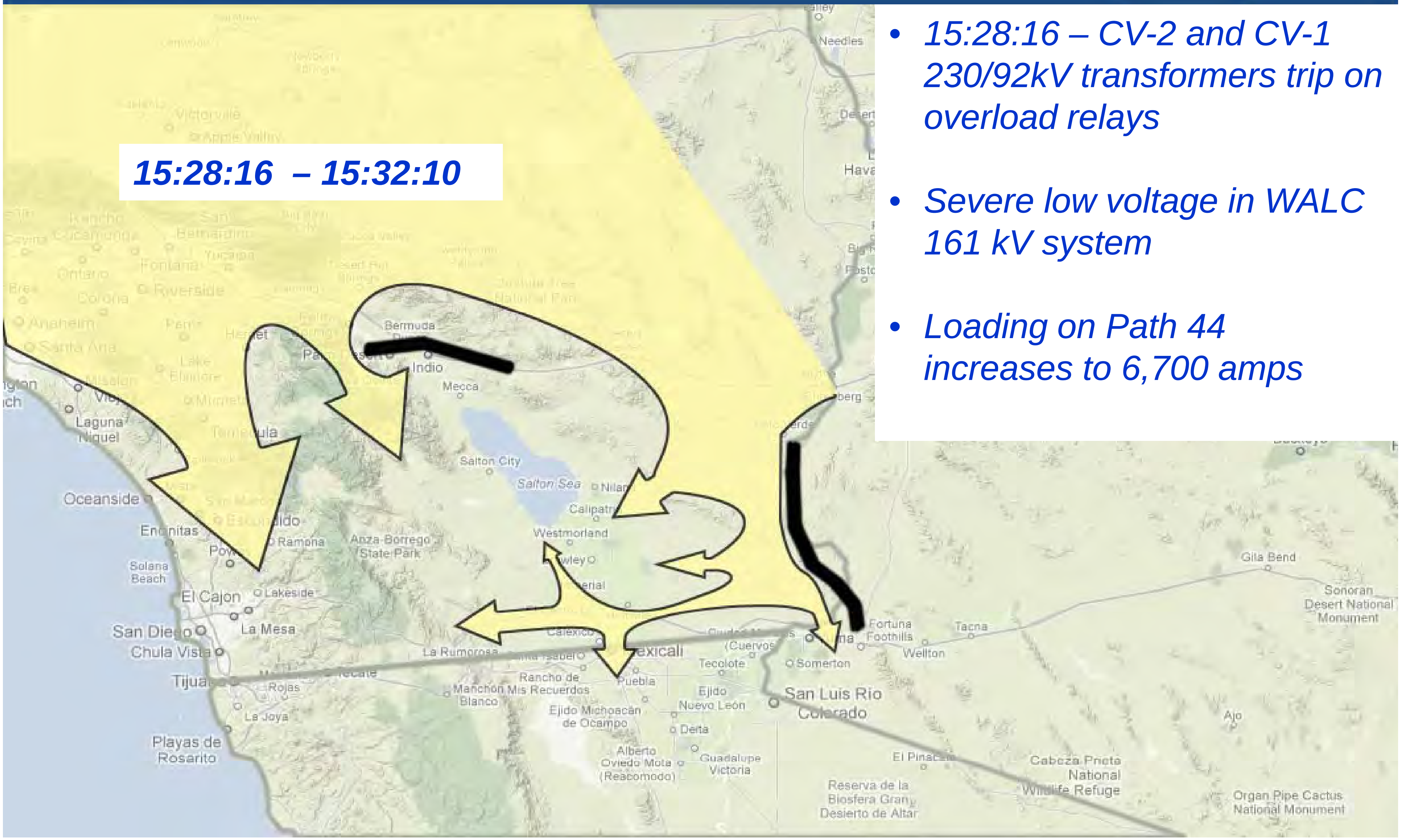
Initiating Event – Tripping of Hassayampa – North Gila 500 kV Line



Hass. – N. Gila 500 kV Line Trip



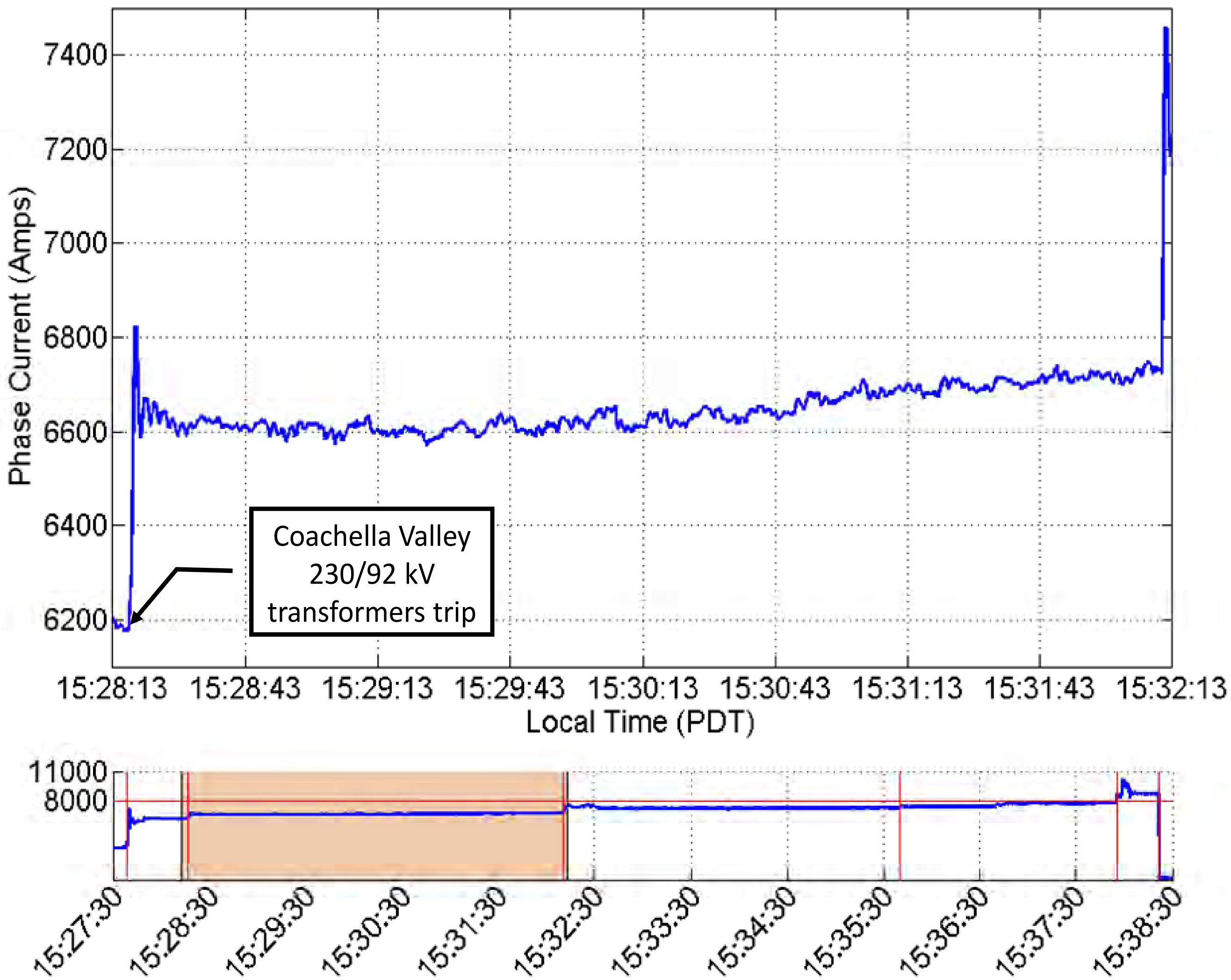
Phase 3 – Trip of CV Transformers



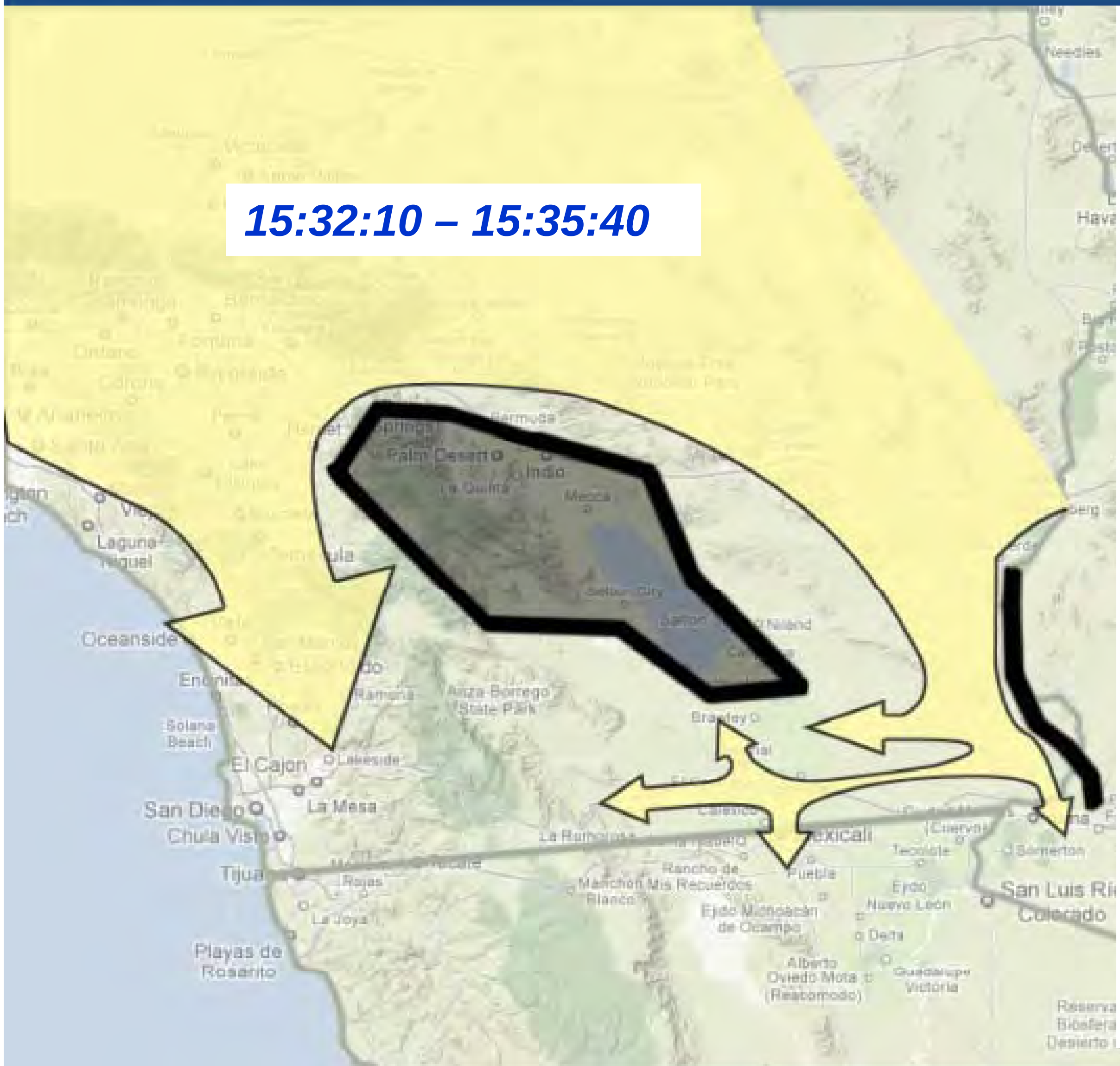
- *15:28:16 – CV-2 and CV-1 230/92kV transformers trip on overload relays*
- *Severe low voltage in WALC 161 kV system*
- *Loading on Path 44 increases to 6,700 amps*

CV Transformers Trip

South of SONGS Current

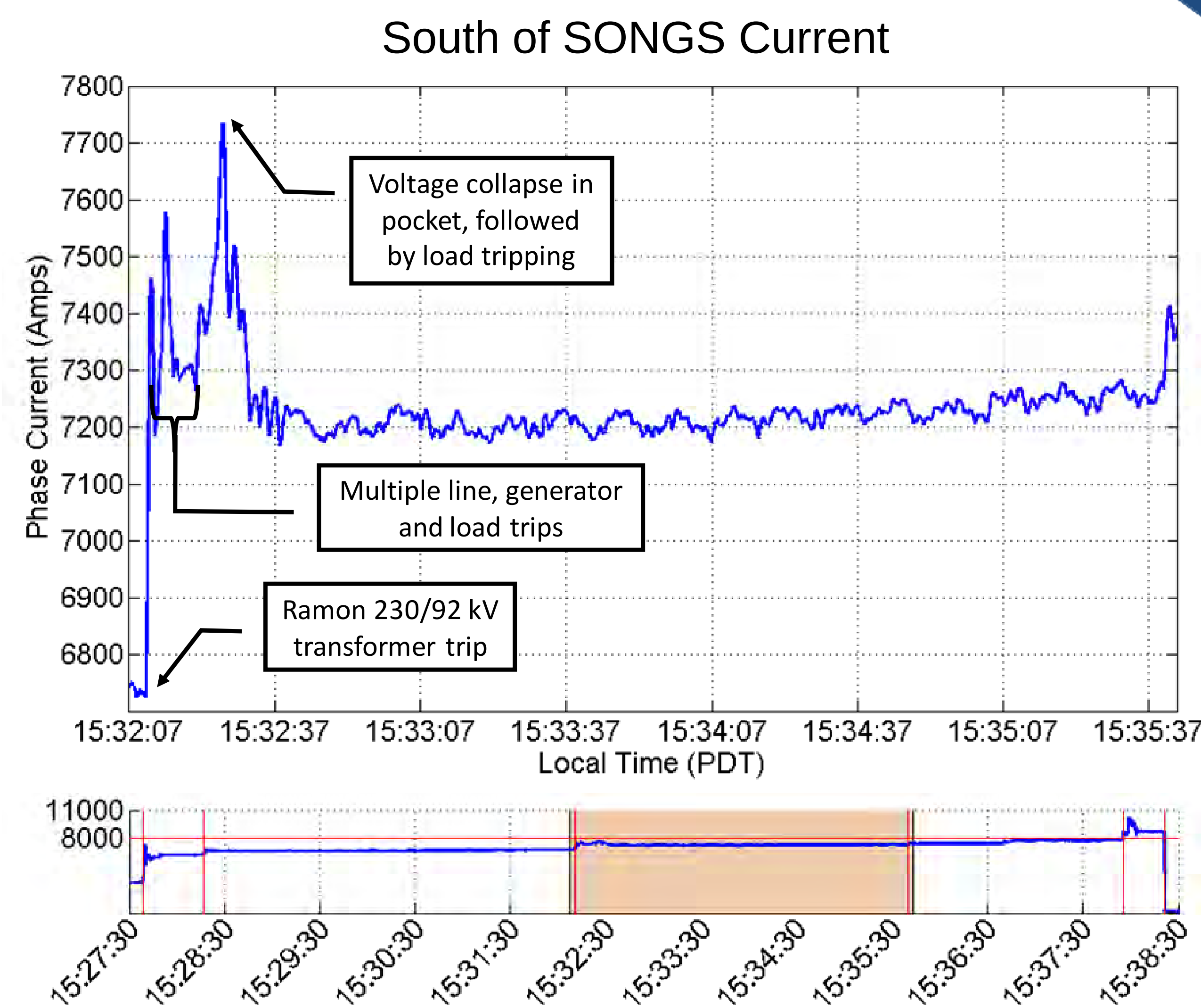


Phase 4 – Ramon Xfmr Trip

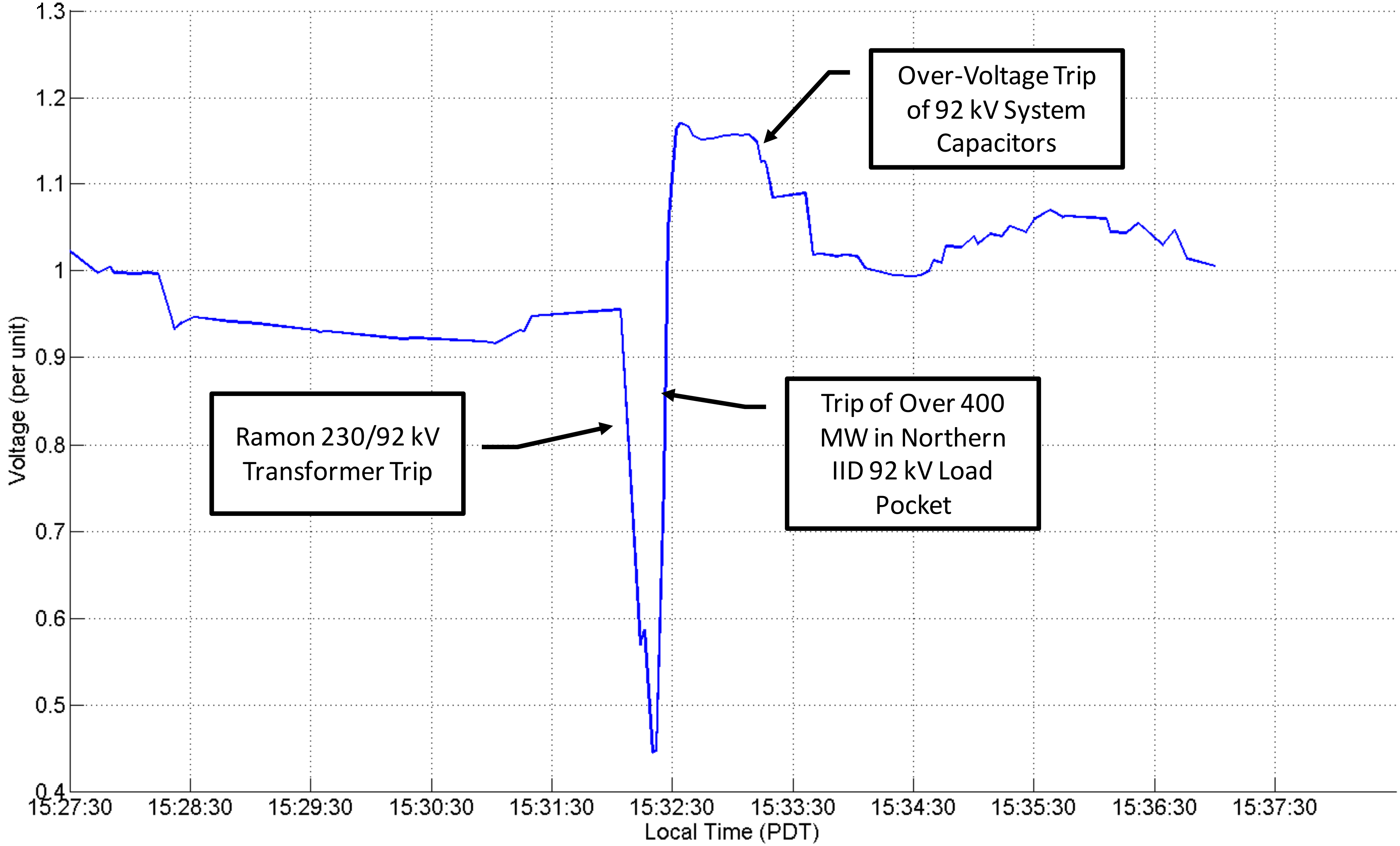


- *15:32:10 Ramon 230/92kV transformer trips on overload relay*
- *15:32:13 Blythe-Niland 161kV line trips*
- *15:32:15 Niland – CV 161kV line trips*
- *IID undervoltage load shedding; loss of generation and 92 kV transmission lines*
- *Severe low voltage in WALC 161 kV system*
- *Loading on Path 44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

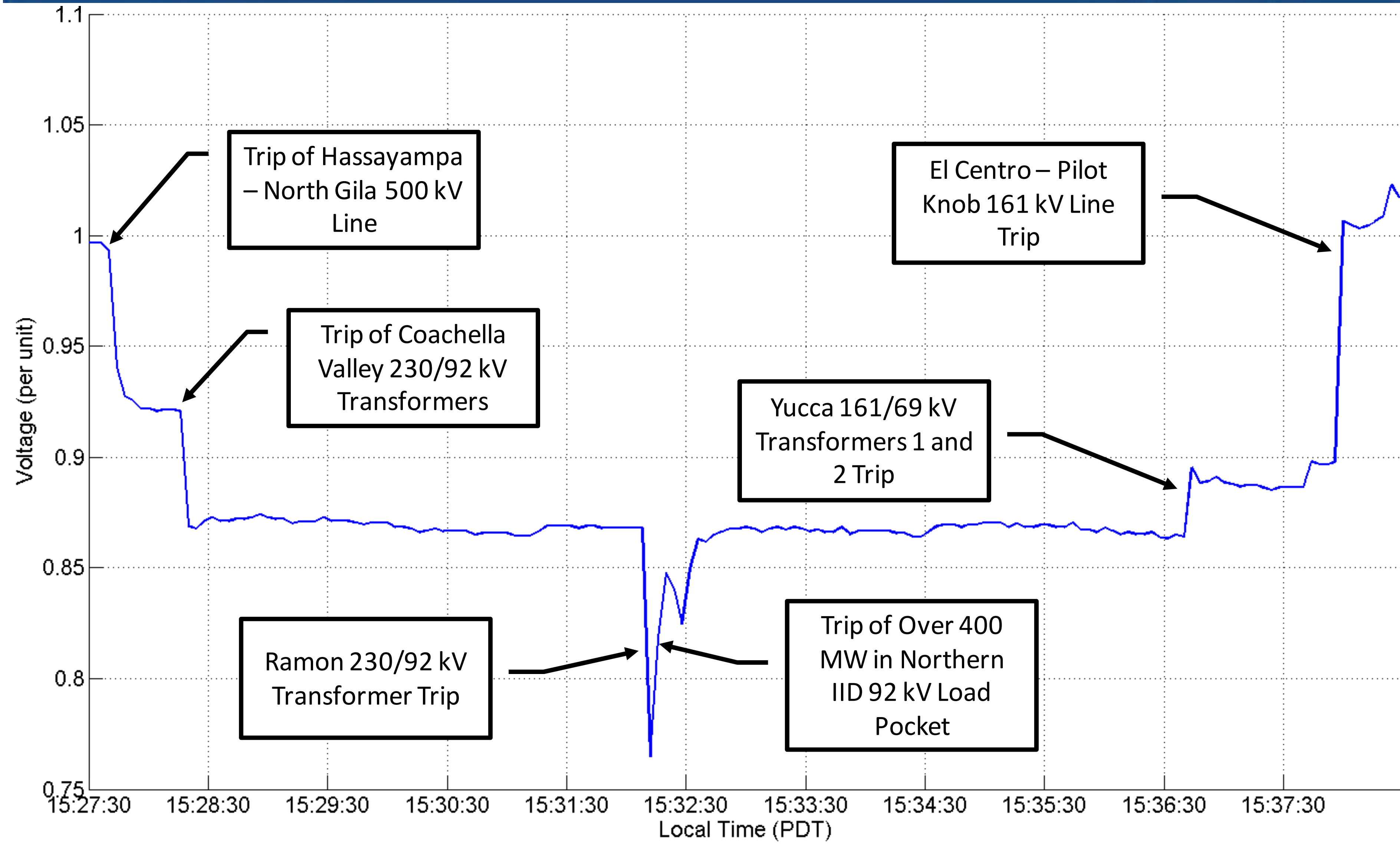
Ramon Transformer Trip



Voltage in Northern IID 92 kV System

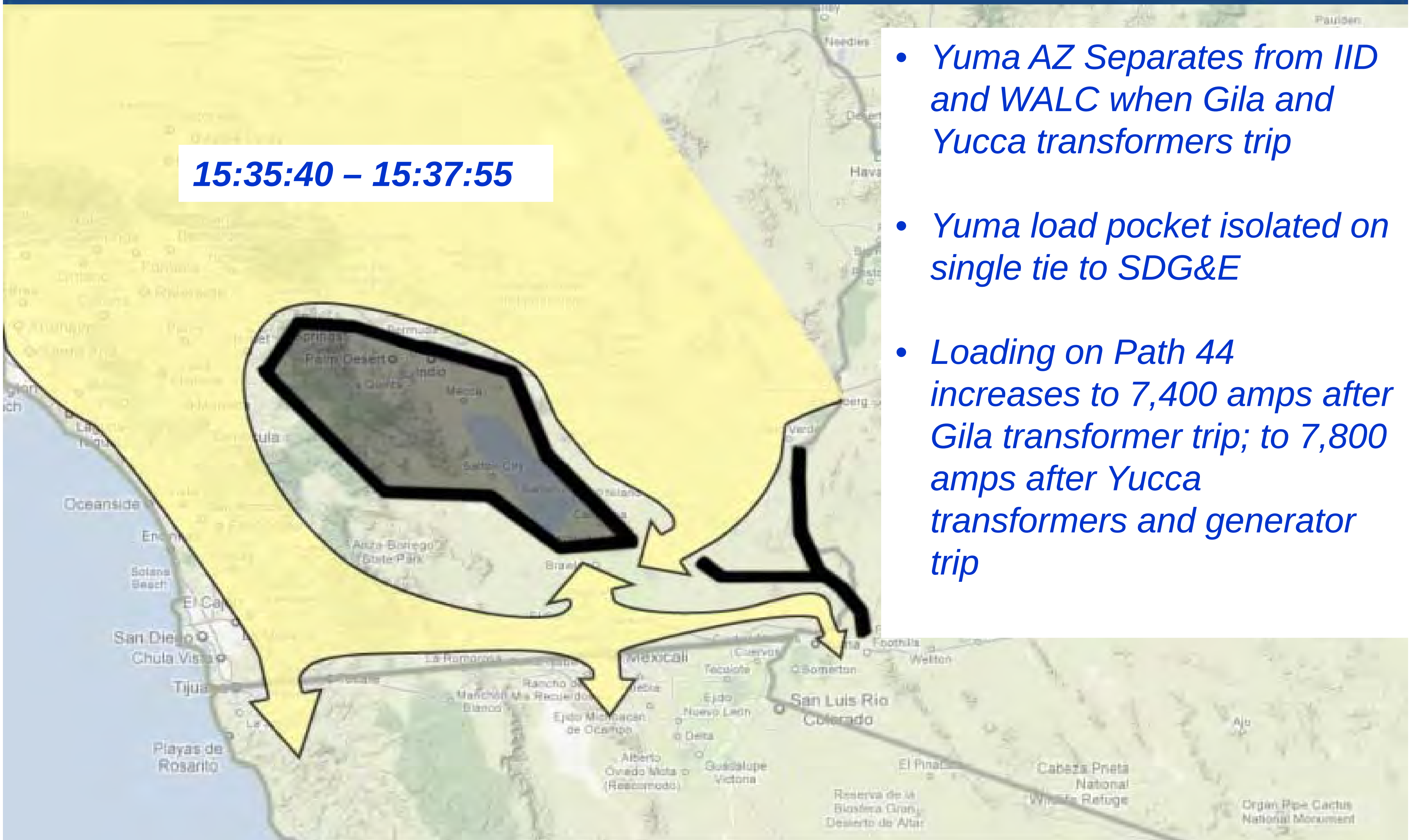


Blythe 161 kV Voltage



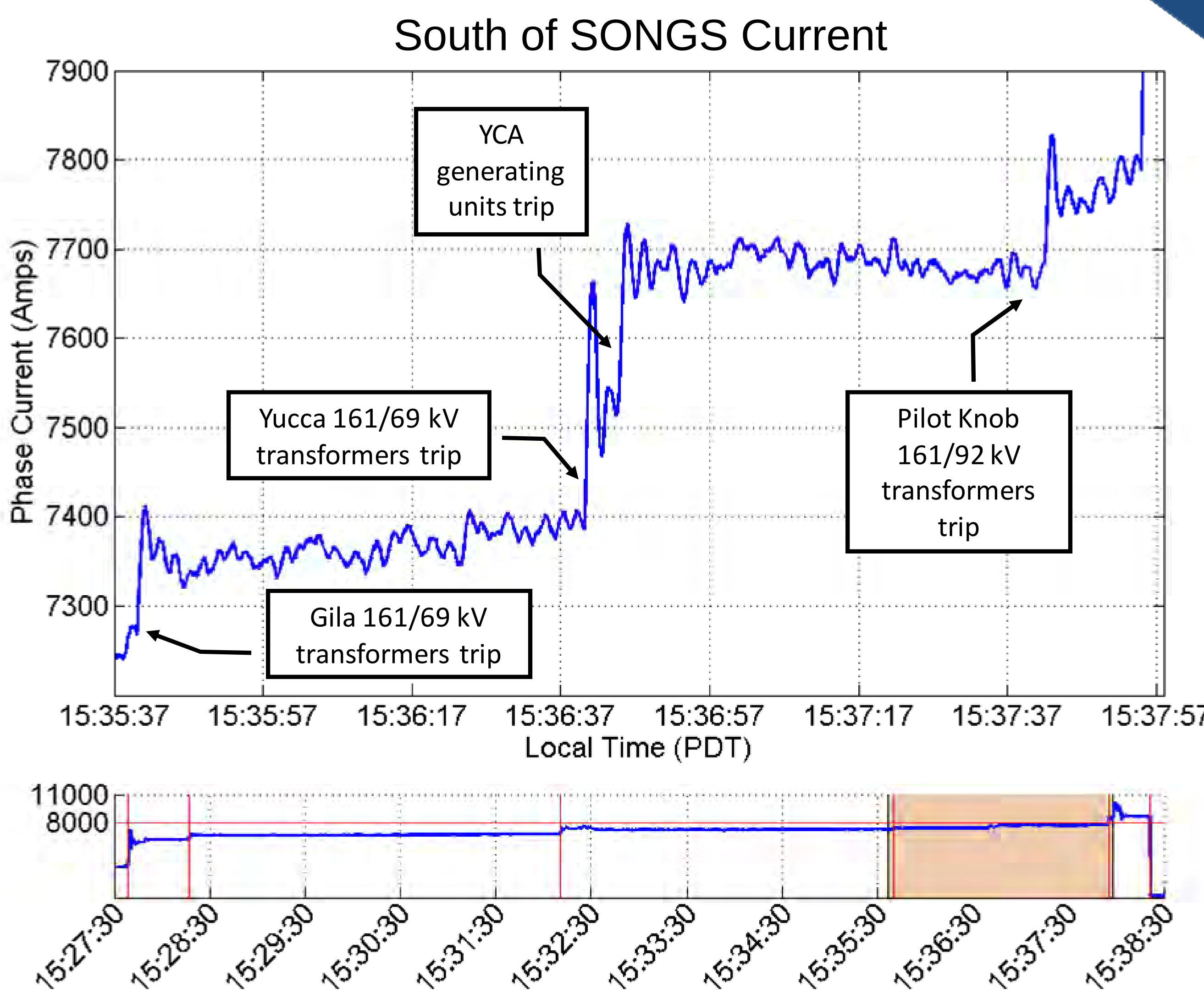
Phase 5 – Yuma Separates

15:35:40 – 15:37:55

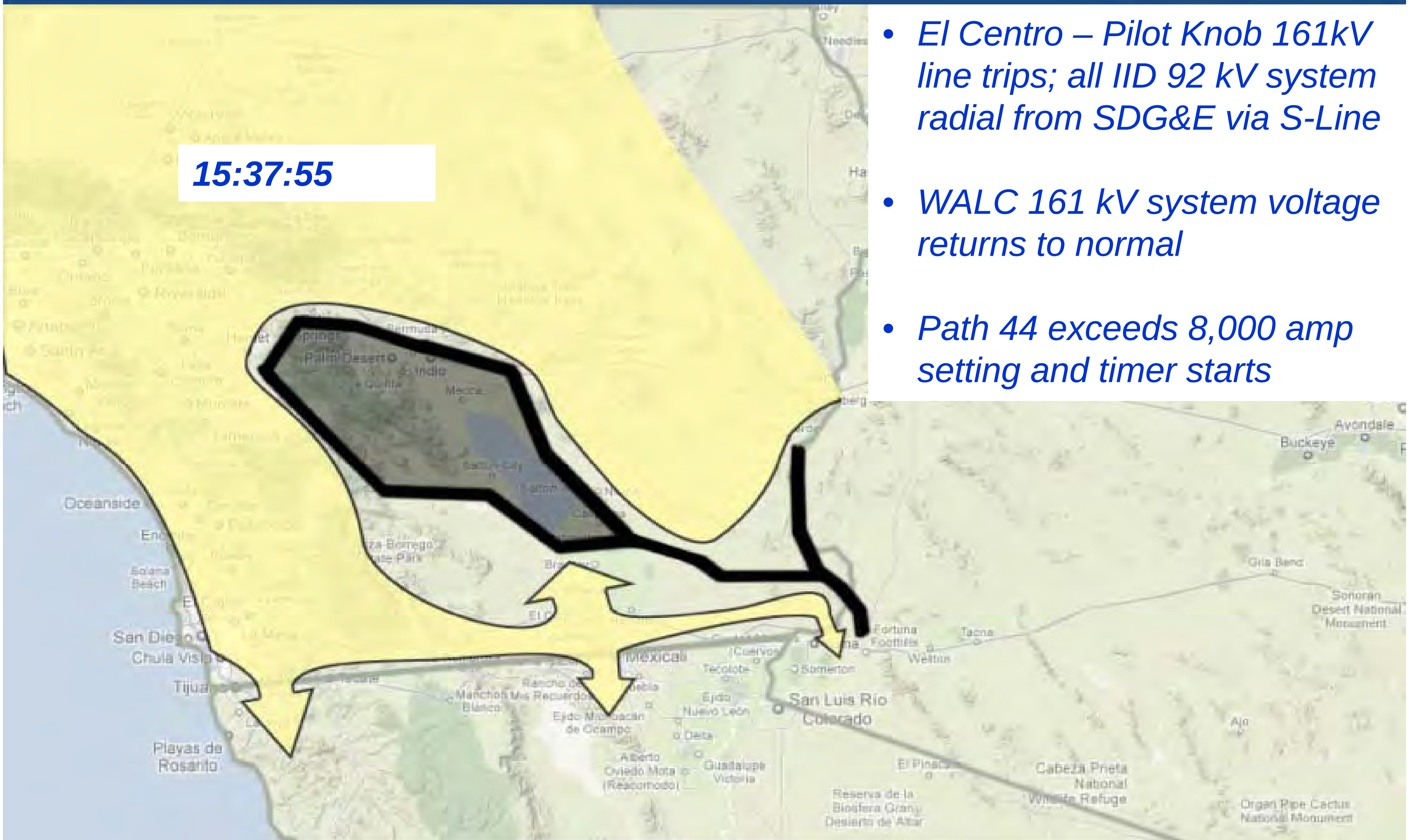


- *Yuma AZ Separates from IID and WALC when Gila and Yucca transformers trip*
- *Yuma load pocket isolated on single tie to SDG&E*
- *Loading on Path 44 increases to 7,400 amps after Gila transformer trip; to 7,800 amps after Yucca transformers and generator trip*

Yuma Separation

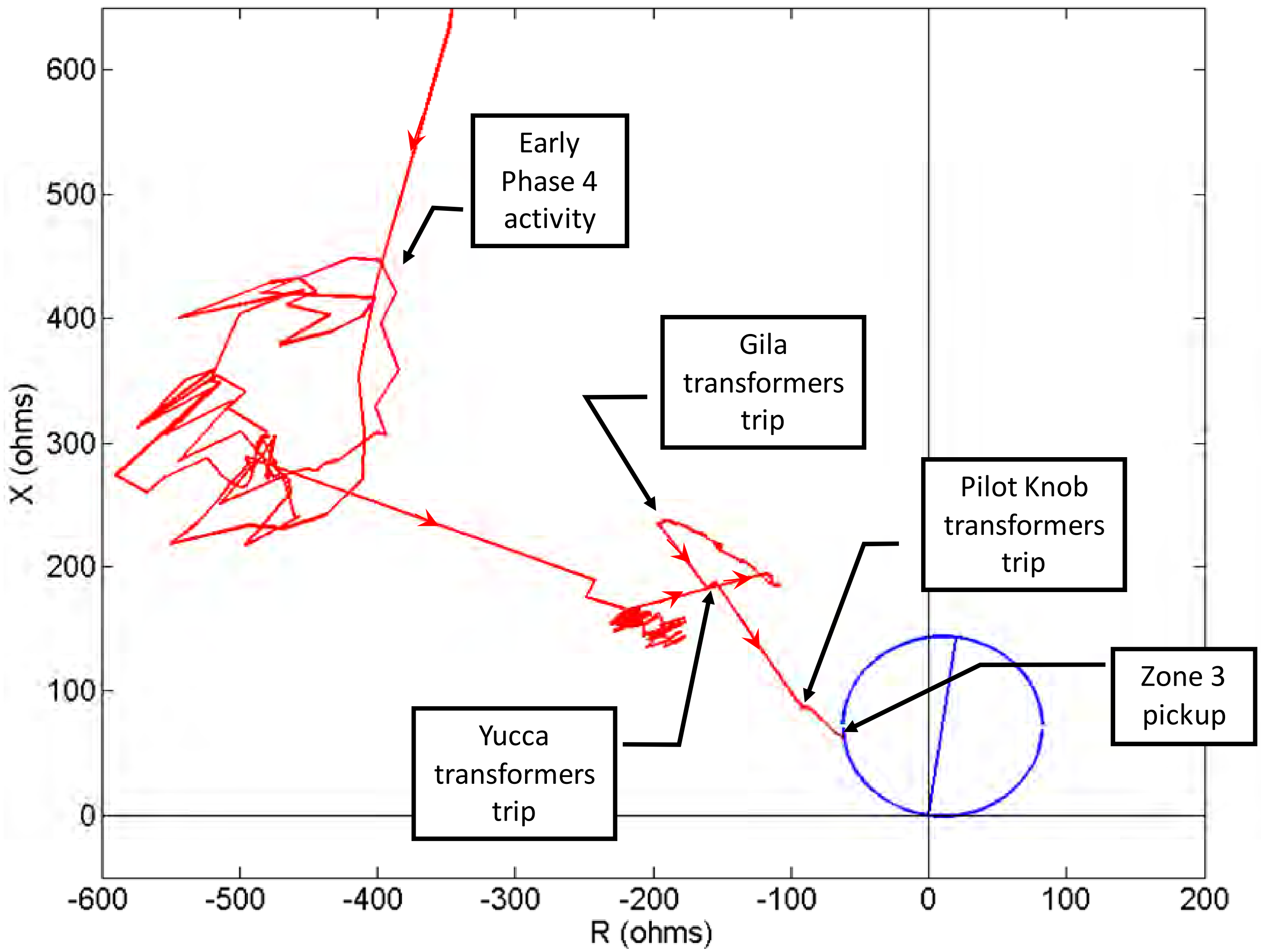


Phase 6 – High-Speed Cascade

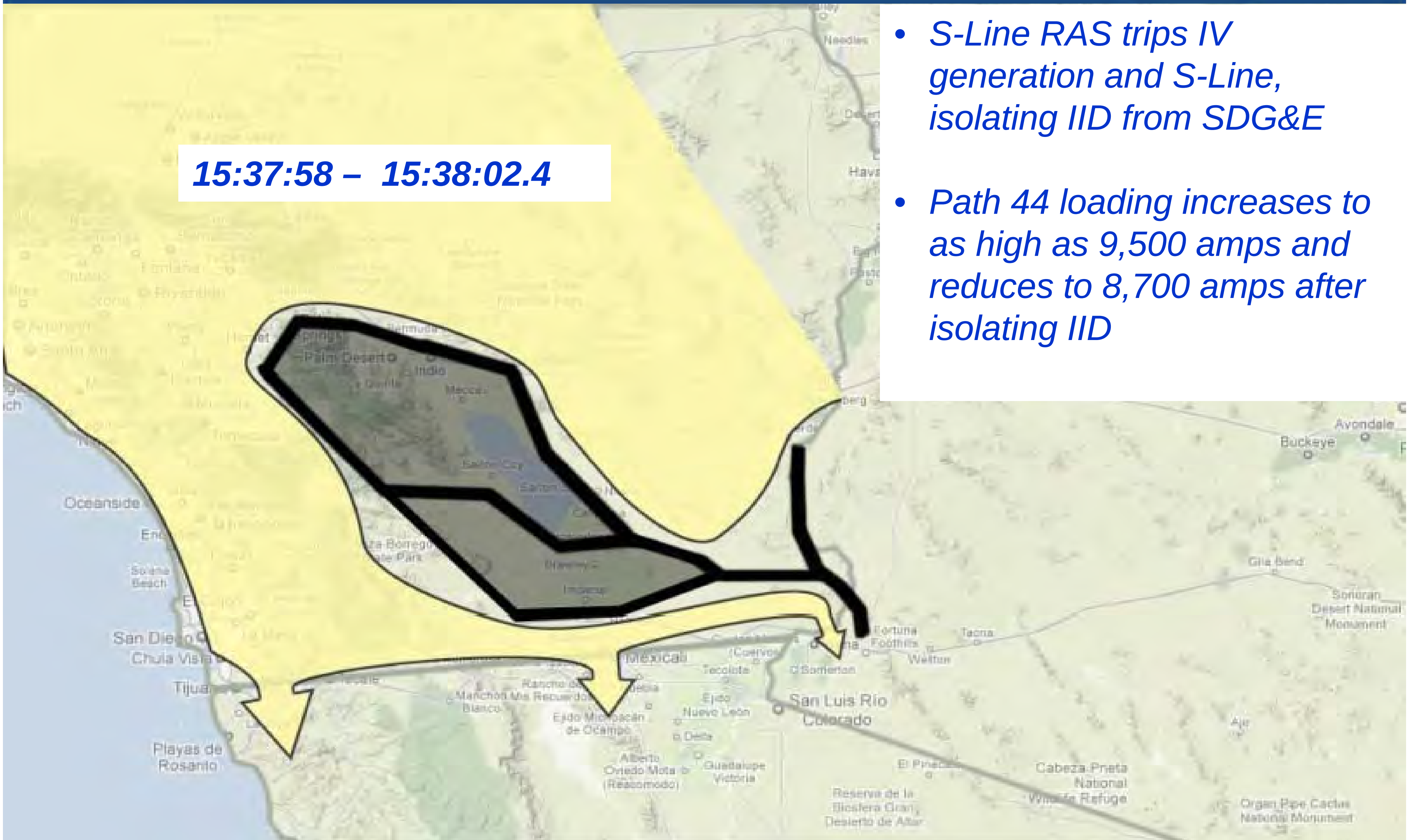


- *El Centro – Pilot Knob 161kV line trips; all IID 92 kV system radial from SDG&E via S-Line*
- *WALC 161 kV system voltage returns to normal*
- *Path 44 exceeds 8,000 amp setting and timer starts*

El Centro – Pilot Knob 161 kV Trips

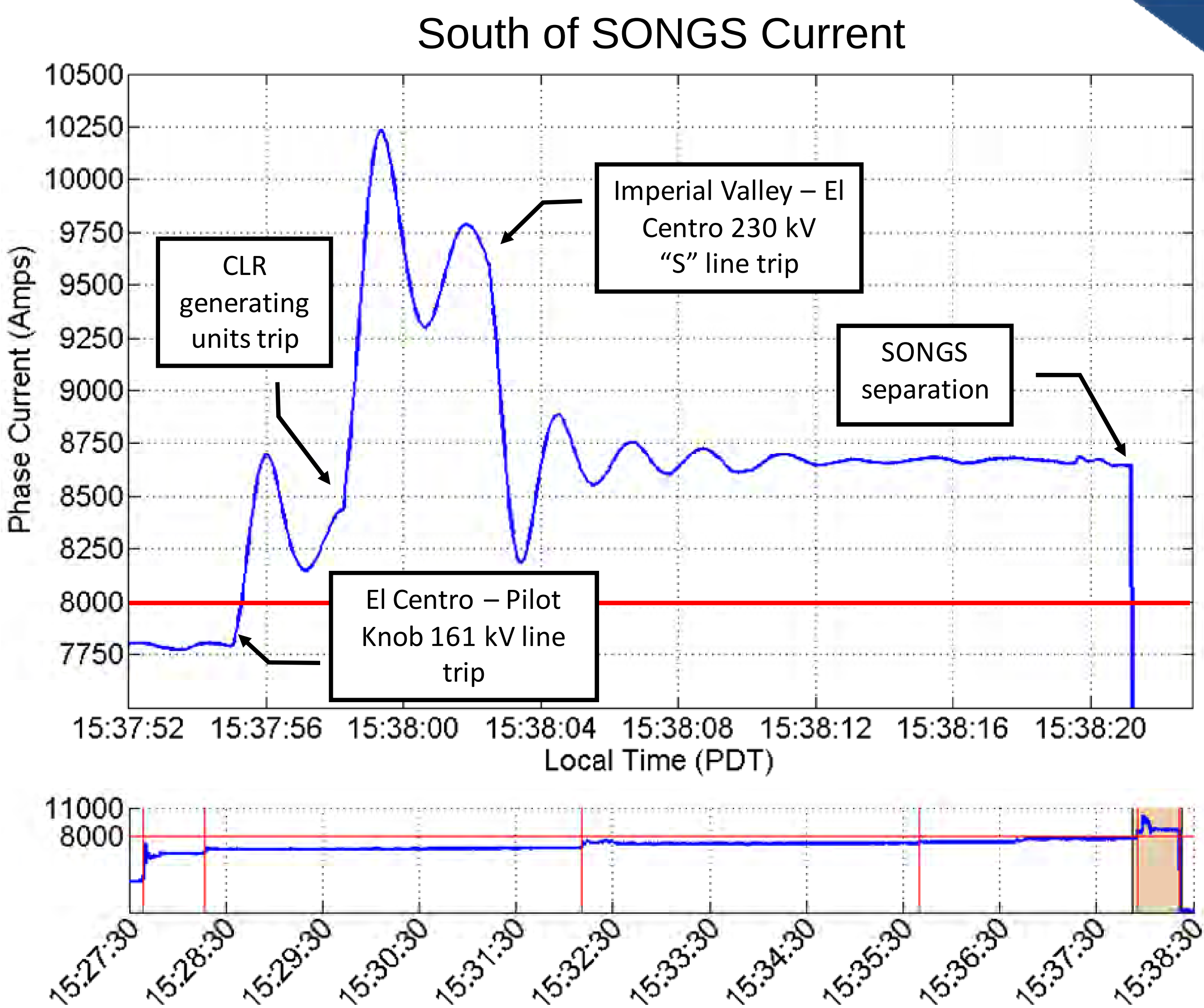


Phase 6 – High-Speed Cascade

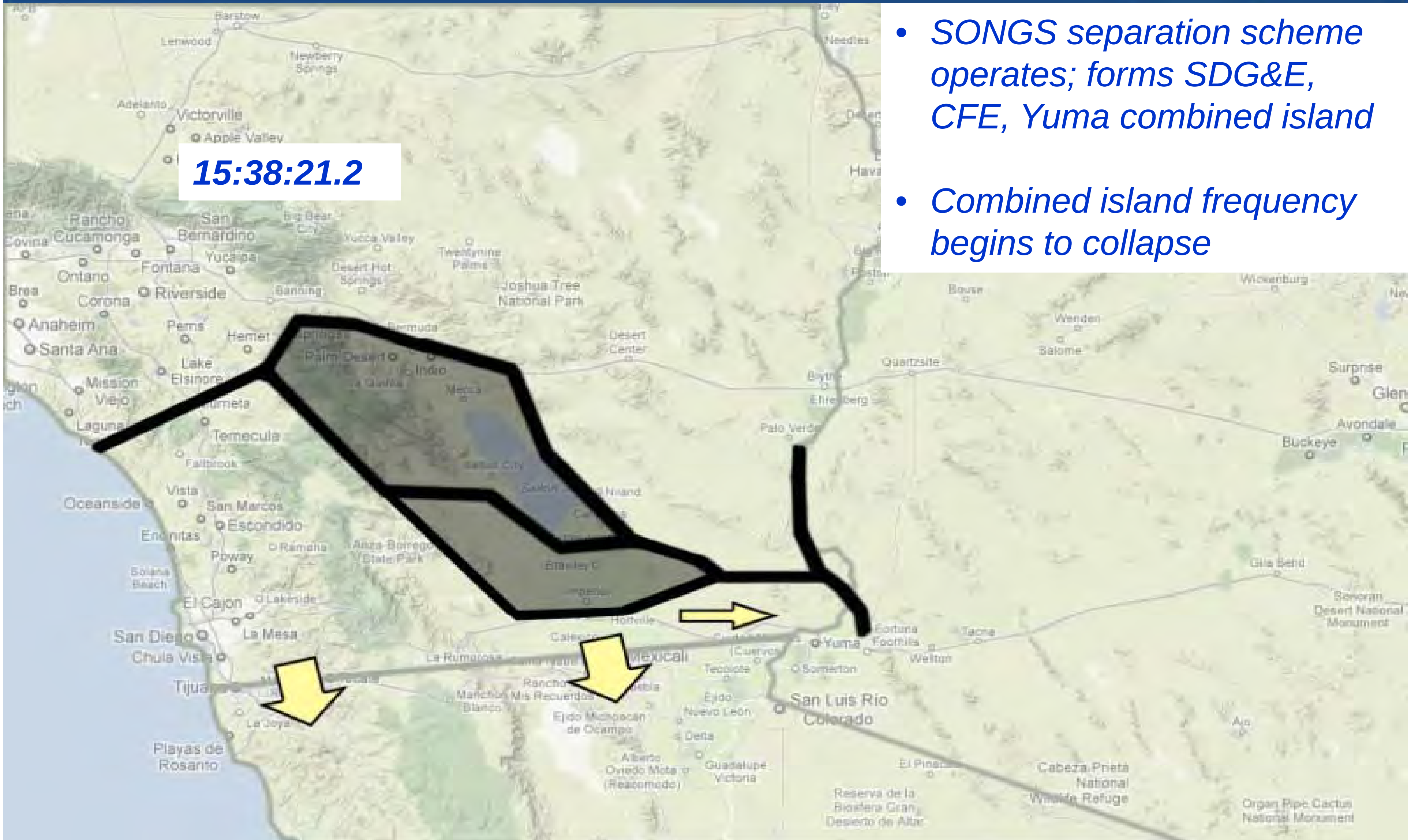


- *S-Line RAS trips IV generation and S-Line, isolating IID from SDG&E*
- *Path 44 loading increases to as high as 9,500 amps and reduces to 8,700 amps after isolating IID*

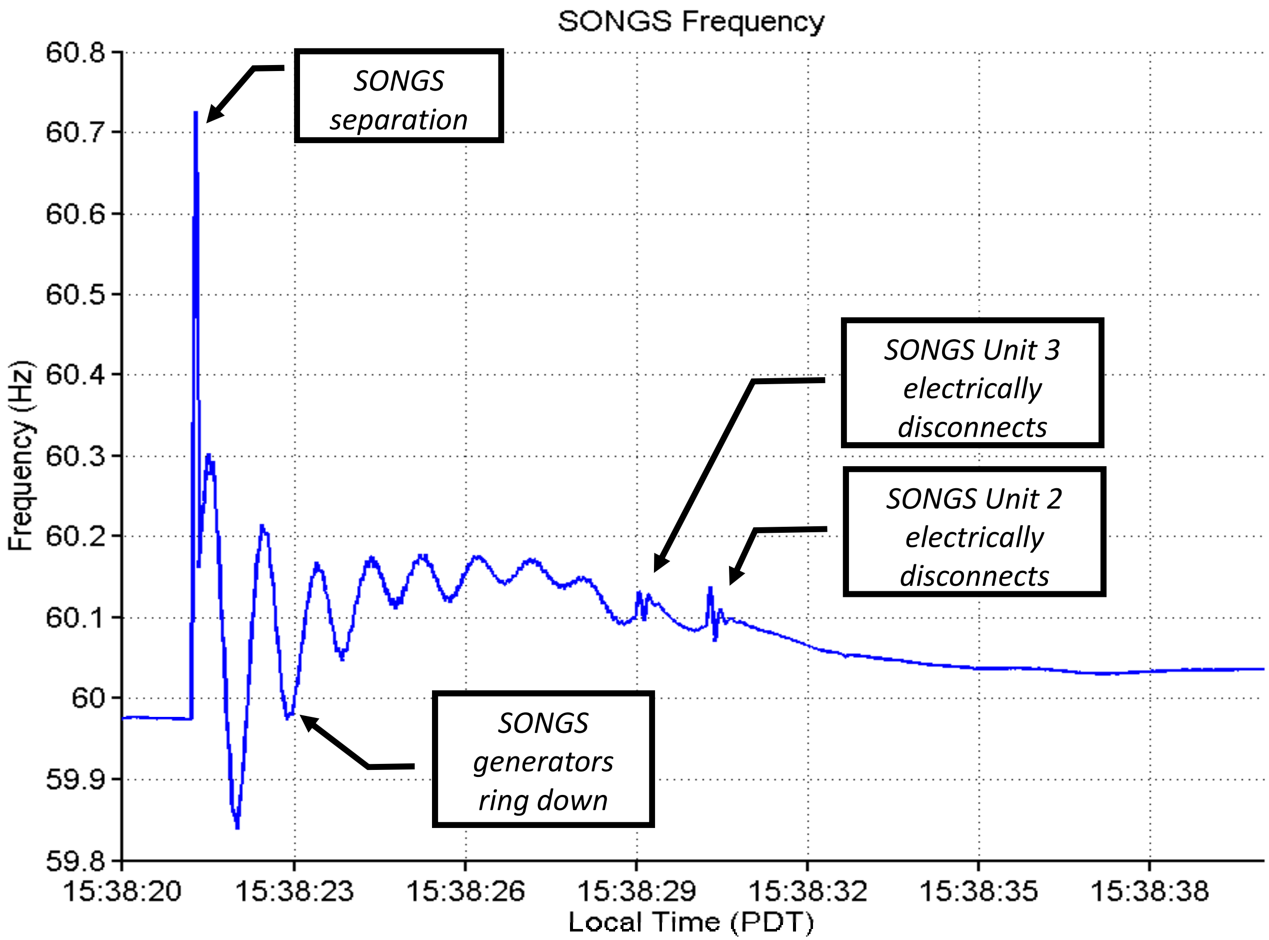
Phase 6 – High-Speed Cascade

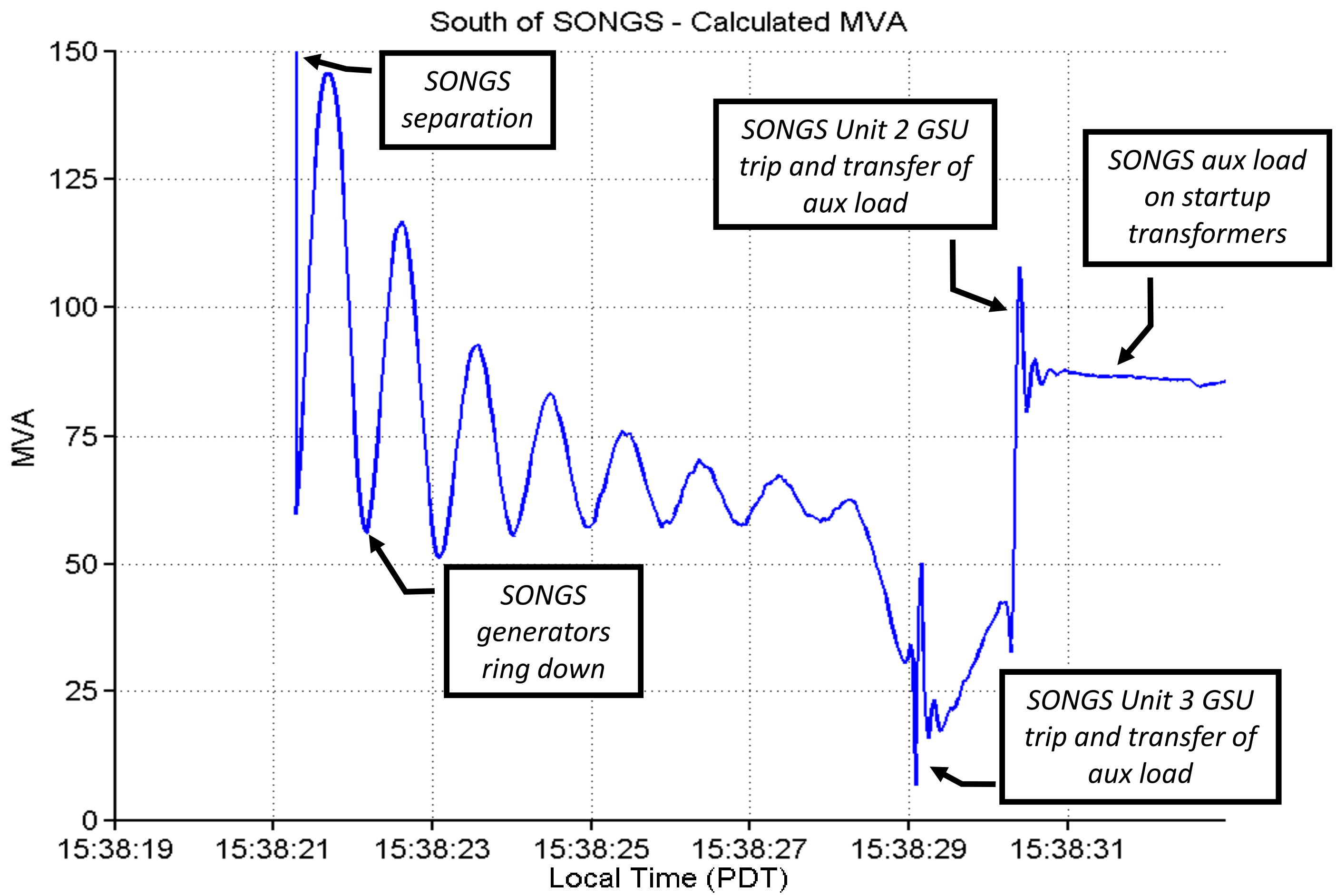


Phase 6 – High-Speed Cascade

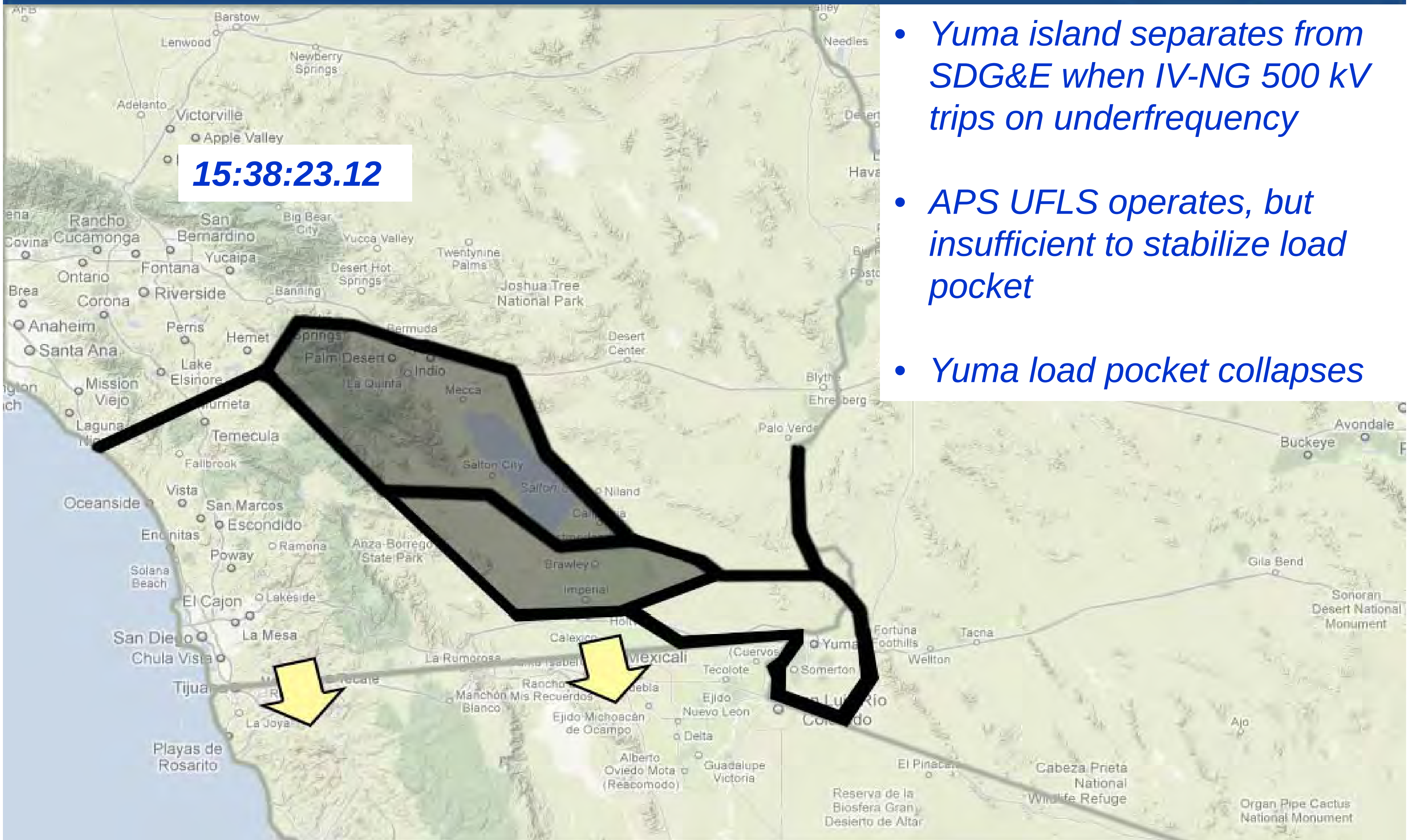


- *SONGS separation scheme operates; forms SDG&E, CFE, Yuma combined island*
- *Combined island frequency begins to collapse*


SONGS Frequency
SONGS separation
SONGS Unit 3 electrically disconnects
SONGS Unit 2 electrically disconnects
SONGS generators ring down
Frequency (Hz)
60.8
60.7
60.6
60.5
60.4
60.3
60.2
60.1
60
59.9
59.8
15:38:20
15:38:23
15:38:26
15:38:29
15:38:32
15:38:35
15:38:38
Local Time (PDT)

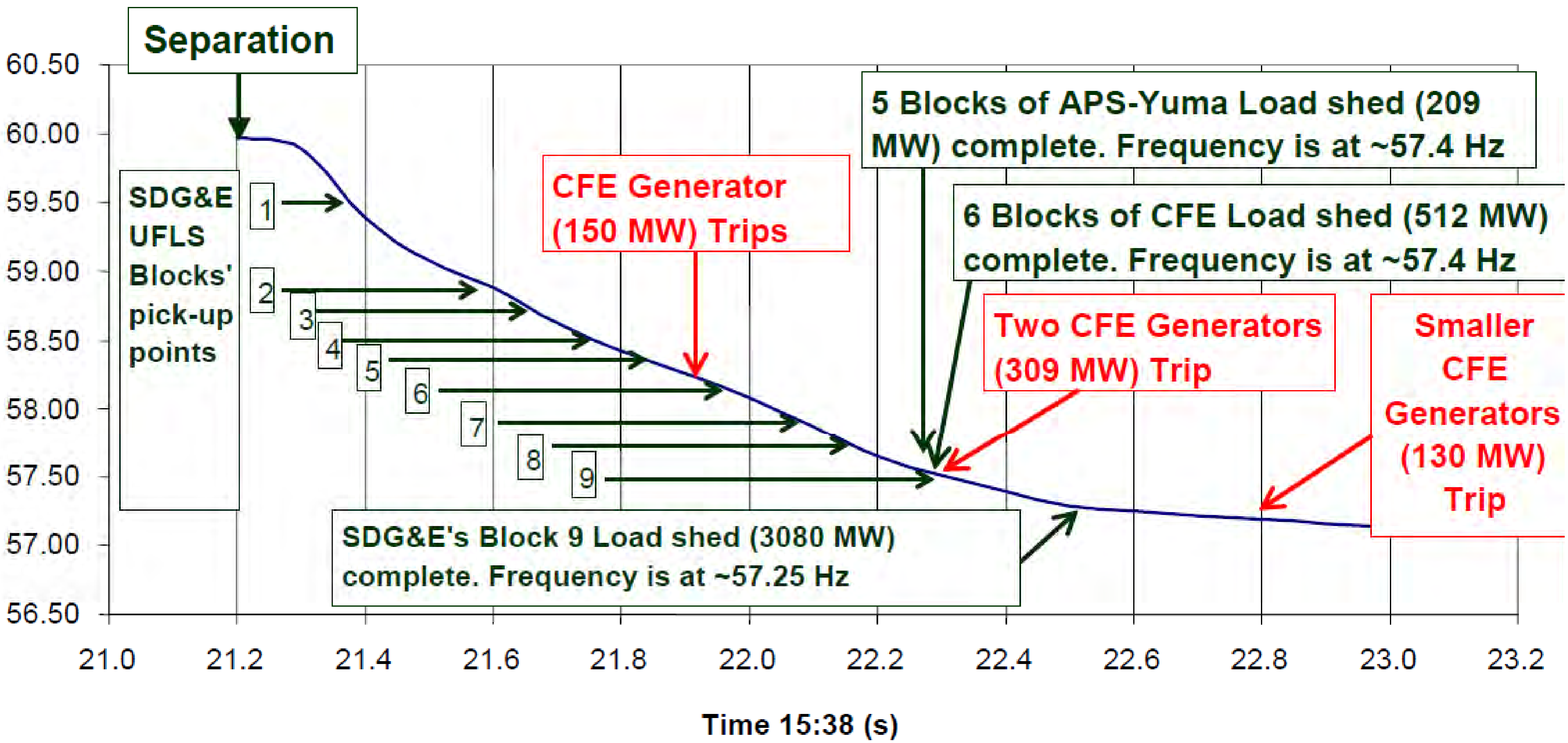

South of SONGS - Calculated MVA
150
125
100
75
50
25
0
MVA
15:38:19
15:38:21
15:38:23
15:38:25
15:38:27
15:38:29
15:38:31
Local Time (PDT)
SONGS separation
SONGS generators ring down
SONGS Unit 2 GSU trip and transfer of aux load
SONGS aux load on startup transformers
SONGS Unit 3 GSU trip and transfer of aux load

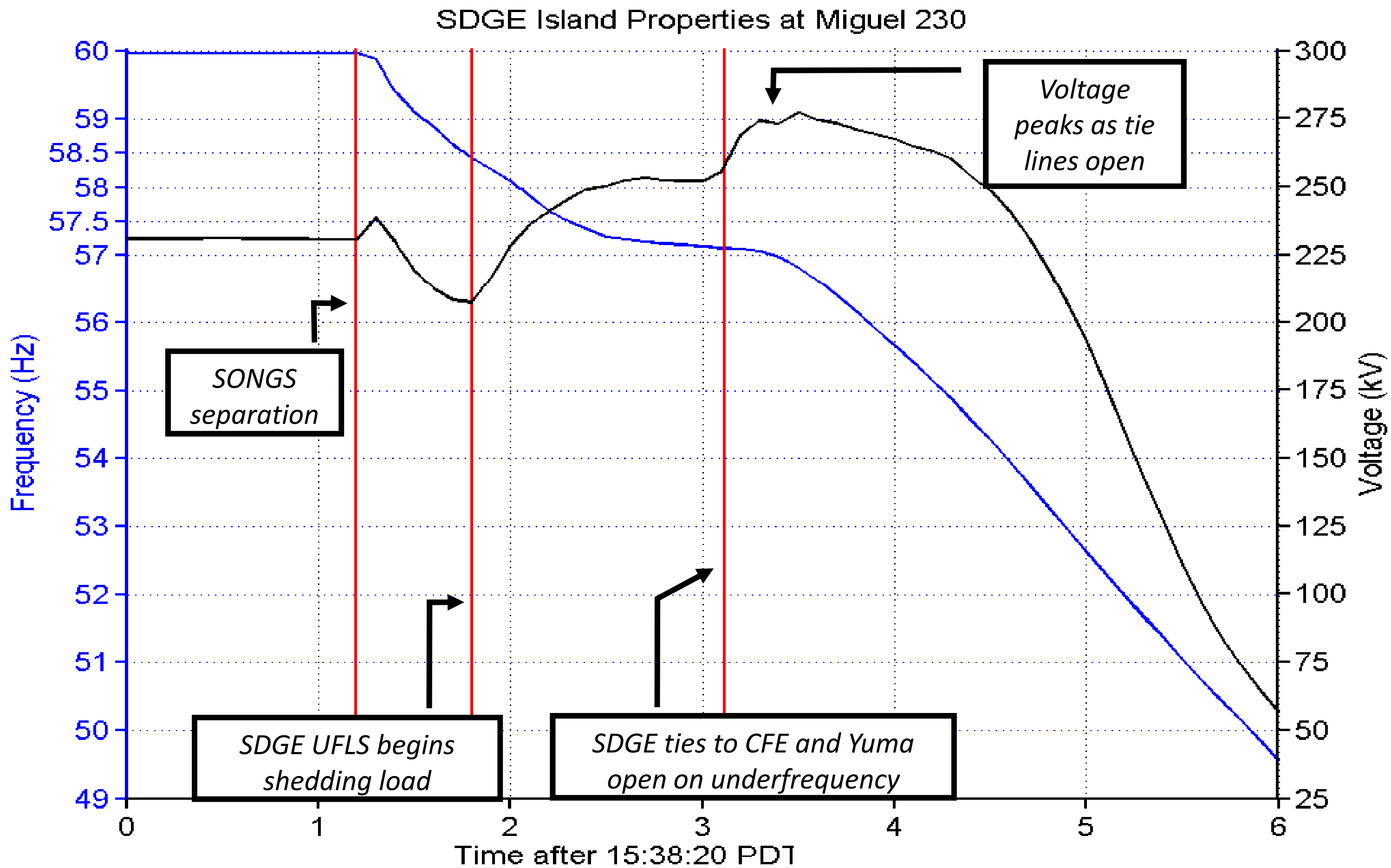
Phase 7 – S CA Separates



- *Yuma island separates from SDG&E when IV-NG 500 kV trips on underfrequency*
- *APS UFLS operates, but insufficient to stabilize load pocket*
- *Yuma load pocket collapses*

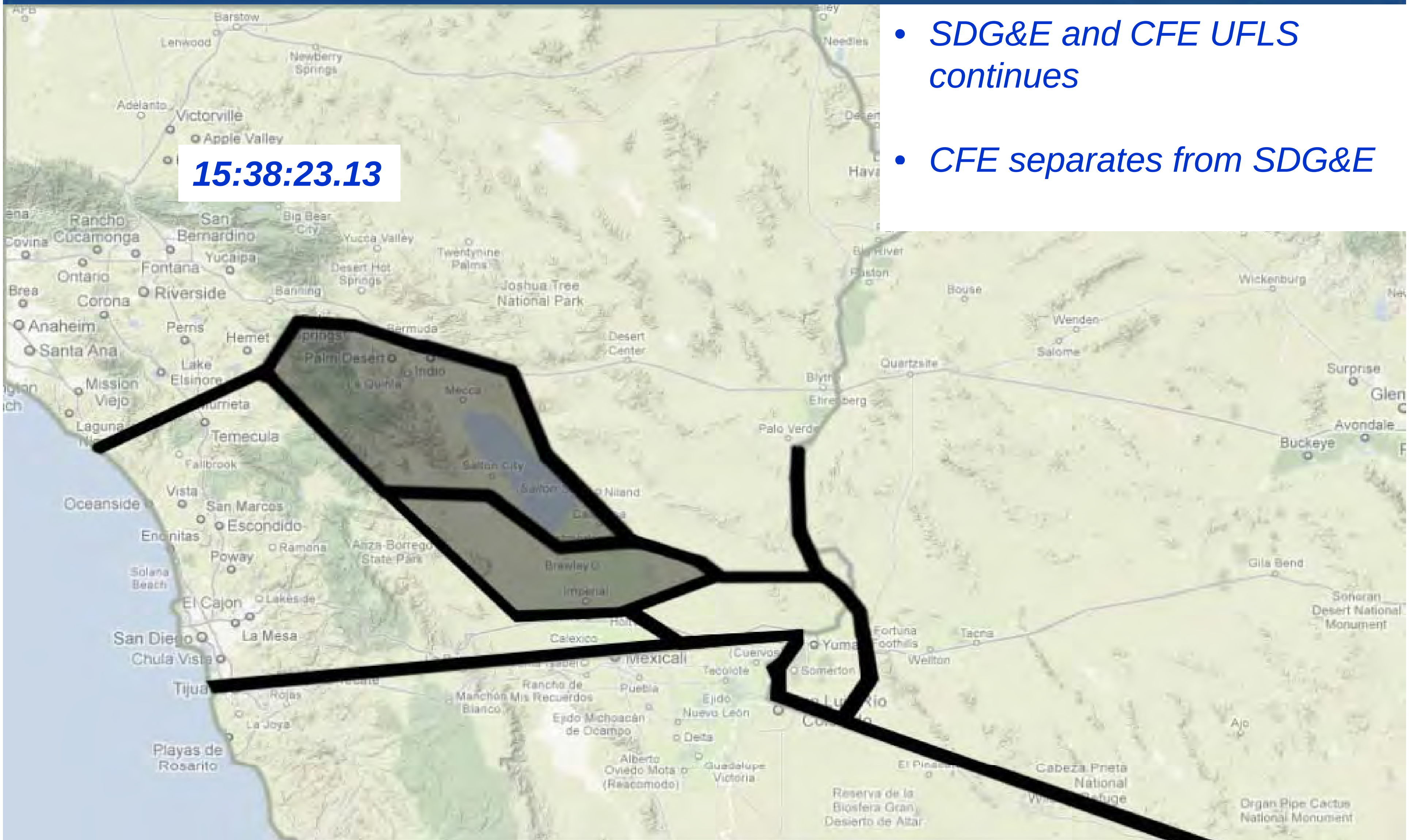
UFLS Operations in the Island



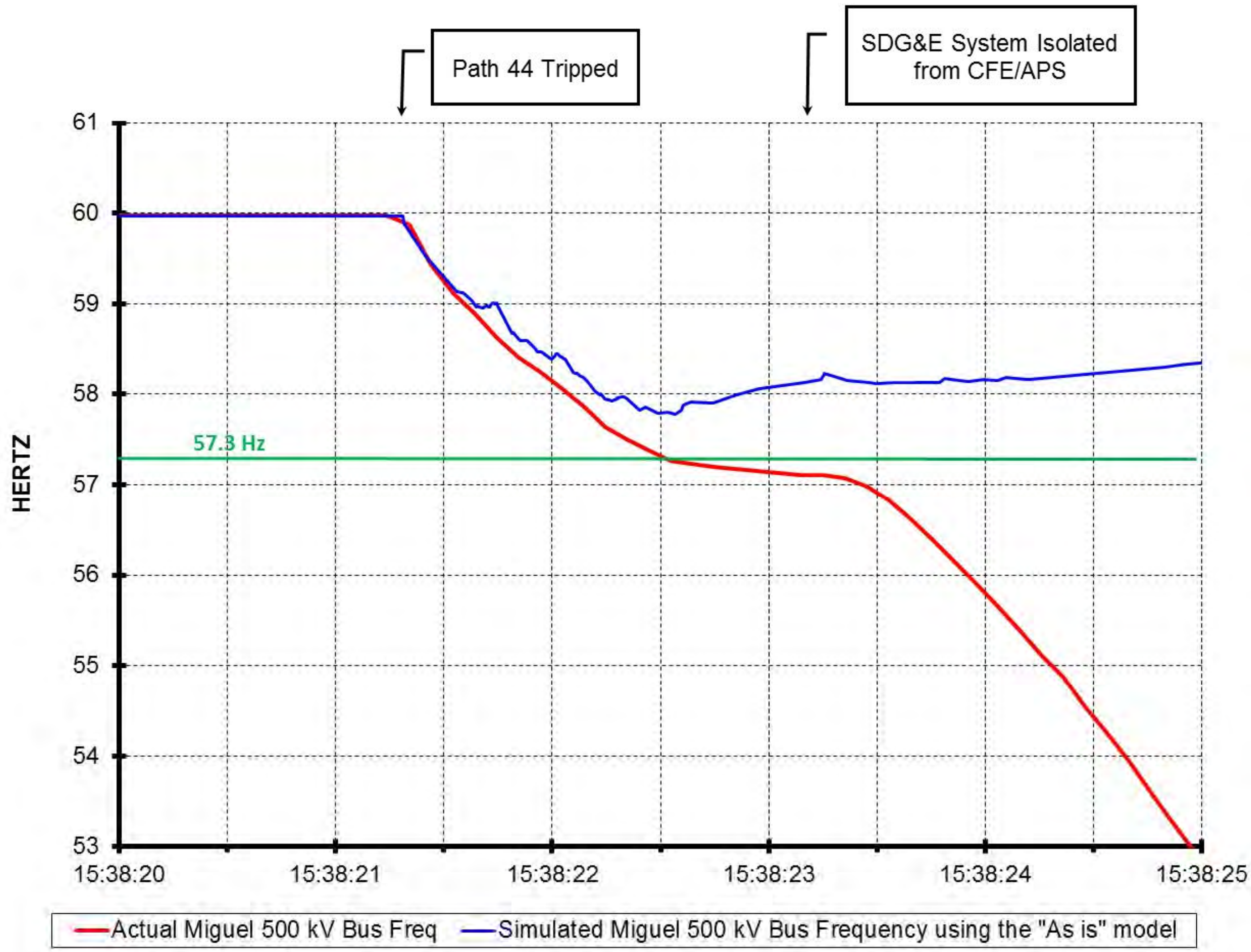

SDGE Island Properties at Miguel 230
Frequency (Hz)
Voltage (kV)
60
59
58.5
58
57.5
57
56
55
54
53
52
51
50
49
300
275
250
225
200
175
150
125
100
75
50
25
0
1
2
3
4
5
6
Time after 15:38:20 PDT
Voltage peaks as tie lines open
SONGS separation
SDGE UFLS begins shedding load
SDGE ties to CFE and Yuma open on underfrequency

Phase 7 – CFE Separates

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

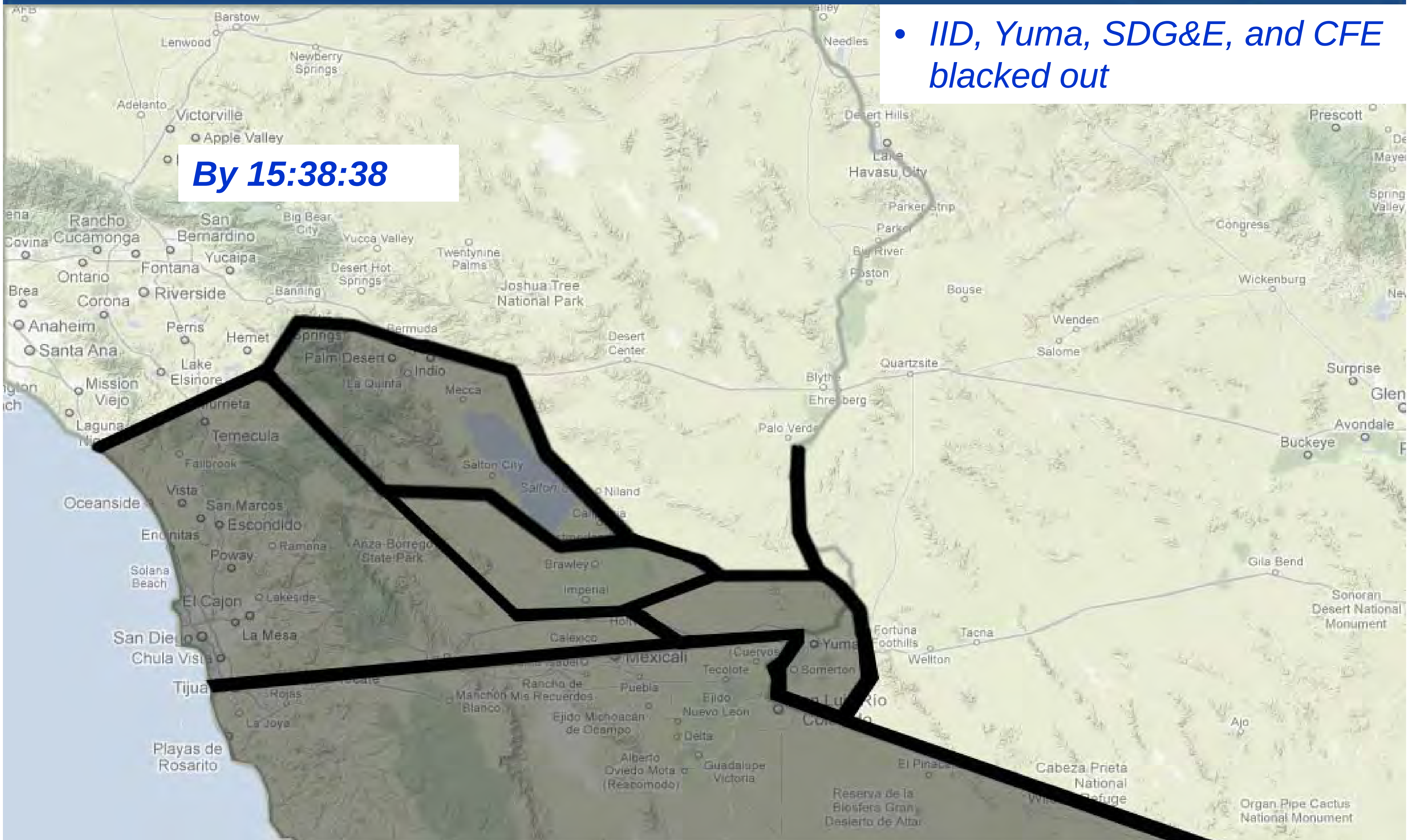


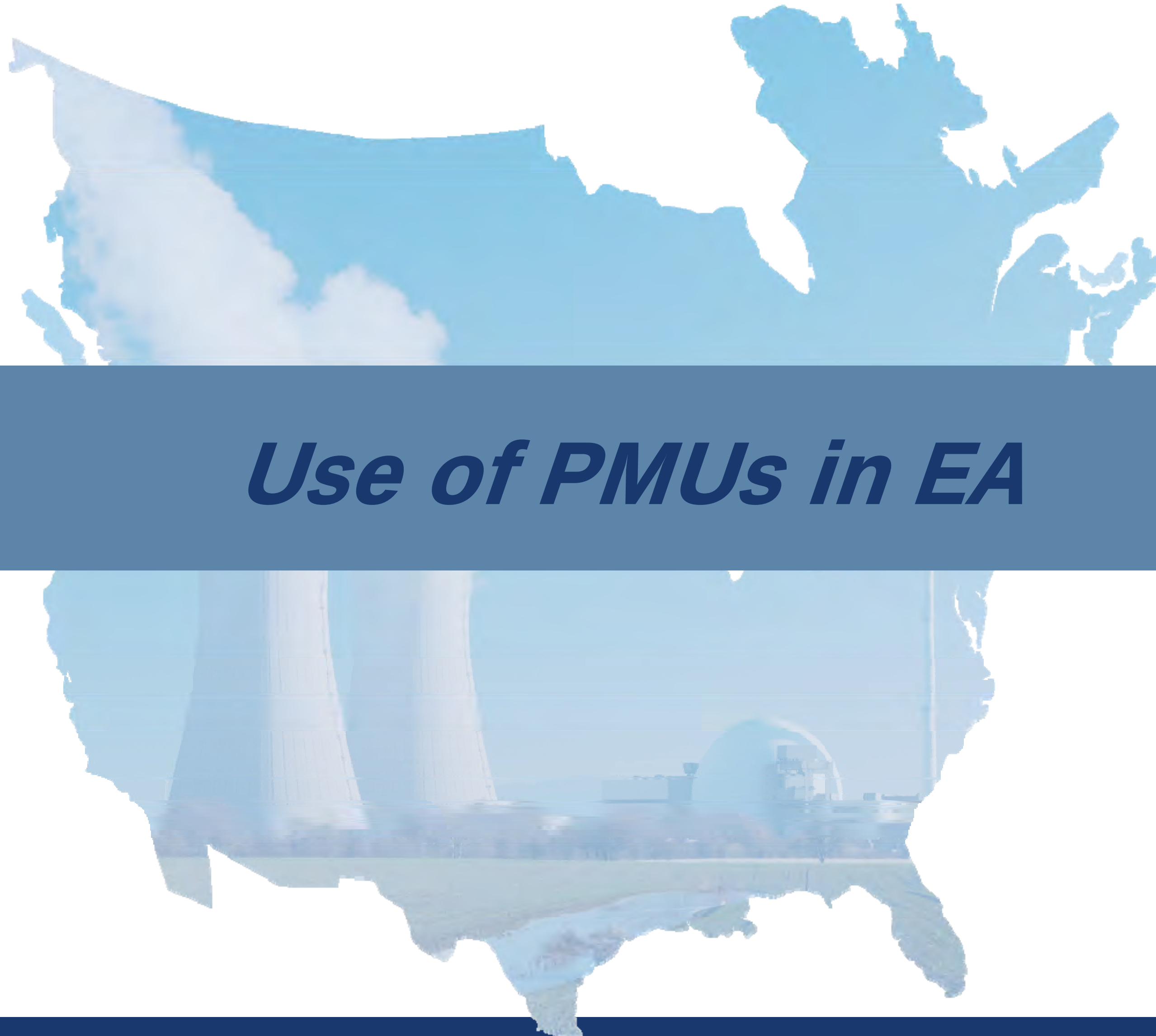
Actual vs. Simulated Frequency



Phase 7 – Complete Blackout

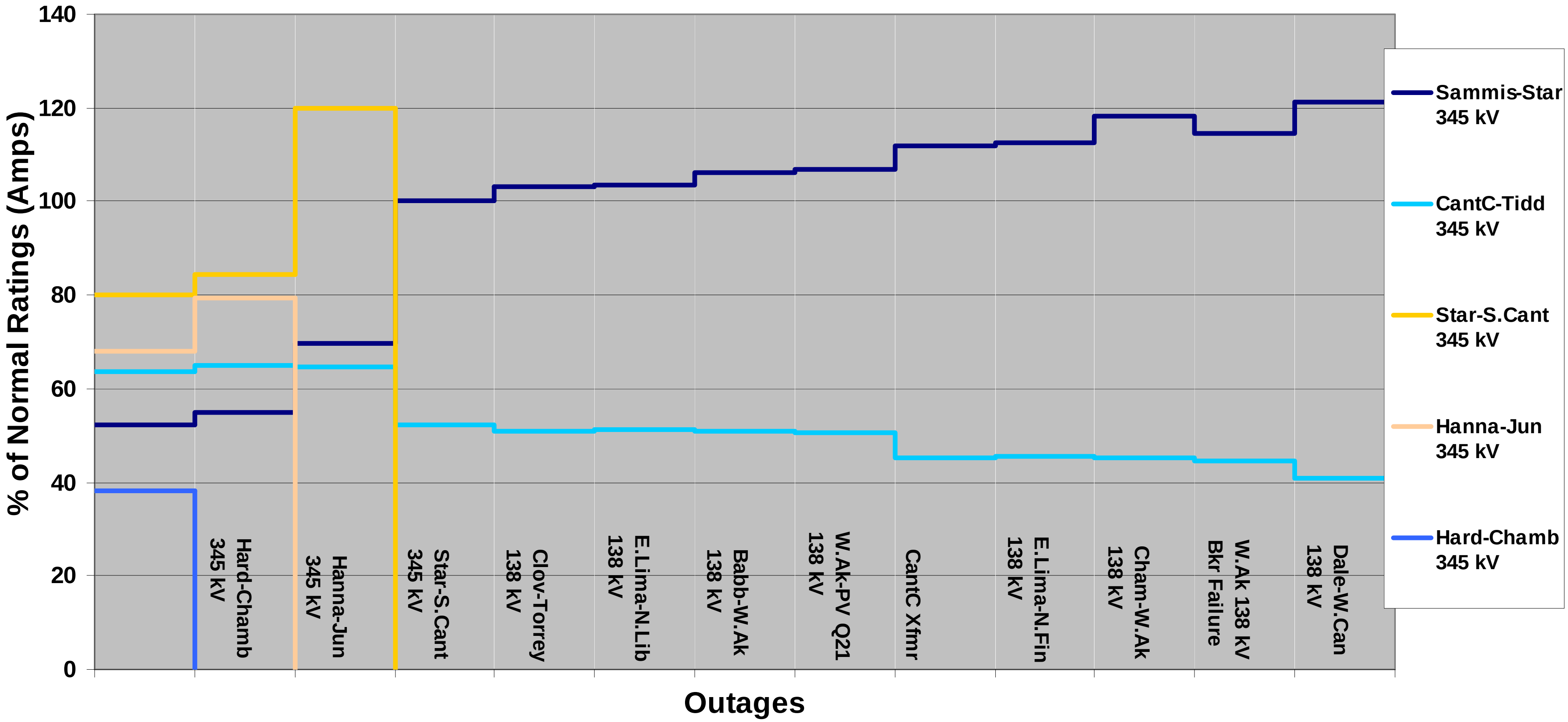
- *IID, Yuma, SDG&E, and CFE blacked out*



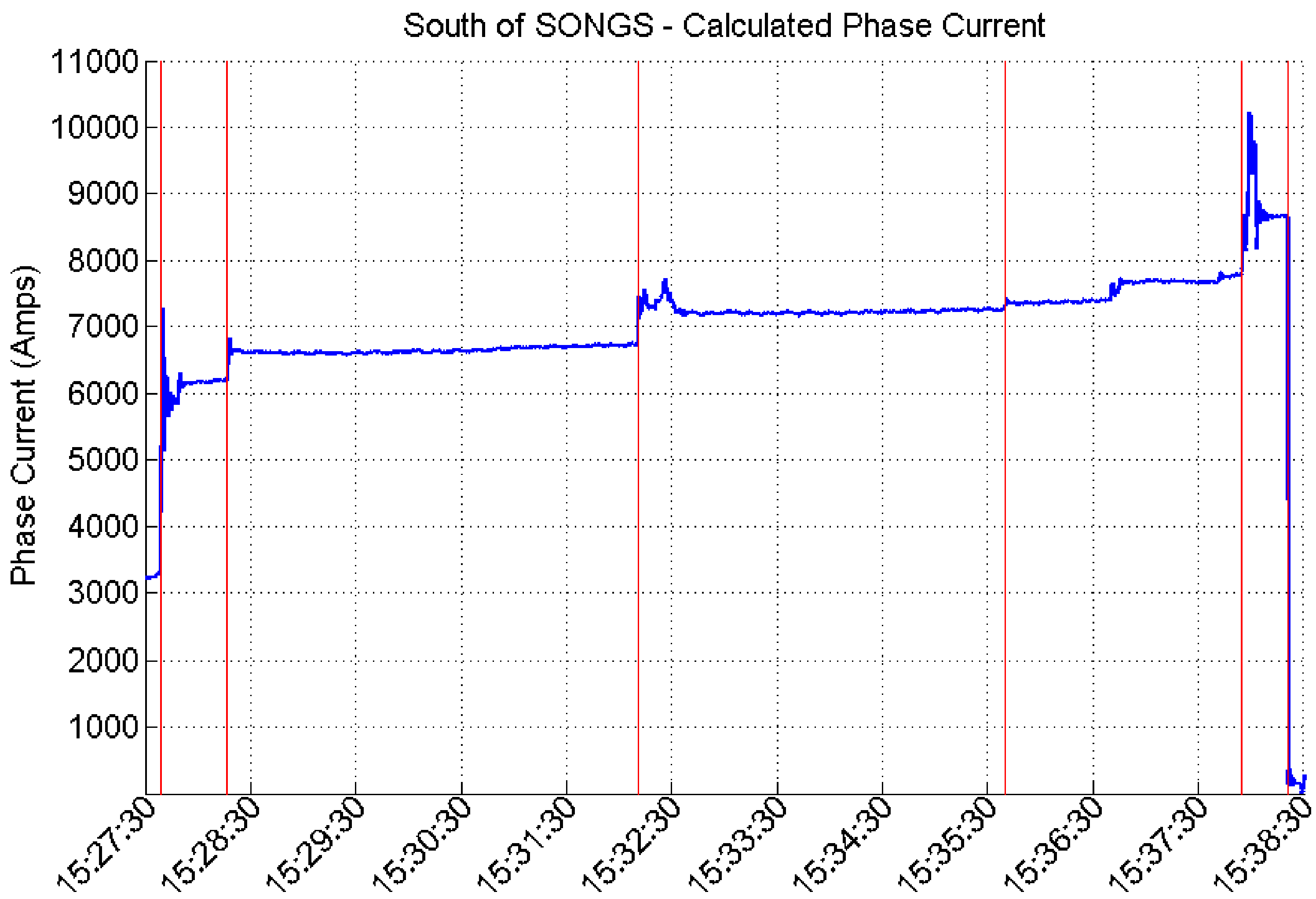


Use of PMUs in EA

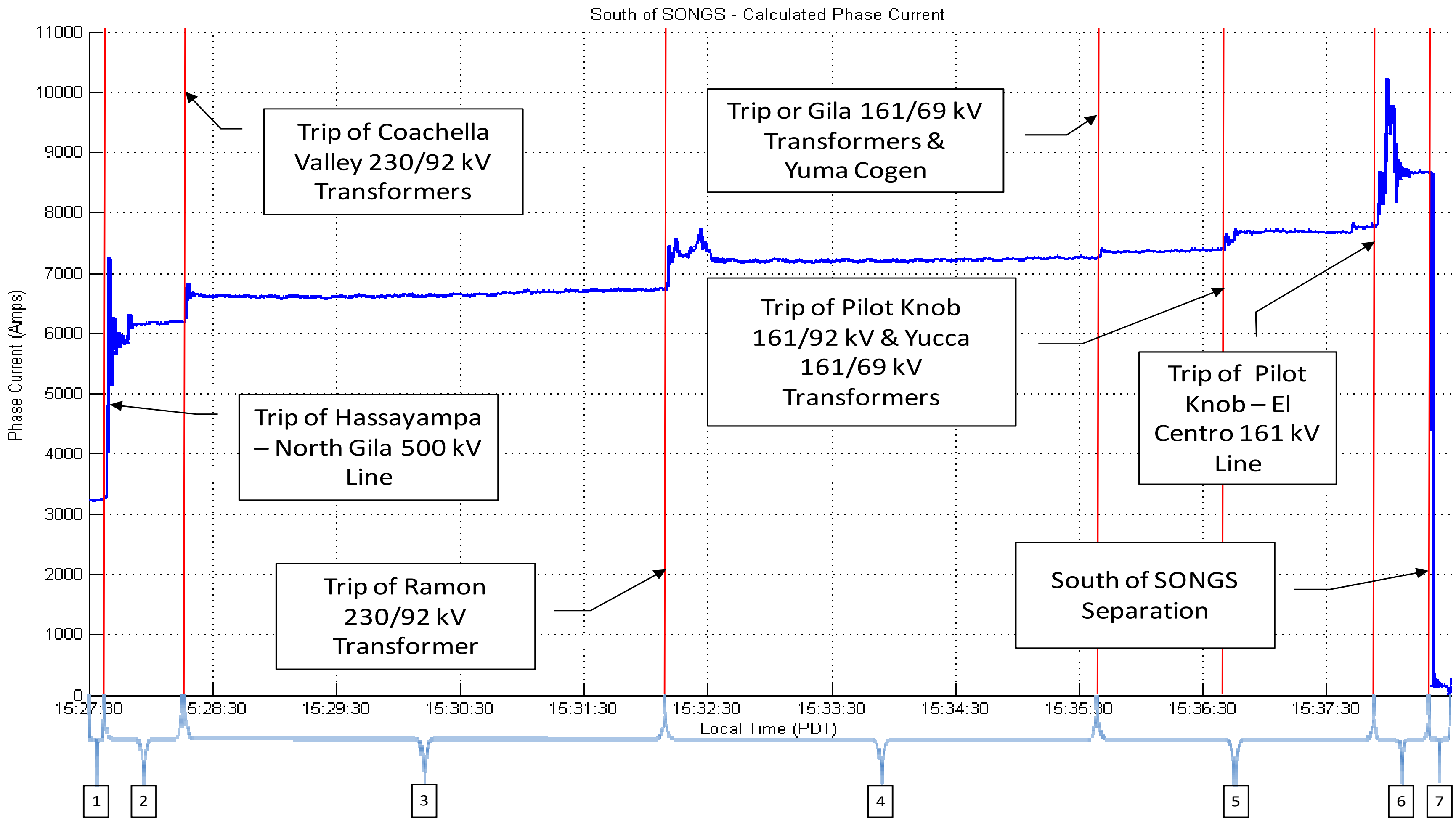
2003 Blackout Simulations



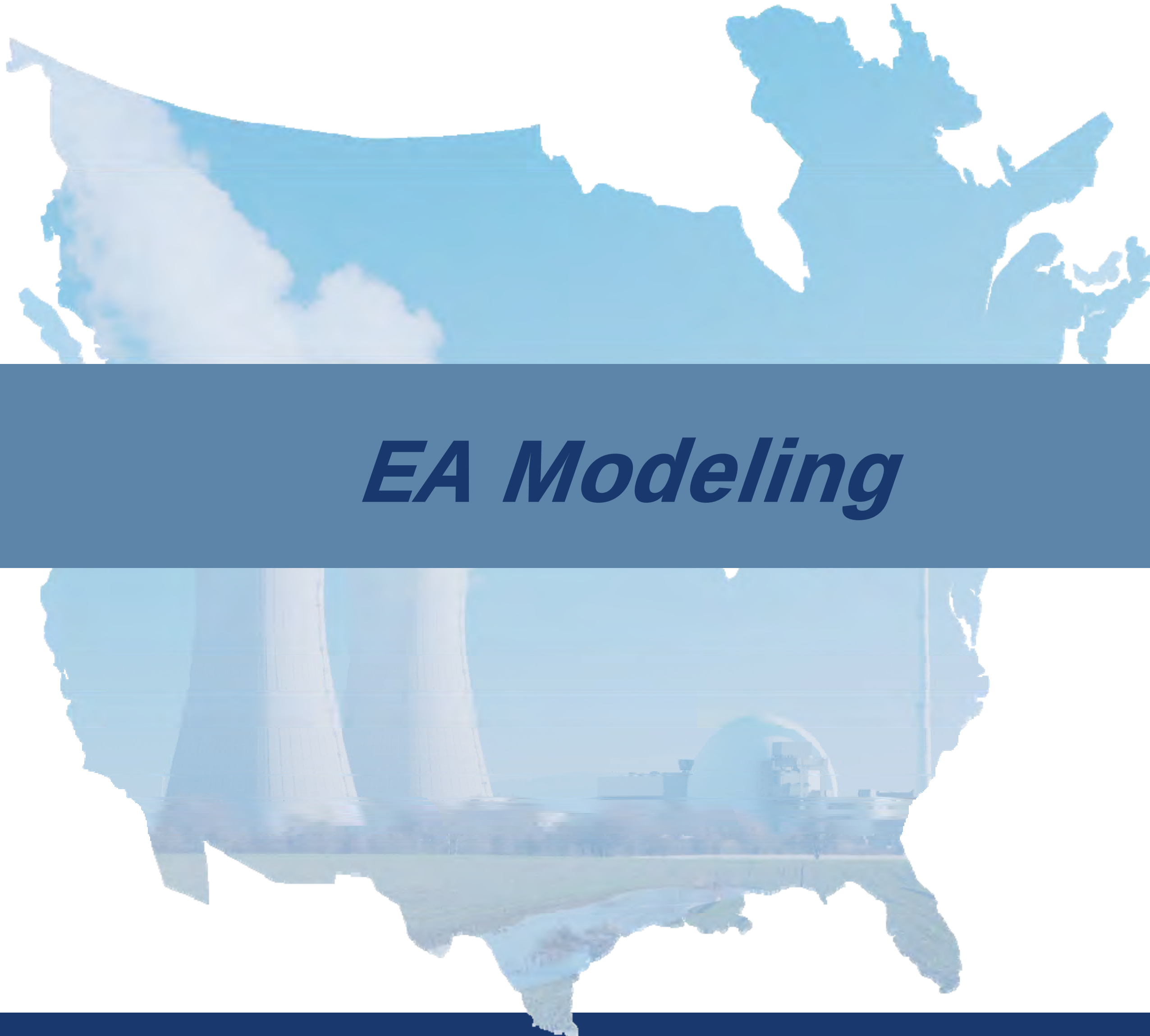
PMU Data from SONGS



7 Phases of Event

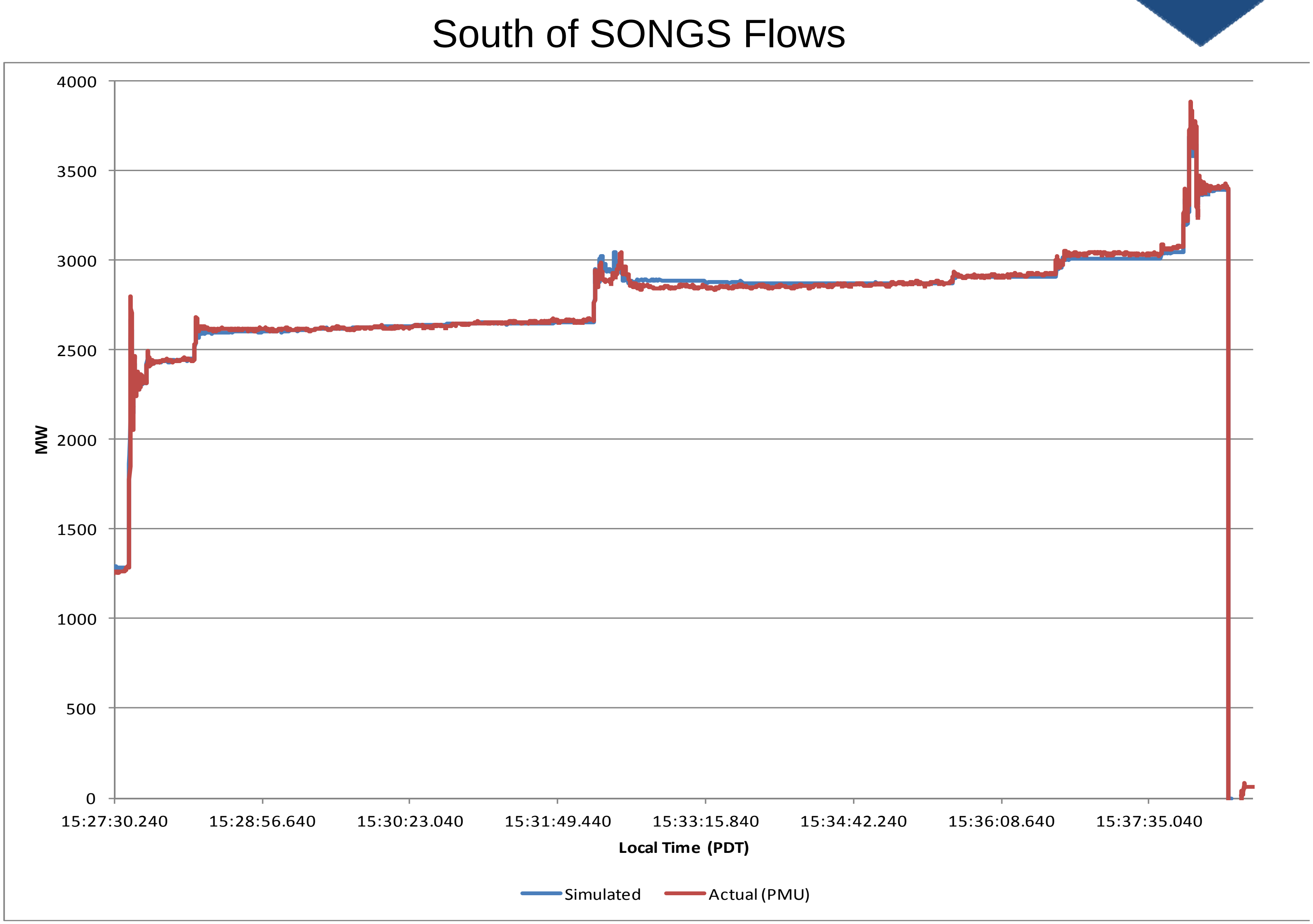


Disturbance Phases



EA Modeling

Simulation vs. Actual Flows



Inquiry Findings

Key Findings

Weaknesses in two broad areas:

- Operations planning
- Real-time situational awareness

Contributing factors:

- Not studying impact of sub 100 kV facilities parallel to EHV
- Failure to recognize IROLs
- Not studying/coordinating effects of protection systems and RASs during contingency scenarios
- Not providing effective operator tools and instructions for reclosing lines with large phase angle differences

Operations Planning

Failure to consider in seasonal, next-day, and real-time studies:

- Status of external generation and transmission facilities
- Impact of external contingencies
- Impacts on external systems
- Impact on BPS of reliability of sub-100 kV facilities parallel to EHV system

Operations Planning

Recommended TOP/BA Improvements in WECC:

- Obtain information on neighboring BAs and TOPs, including transmission outages, generation outages and schedules, load forecasts, and scheduled interchanges
- Identify and plan for external contingencies that could impact their systems and internal contingencies that could impact neighbors' systems
- Consider facilities operated at less than 100 kV parallel to EHV system that could impact BPS reliability
- Coordinated review of planning studies to ensure operation of affected Rated Paths will not result in reliability problems

Situational Awareness

Recommended Improvements in WECC:

- Expand entities' external visibility in models through more complete data sharing
- Improve use of real-time tools to ensure constant monitoring of potential internal or external contingencies
- Improve communications among entities to help maintain situational awareness
- TOPs should review their real-time monitoring tools (State Estimator and RTCA) to ensure critical facilities are represented

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System Protection Issues

Recommendations:

- IID and other TOs review transformer overload protection relay settings
- TOPs plan to take proper pre-contingency mitigation measures considering emergency ratings and overload protection systems
- All protection systems and separation schemes (Safety Nets, RAS, and SPS) studied and coordinated periodically to understand their impact on BPS reliability to ensure no unintended or undesirable effects

Questions?