San Diego – Southwest Blackout
September 8, 2011

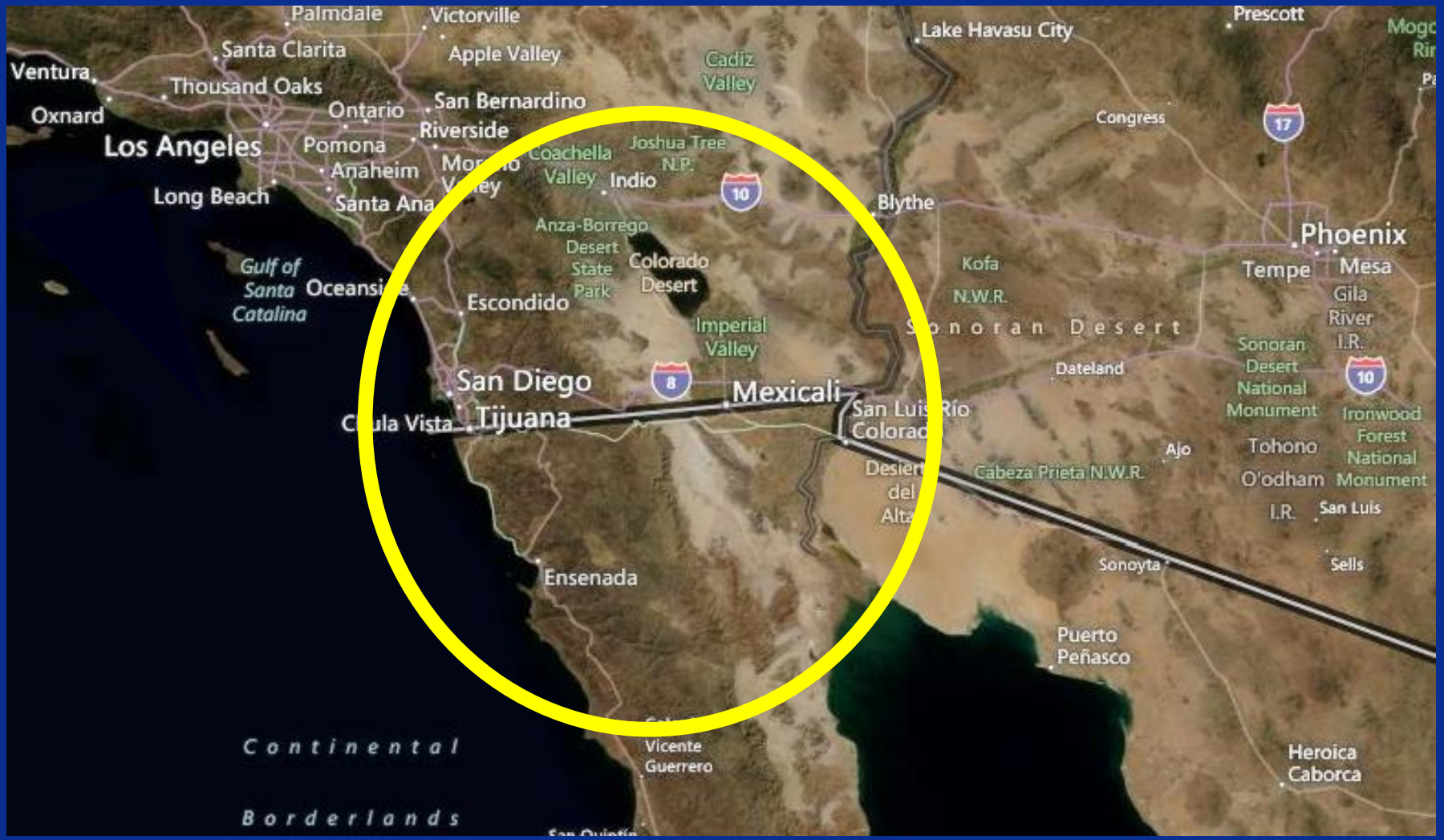
Dan Head
Consolidated Edison of NY, Inc.
System Operations (Operations Analysis Group)

Agenda

- System Overview
- Voltage Angle & Power Transfer
- System Conditions
- Sequence of Events
- Frequency
- Impacts
- Recommendations
- Questions

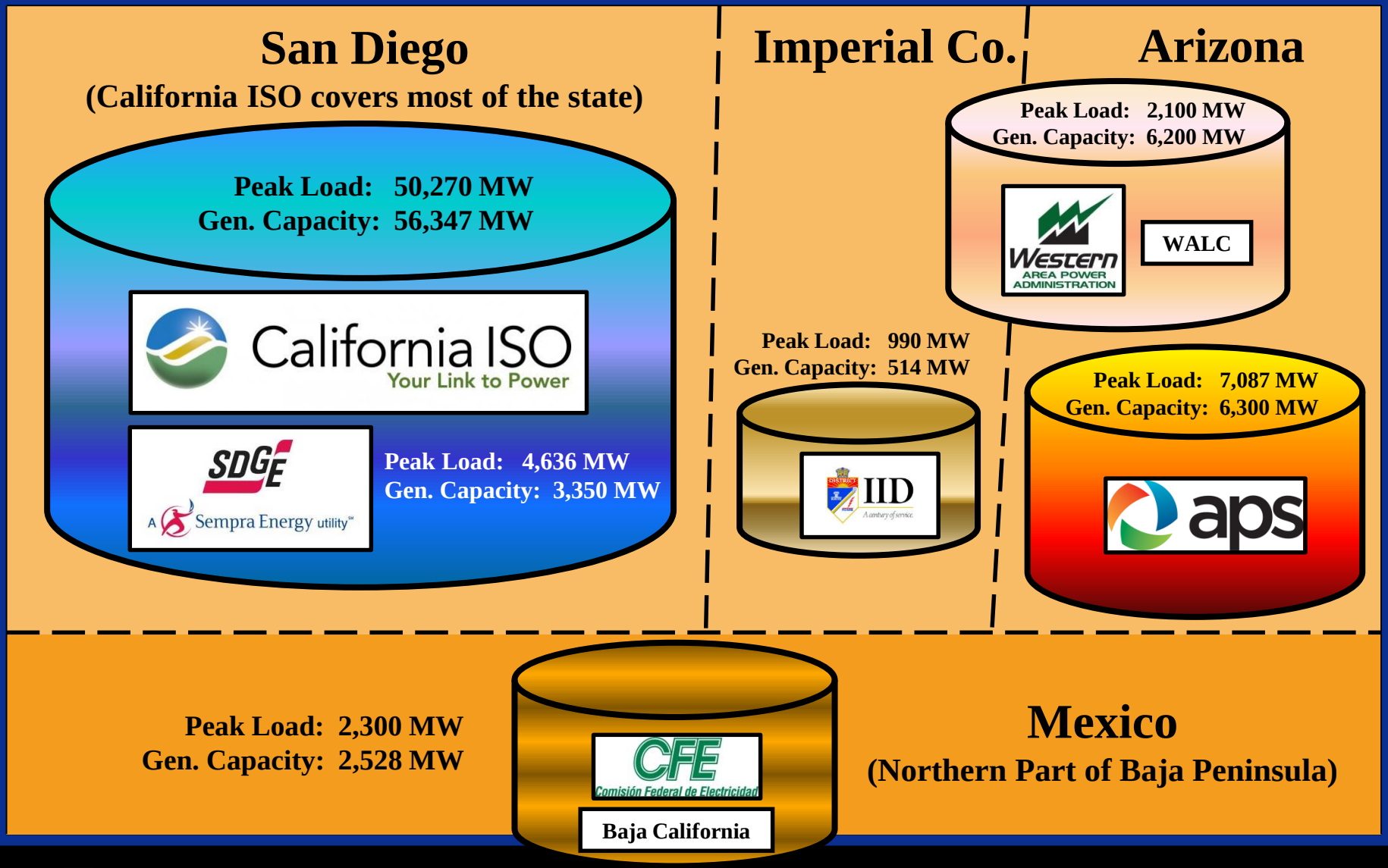
System Overview: San Diego

System Overview: Affected Area

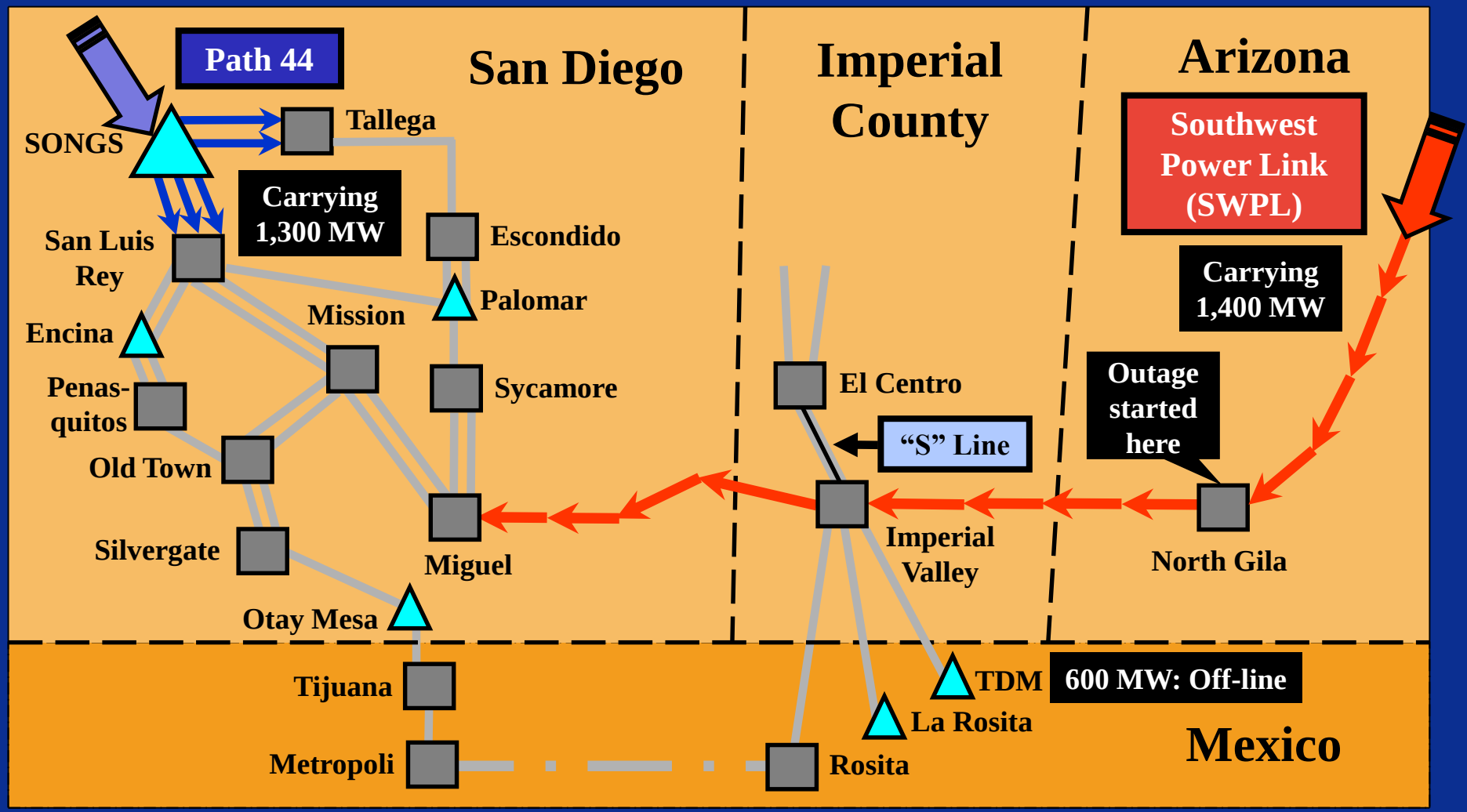


System Overview: Balancing Authorities

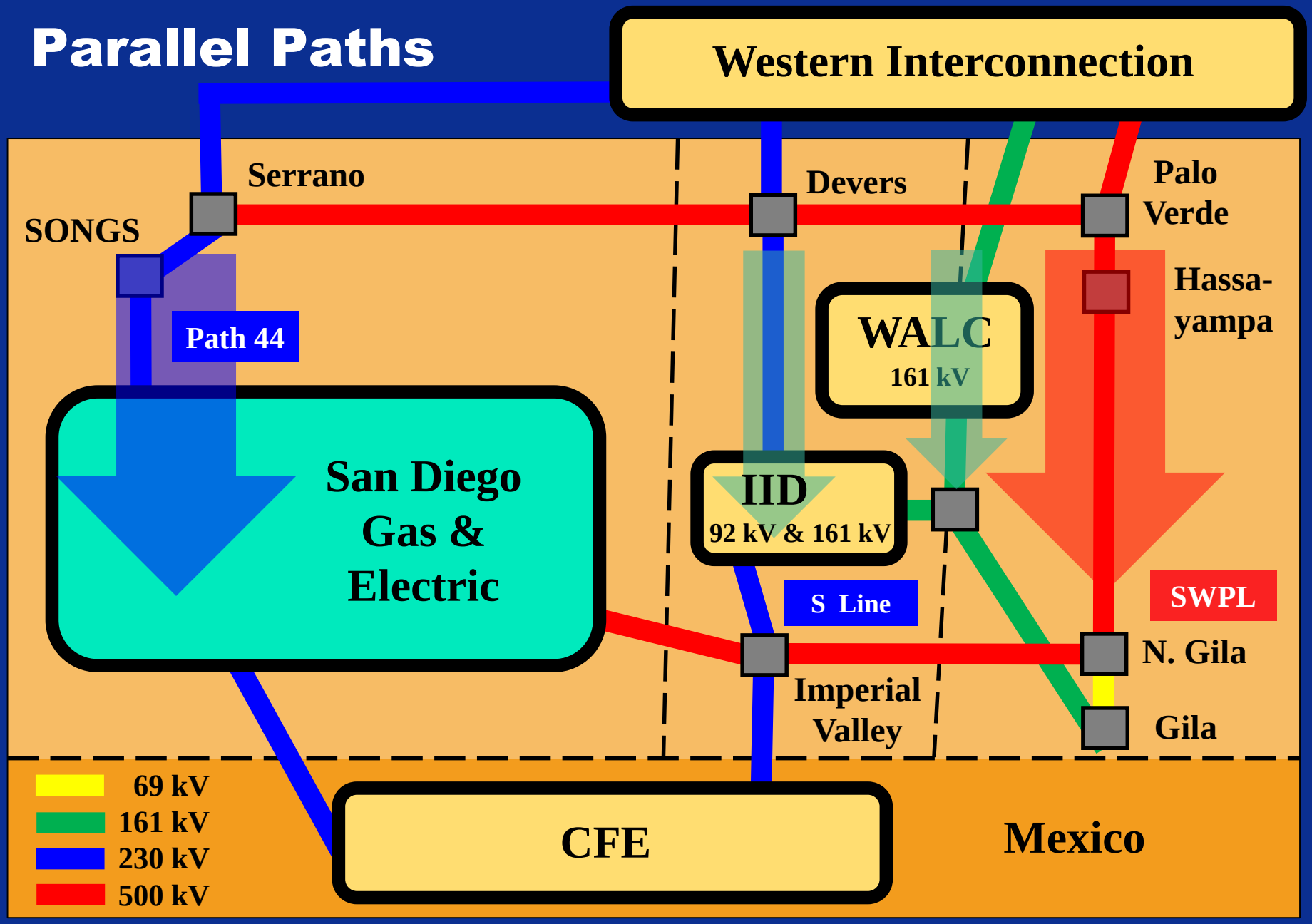
5 of 37 total in the Western Electricity Coordinating Council (WECC)



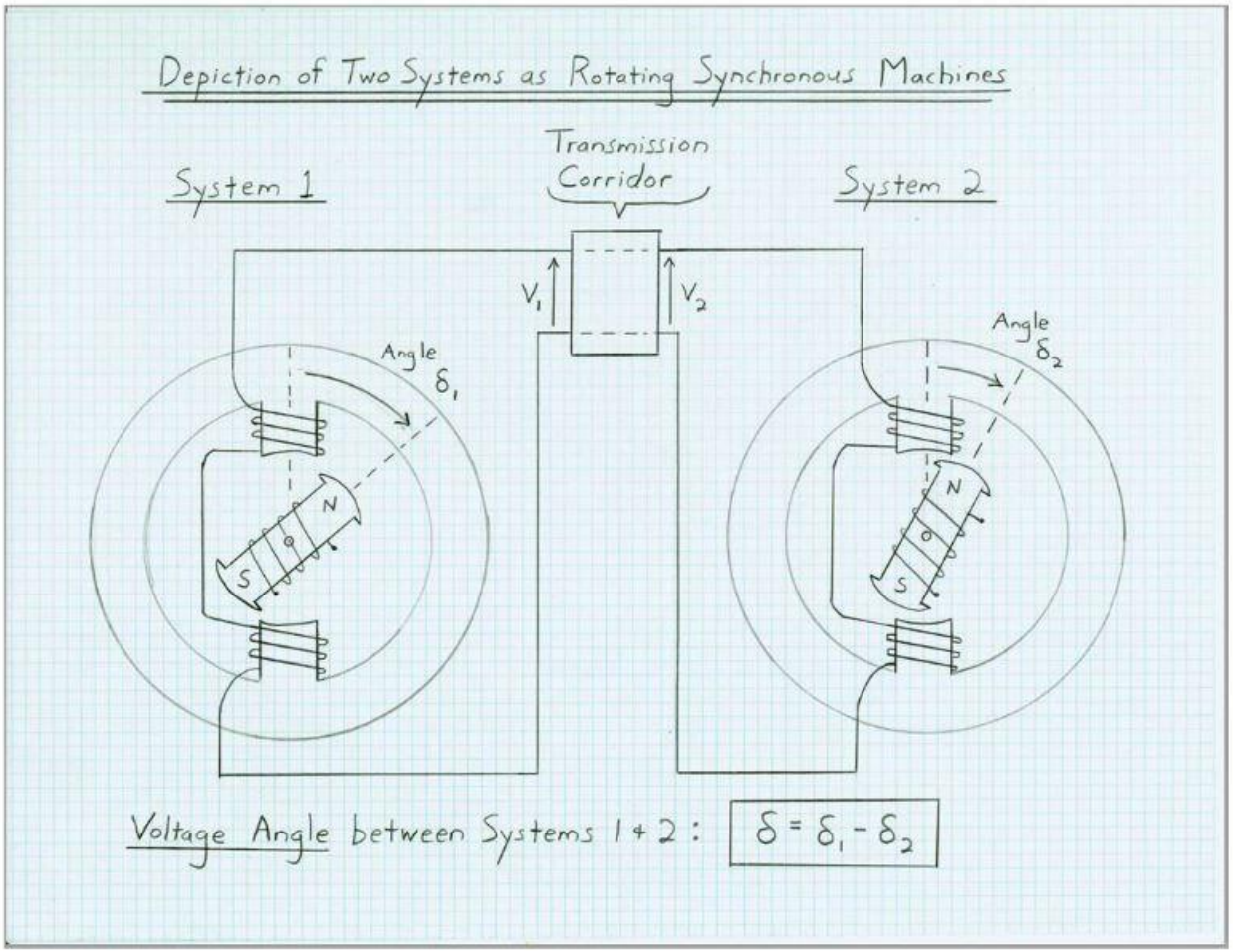
System Overview:
Supplying San Diego



Parallel Paths



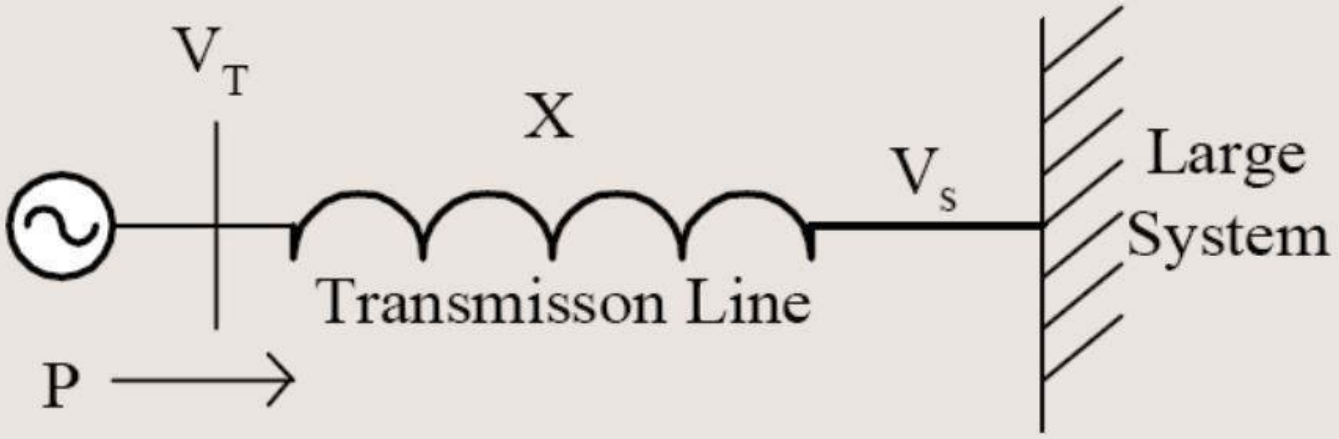
Voltage Angle & Power Transfer
Two Systems as Synchronous Machines



Depiction of Two Systems as Rotating Synchronous Machines

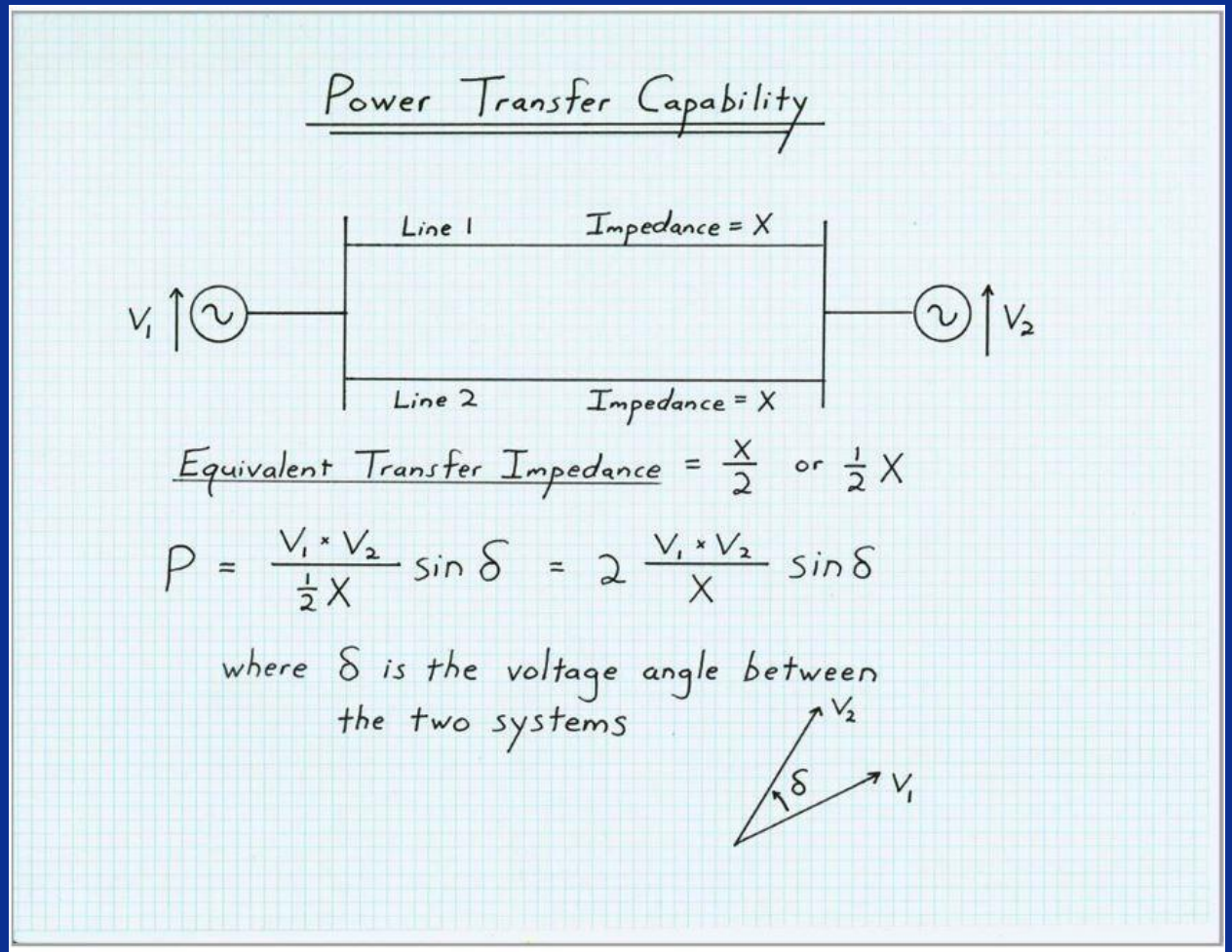
Voltage Angle & Power Transfer

Power Transfer Equation



$$P = \frac{V_T V_s}{X} \sin \partial$$

Voltage Angle & Power Transfer
Two Parallel Lines



Power Transfer Capability: Two Parallel Lines

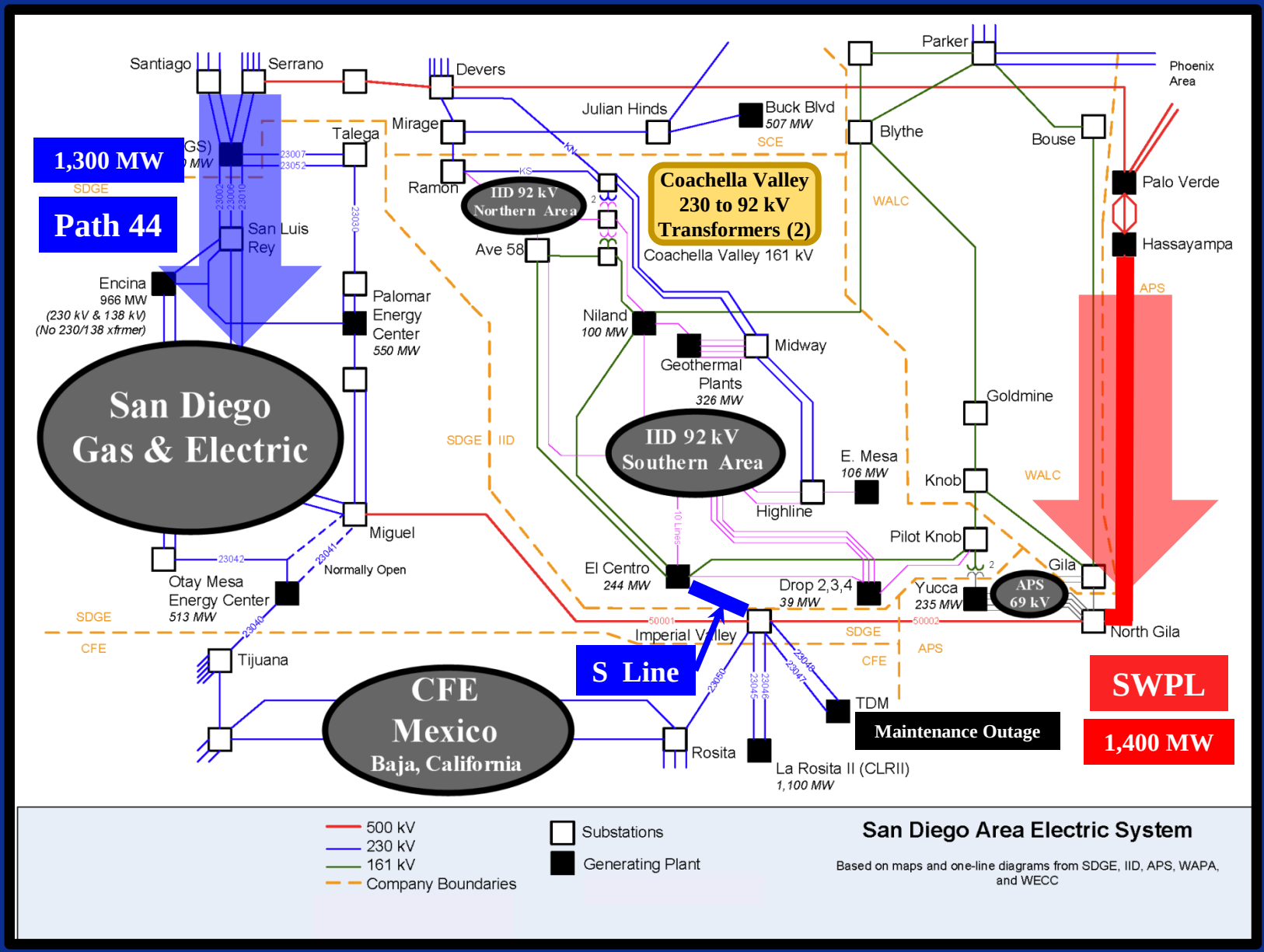
System Conditions

- **Good weather, but warm**
  - 86 degrees Fahrenheit in San Diego (vs. 77 normal)
  - 113 degrees in Yuma, Arizona (vs. 104 normal)
  - Loads in the range of 90 to 95 percent of summer peak
  - San Diego load running 6% above the day-ahead forecast
- **Thursday after Labor Day**
  - “Shoulder” season for maintenance outages had begun
  - Mid afternoon
- **Heavy imports**
  - San Diego importing almost half its load level of 4,300 MW
  - Impacted area importing about one third of its load level of 7,900 MW

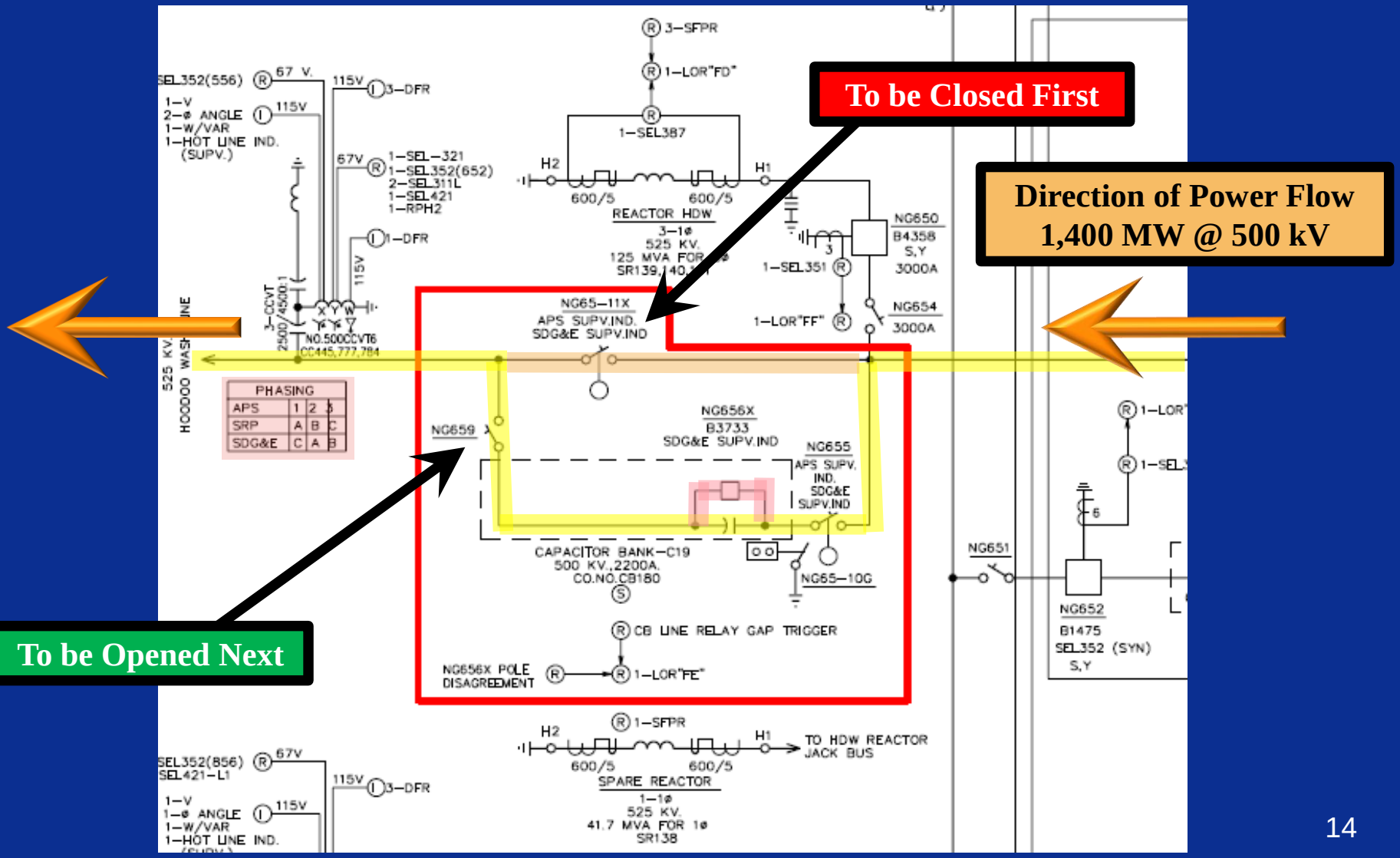
System Conditions: Critical Issues

- **SONGS Separation scheme not monitored**
  - WECC and California ISO *unaware* of automatic separation scheme between Southern Cal Edison and San Diego Gas & Electric
- **Outages in neighboring areas not taken into consideration**
  - Maintenance outage on a 600 MW generator in Mexico *not included* in day-ahead plan of Imperial Irrigation District (IID)
- **Contingency Alarm Missed**
  - 44 minutes prior to the initiating event, IID's real-time contingency analysis showed the loss of one 230/92 kV transformer would overload another beyond its trip point
  - *Operator was not monitoring the contingency analysis*
- **Phase imbalance relay operation on series capacitor**
  - 2-1/2 hours prior to the initiating event, the series capacitor on a 500 kV line in Arizona was automatically by-passed

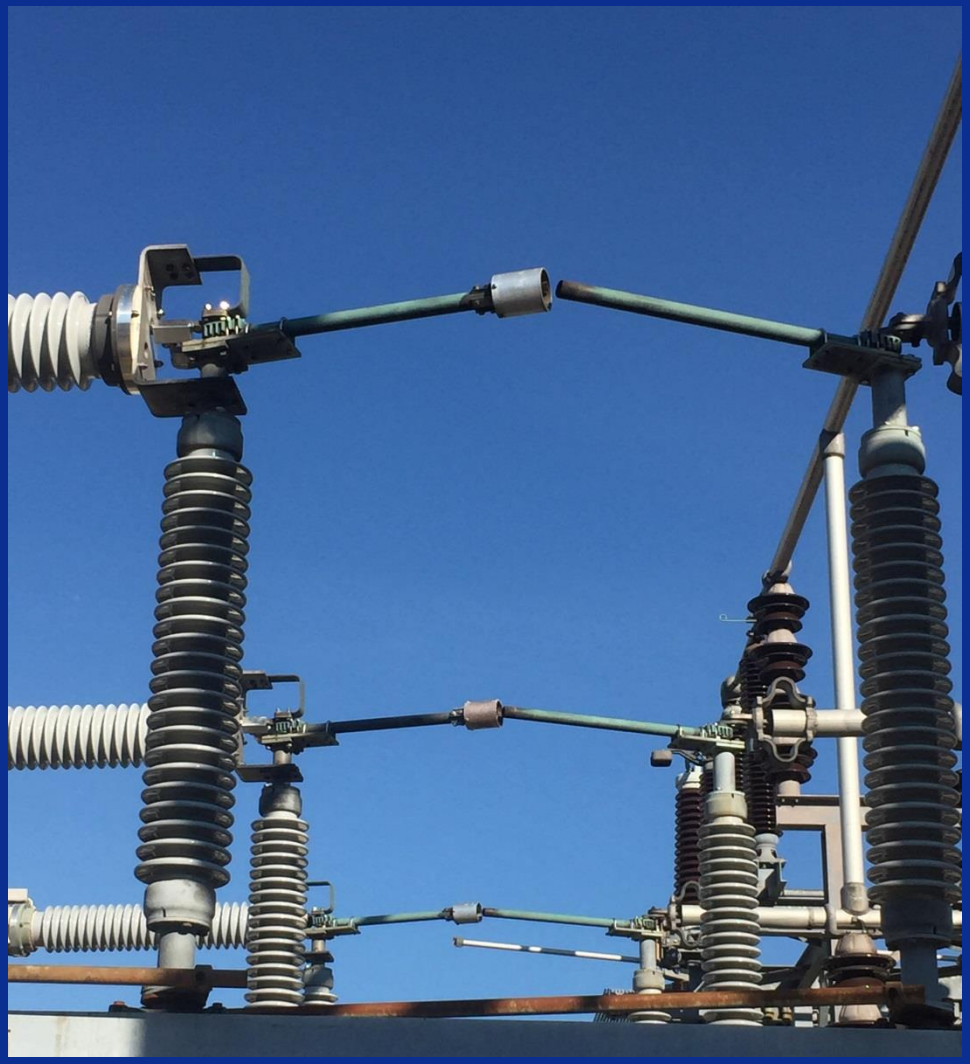
System Conditions: One-Line Diagram & Flows



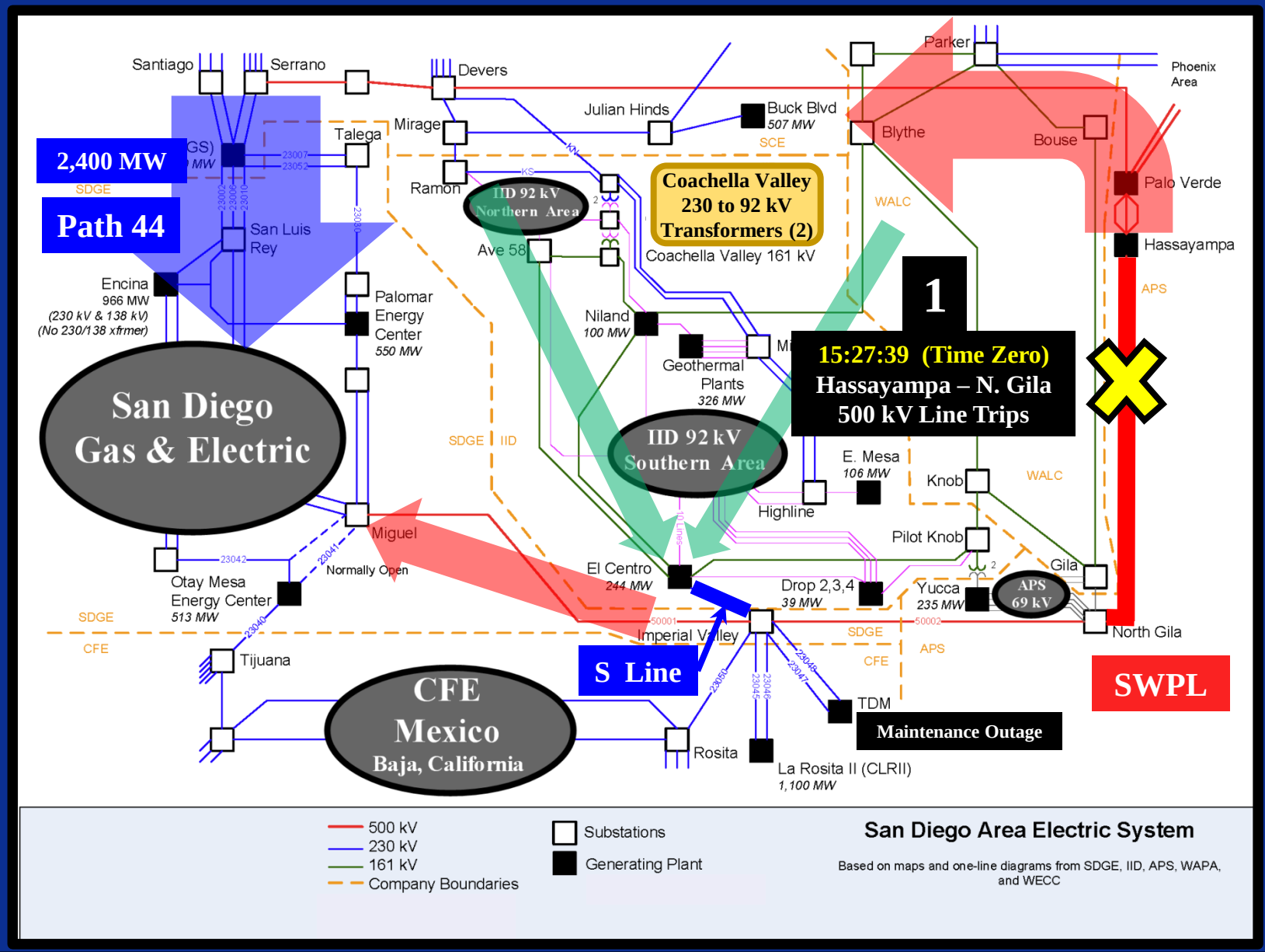
Sequence of Events
Series Capacitors at North Gila Station



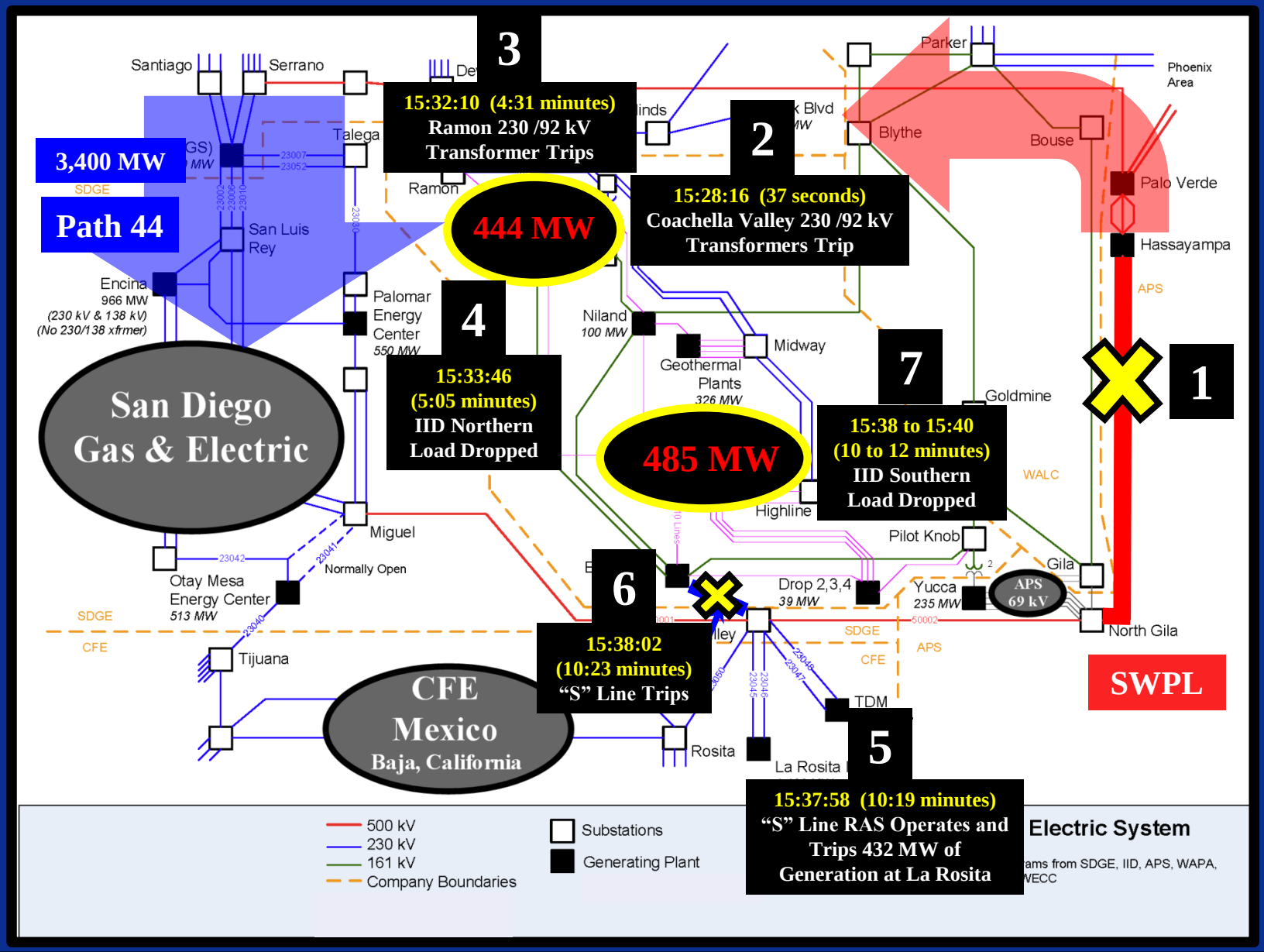
Sequence of Events
Disconnect Switch



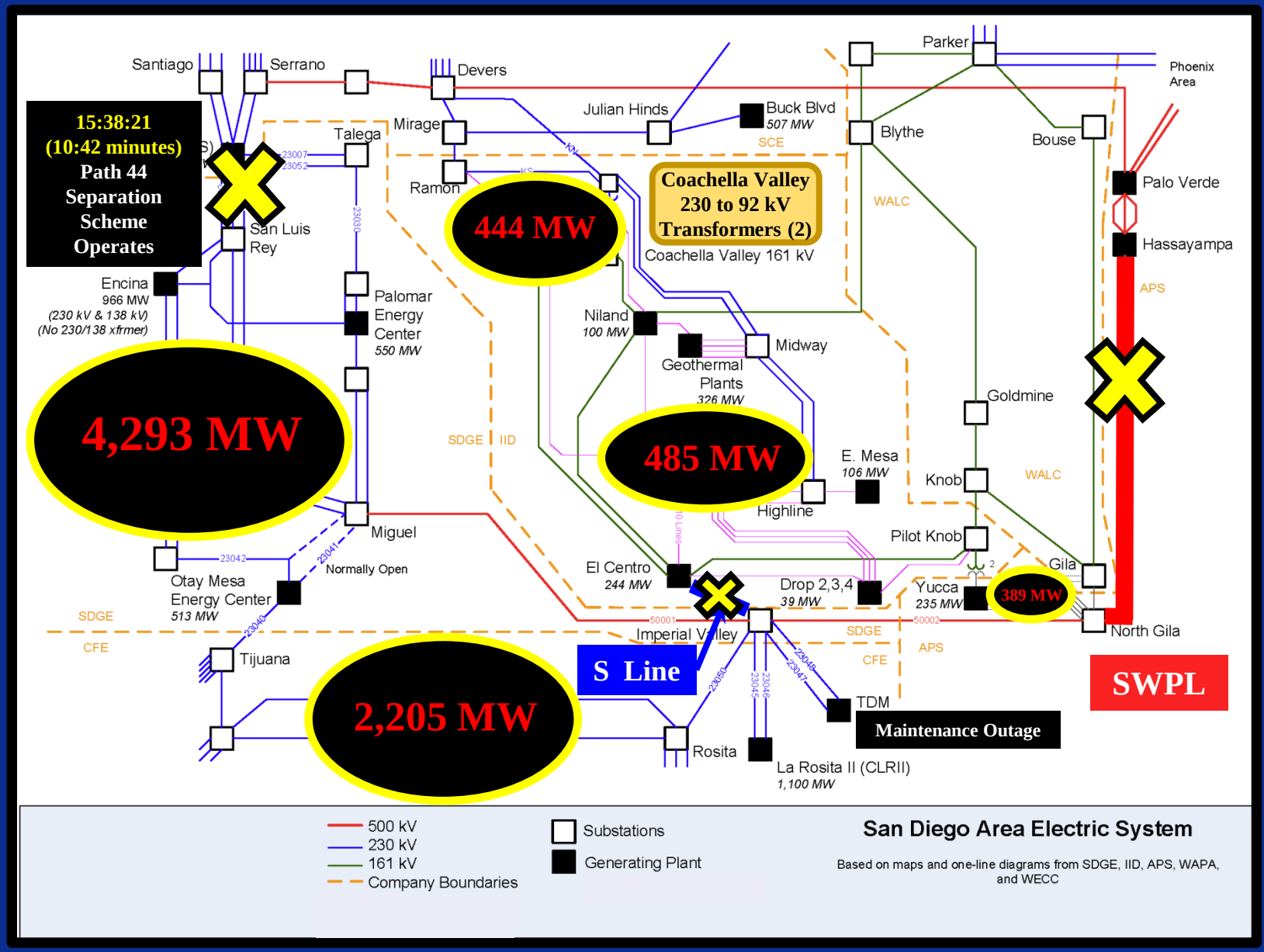
Sequence of Events: Line Trips



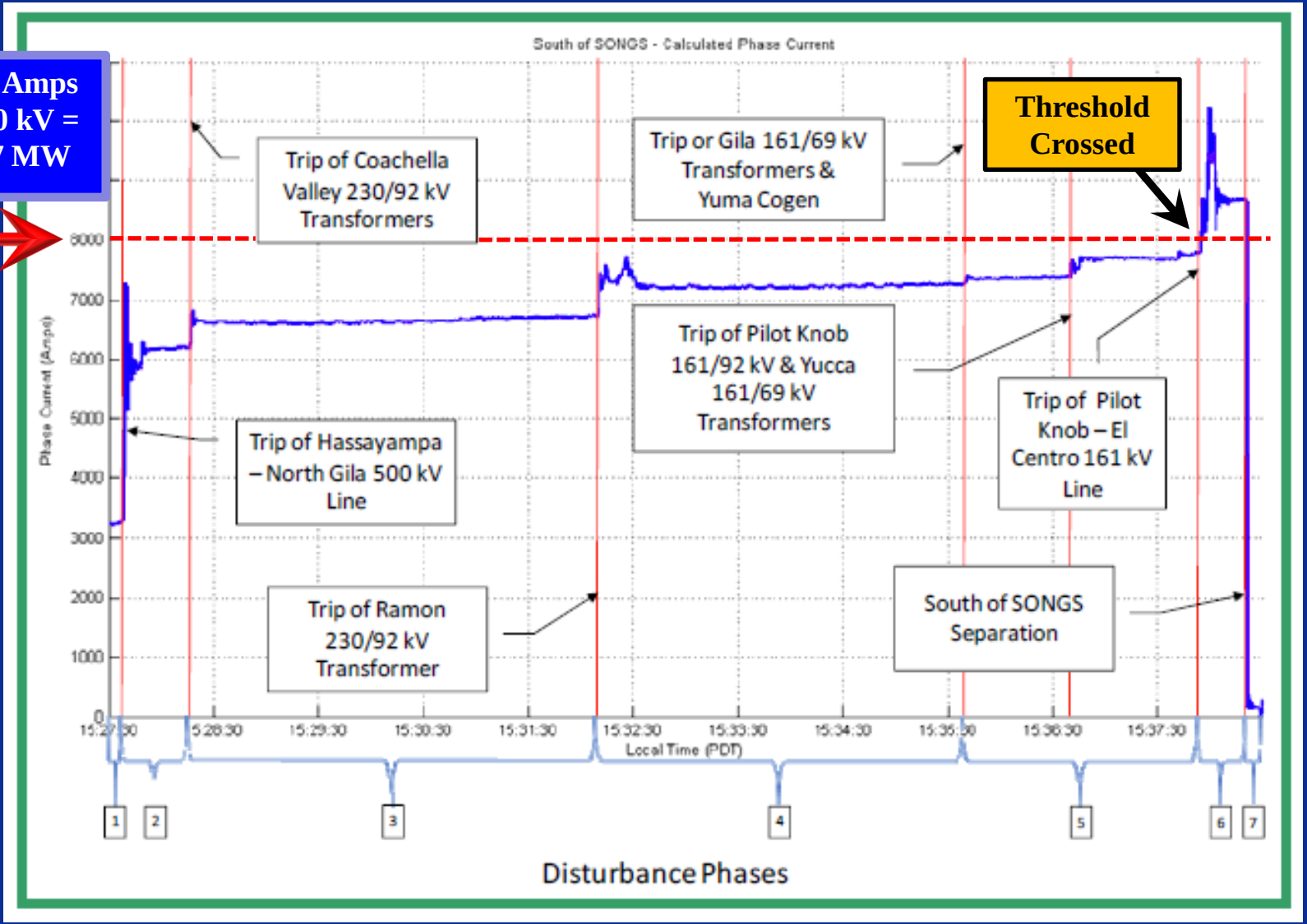
Sequence of Events: Cascading Outages



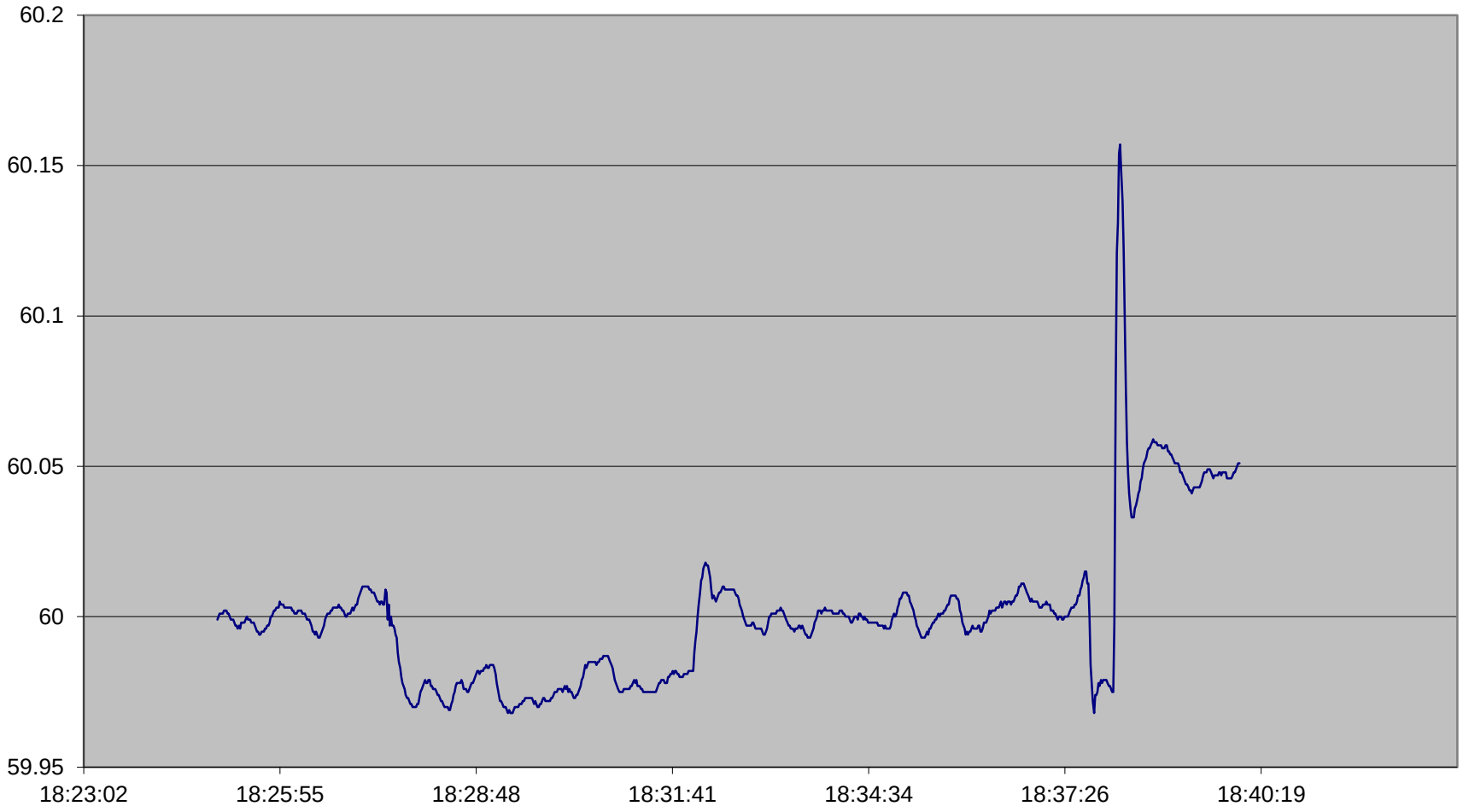
Sequence of Events: Separation & Collapse



Sequence of Events: Path 44 Current

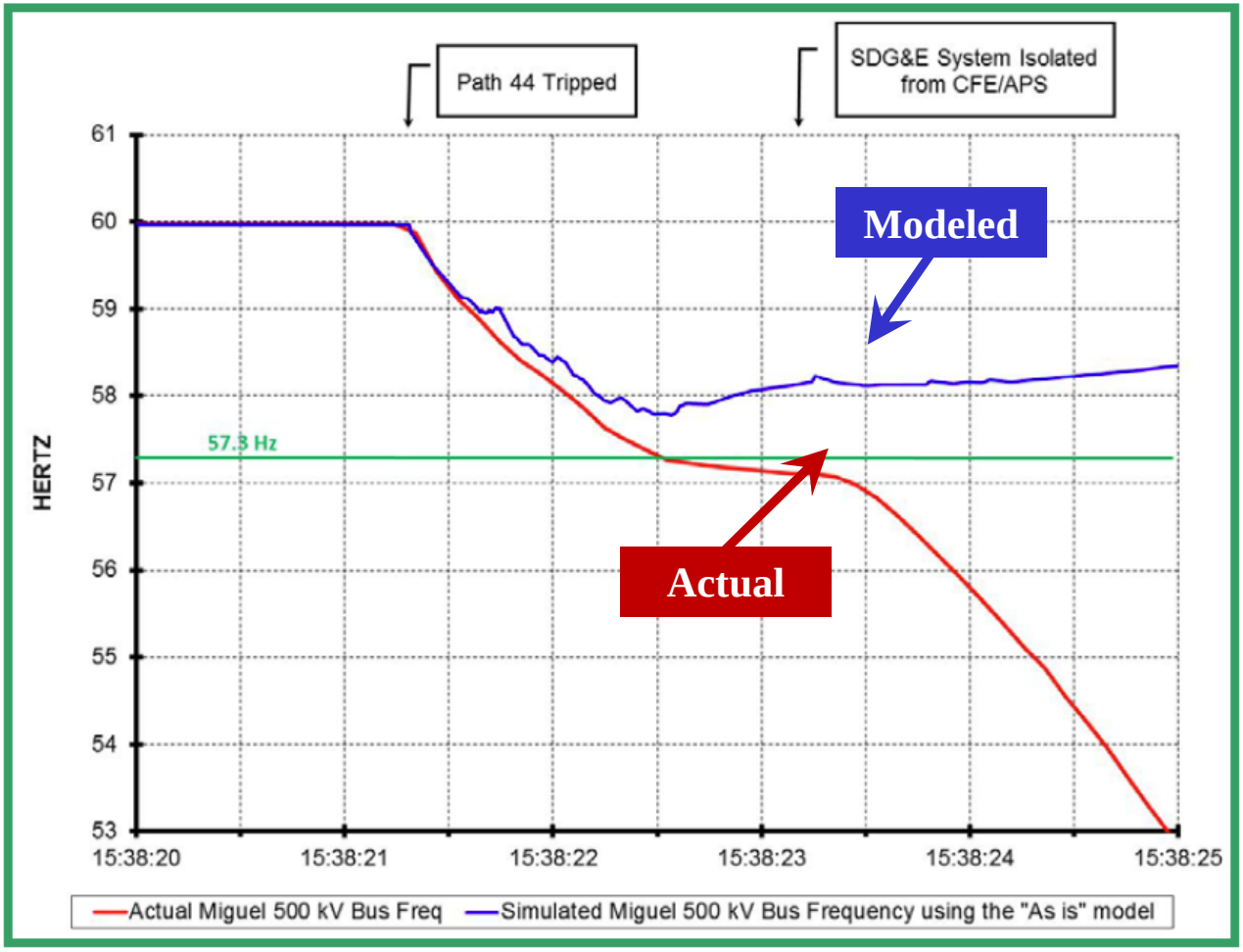


Frequency: One-Second Resolution (WECC)



Frequency: Underfrequency Load Shedding

Figure 14: Actual and Simulated Frequency at Miguel 500 kV Bus



Effects: Key Statistics

- **2.7 million customers interrupted**
  - Population of roughly 6.9 million
  - Land area of roughly 38,000 square miles (size of Indiana)
- **7,890 MW of firm load interrupted**
- **6,981 MW of generation forced off-line**
- **No equipment damage reported**
- **12 hours to restore all load**
  - Load restoration proceeded smoothly
- **87 hours to restore all generation**
  - 39 hours, not counting the San Onofre nuclear facility

Impacts: San Diego

FERC/NERC Findings & Recommendations

Twenty-seven in all. The following were highlighted:

- **Failure to update external networks in next-day study models (# 2)**
- **Lack of real-time external visibility into neighboring systems (# 11)**
- **Impact of sub-100 kV facilities on bulk power system reliability (# 3, 6, & 17)**
- **Failure to recognize Interconnection Reliability Operating Limits – IROLs (# 18)**
  - **WECC claimed that these didn't exist within WECC because, if all entities observed their respective System Operating Limits (SOLs), no contingencies would lead to cascading. The September 8 event disproved this claim.**
- **# 19 – 23: Failure to study and coordinate special protection systems (# 19 – 23)**

Wellinghoff & Cauley News Release

- Overload Protection: Relay settings should not encroach on emergency ratings or, if they do, the emergency ratings should be lowered accordingly.
- Phase Angle Difference: The 500 kV Hassayampa – North Gila line couldn't be restored even though the fault was cleared because the angular separation across its open breaker exceeded the synchronism check setting of 60 degrees.
  - Operators weren't aware of this condition.
  - Tools, such as Phasor Measuring Units (PMUs) can provide the necessary information to Operators.

Questions