APS Experience

U.S. Department of Energy
Workshop
April 22, 2008

Westin, Dallas Fort Worth Airport

Phoenix Metro Area

- 3 Million People
- Served by Arizona Public Service Co. and Salt River Project
- 11000 MW peak summer load
- 3000 MW local generation
- High concentration of air-conditioning load
- Fast growing – 100,000 net population growth in metro area

A/C Load in Phoenix Area

- Summer peak is about 2.5 times the winter peak
- Most of the load increase in summer is due to cooling laod
- Residential air-conditioners contribute substantially to the summer load
- 50,000 new houses, all with air-conditioners added in Phoenix area/year

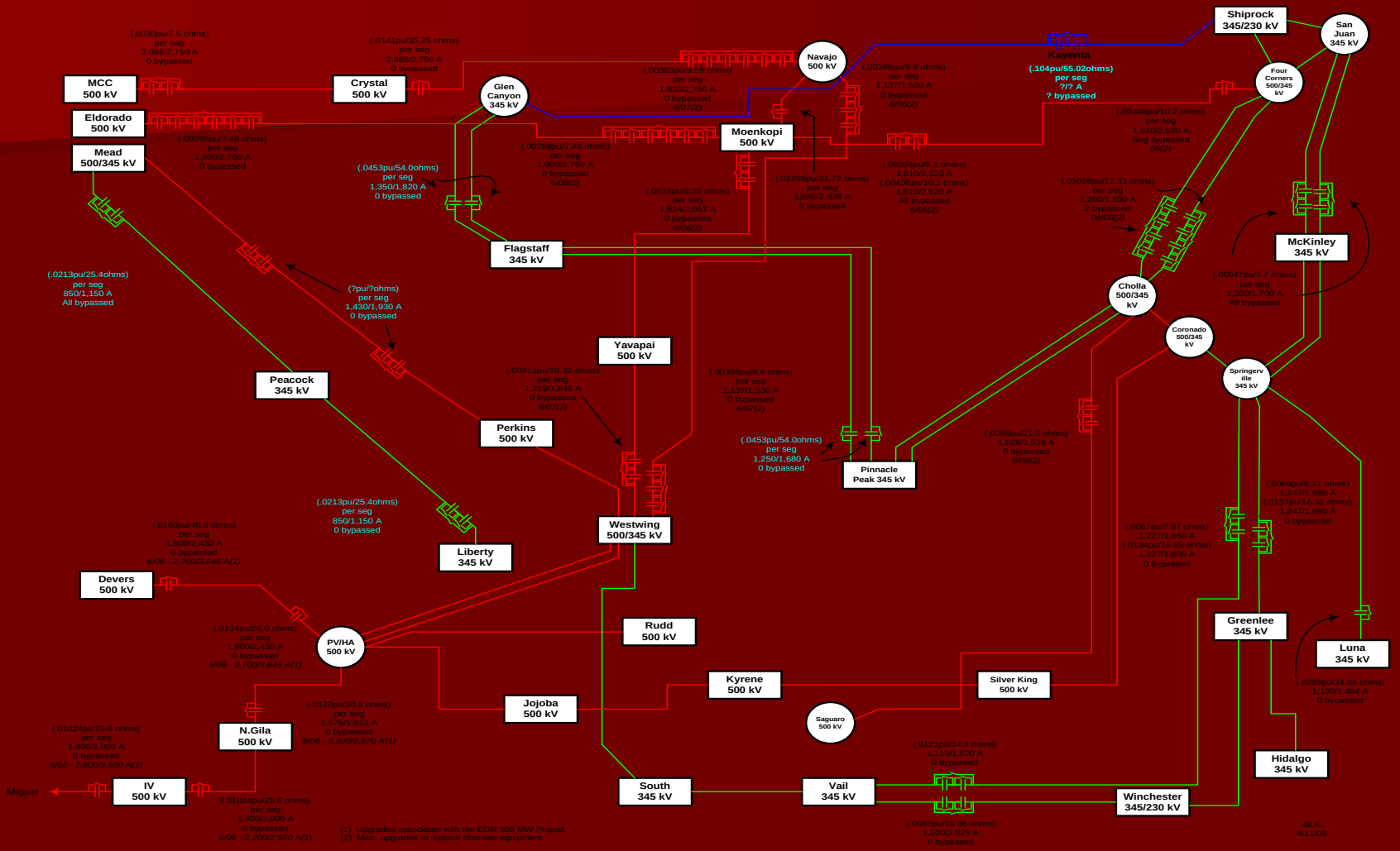
APS Interest

- Residential air-conditioners have a significant impact on electrical system behavior during disturbances
- APS/SRP funded EPRI test program to learn about the residential air-conditioners
- APS has been participating actively in WECC Modeling and Validation Work Group efforts for improving load model

Electric System in Phoenix Metro Area

- Served by 4 Major hubs – Westwing, Pinnacle Peak, Rudd, Kyrene
- 230 kV transmission loop surrounds the valley
- 69 kV subtranmission system
- 12 kV distribution system

Desert Southwest EHV Series Compensation



7-29-1995

Pinnacle Peak Capacitor Fault
Delayed Fault Clearing

Slow Voltage Recovery

Incident 1

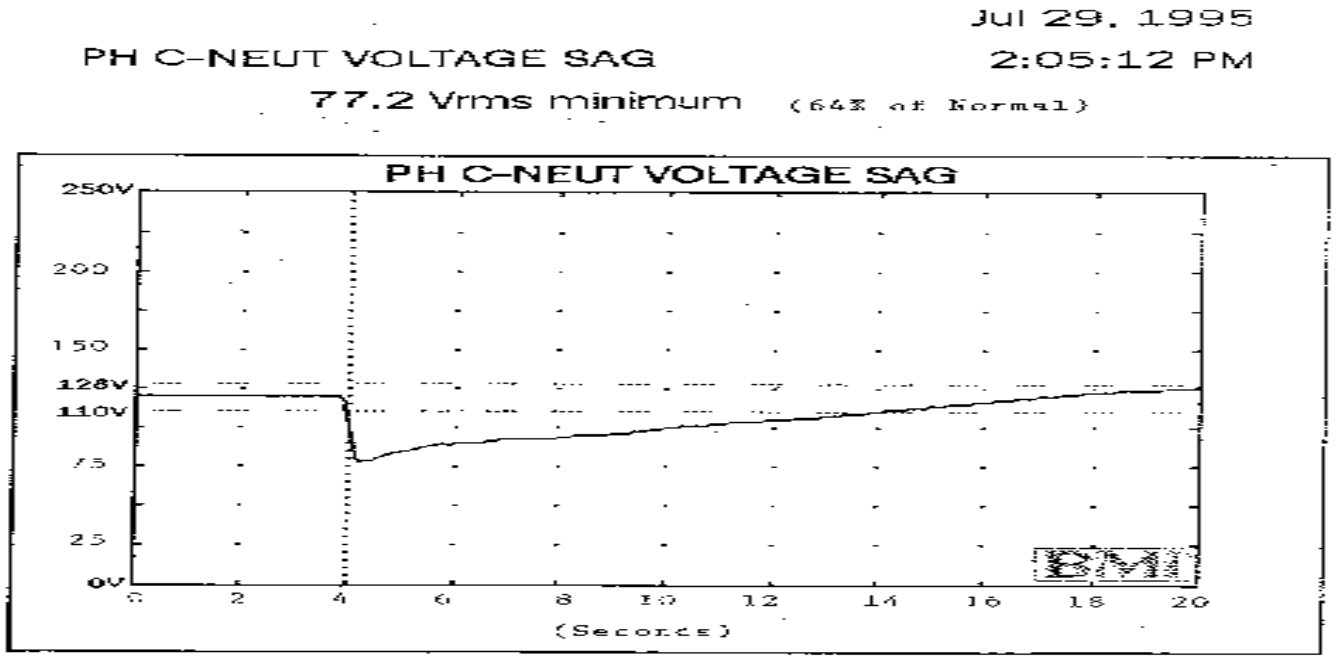
Sequence of Events

- A single-line to ground fault on a cap bank
- Fault clearing delayed from 4 cycles typical to 16 cycles due to CT saturation

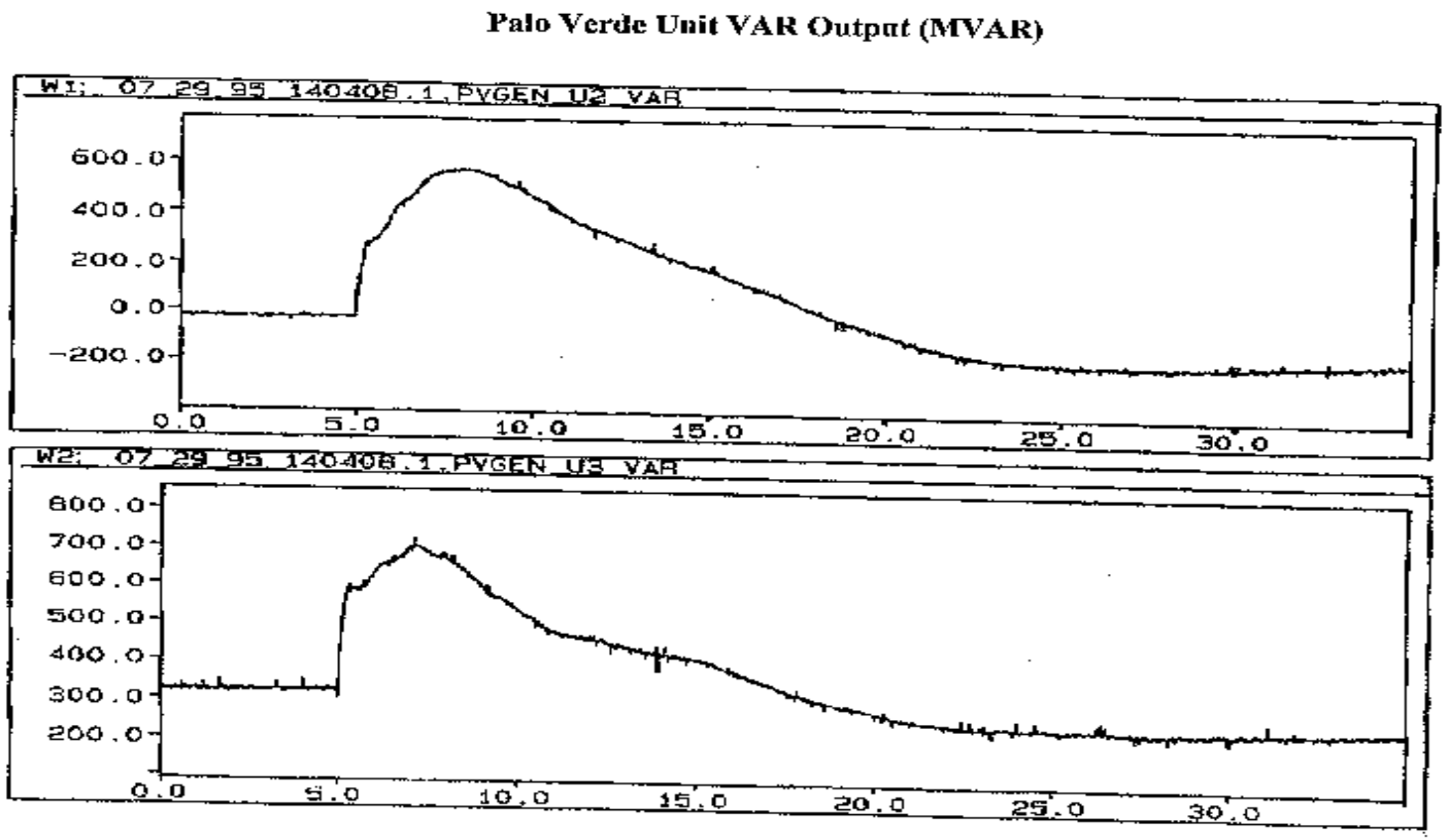
Consequences

- Several lines and transformer tripped
- Sustained low voltages after fault is cleared
- Several SRP feeders tripped on under-voltage
- 10% overshoot in voltage recovery

Voltage at Customer Meter



Palo Verde Generators Provided Significant VAR Support



7-1-03
Pinnacle Peak Capacitor Fault Disturbance

Slow Voltage Recovery

Incident 2

Event Description

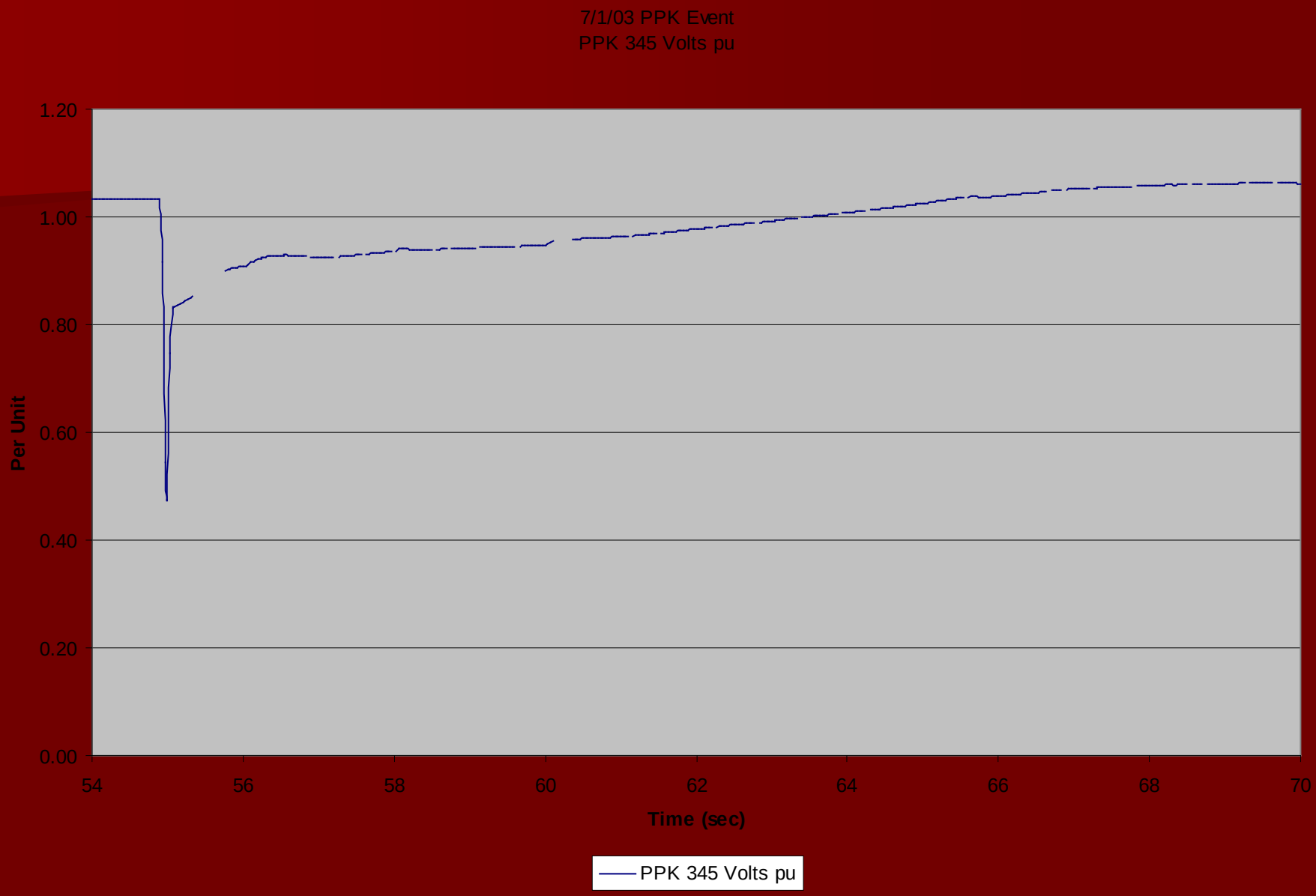
- At Pinnacle Peak substation a 230 kV Capacitor breaker failed catastrophically
- Breaker failure relay operated and cleared the bus section
- 1000 MW of firm load shed
- 48,000 customer were impacted

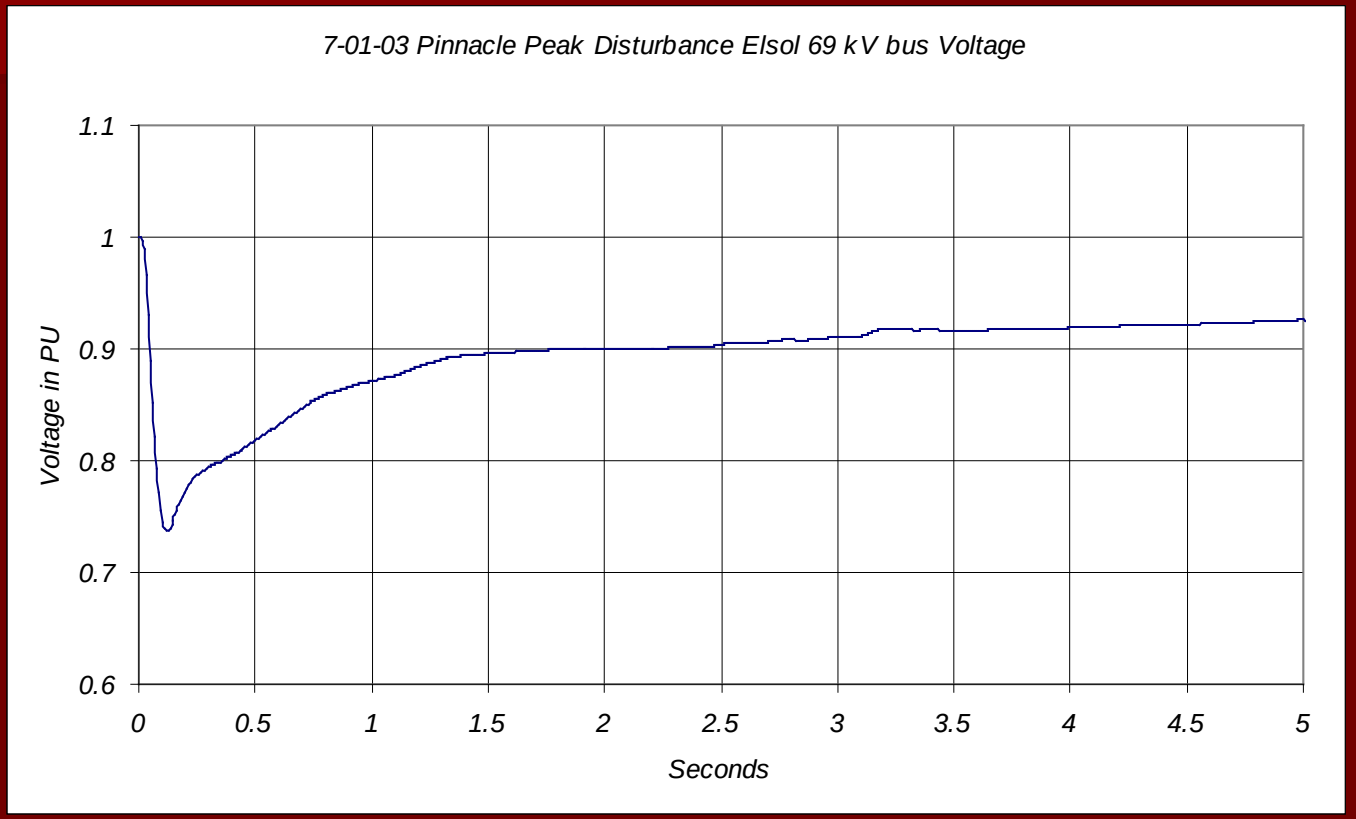
Sequence of Events

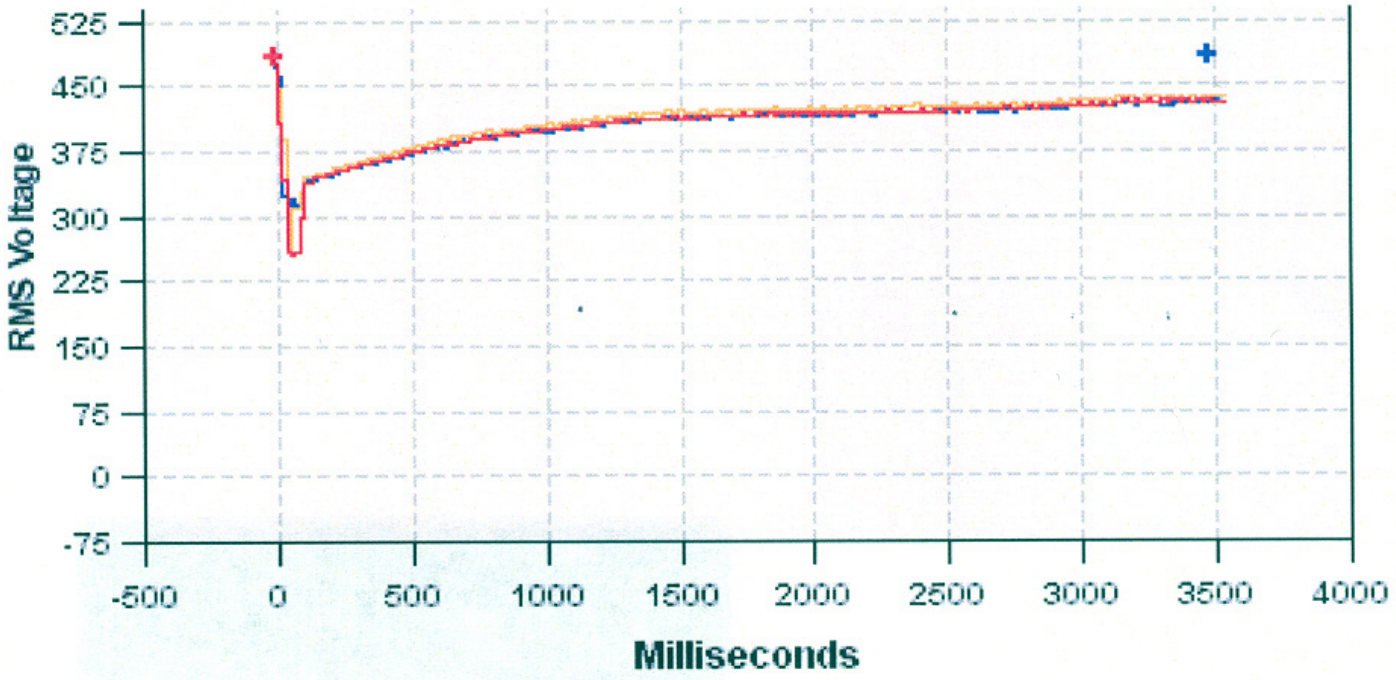
- Complex Fault
- Started as a Single-line-to ground fault but evolved into a 3-ph fault
- T= 3 to 5 Cy Various lines open and isolate the fault
- T=5 Cy Voltage recovery starts
- T=4 S Undervoltage load shedding starts

Voltage Recovery

- Normally 12 kV voltage is slave to the transmission system voltage
- However, due to stalled motors, the 12 kV voltage sags heavily and pulls the transmission voltage lower
- Stalled motors act like short circuits
- MVAR load increases significantly
- Local generators unable to meet the large increase in VAR demand


7/1/03 PPK Event
PPK 345 Volts pu
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Per Unit
54
56
58
60
62
64
66
68
70
Time (sec)
PPK 345 Volts pu


7-01-03 Pinnacle Peak Disturbance Elsol 69 kV bus Voltage
Voltage in PU
1.1
1
0.9
0.8
0.7
0.6
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Seconds


525
450
375
300
225
150
75
0
-75
RMS Voltage
-500
0
500
1000
1500
2000
2500
3000
3500
4000
Milliseconds

Actions Taken

- Ocotillo Capacitors settings changed
- Under-voltage load shedding relays settings changed to trip load faster
- Studies initiated to understand behavior of induction motor load to be able to better understand vulnerability and apply proper mitigation

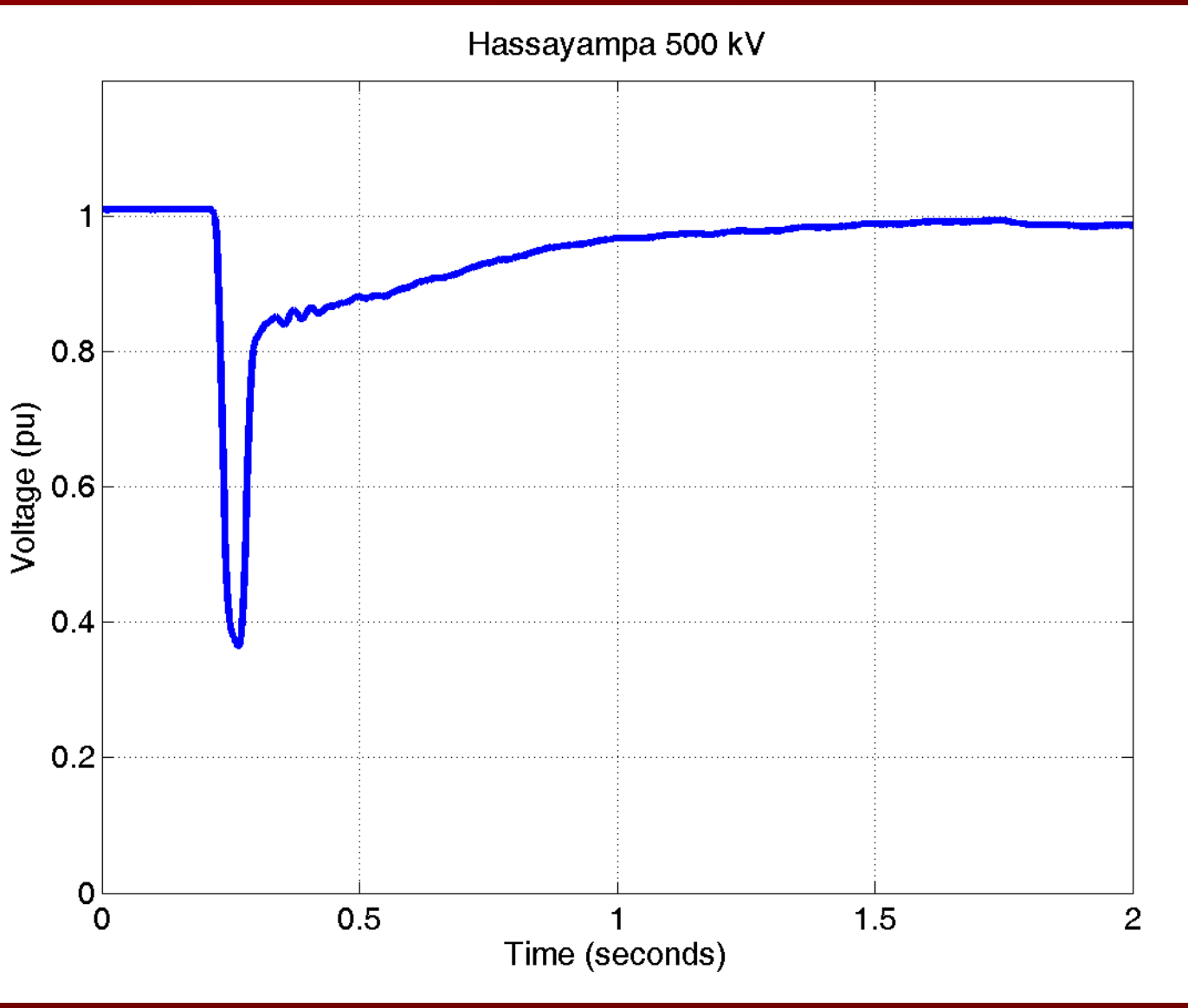
7-28-03, 2003
Hassayampa 500 kV Fault

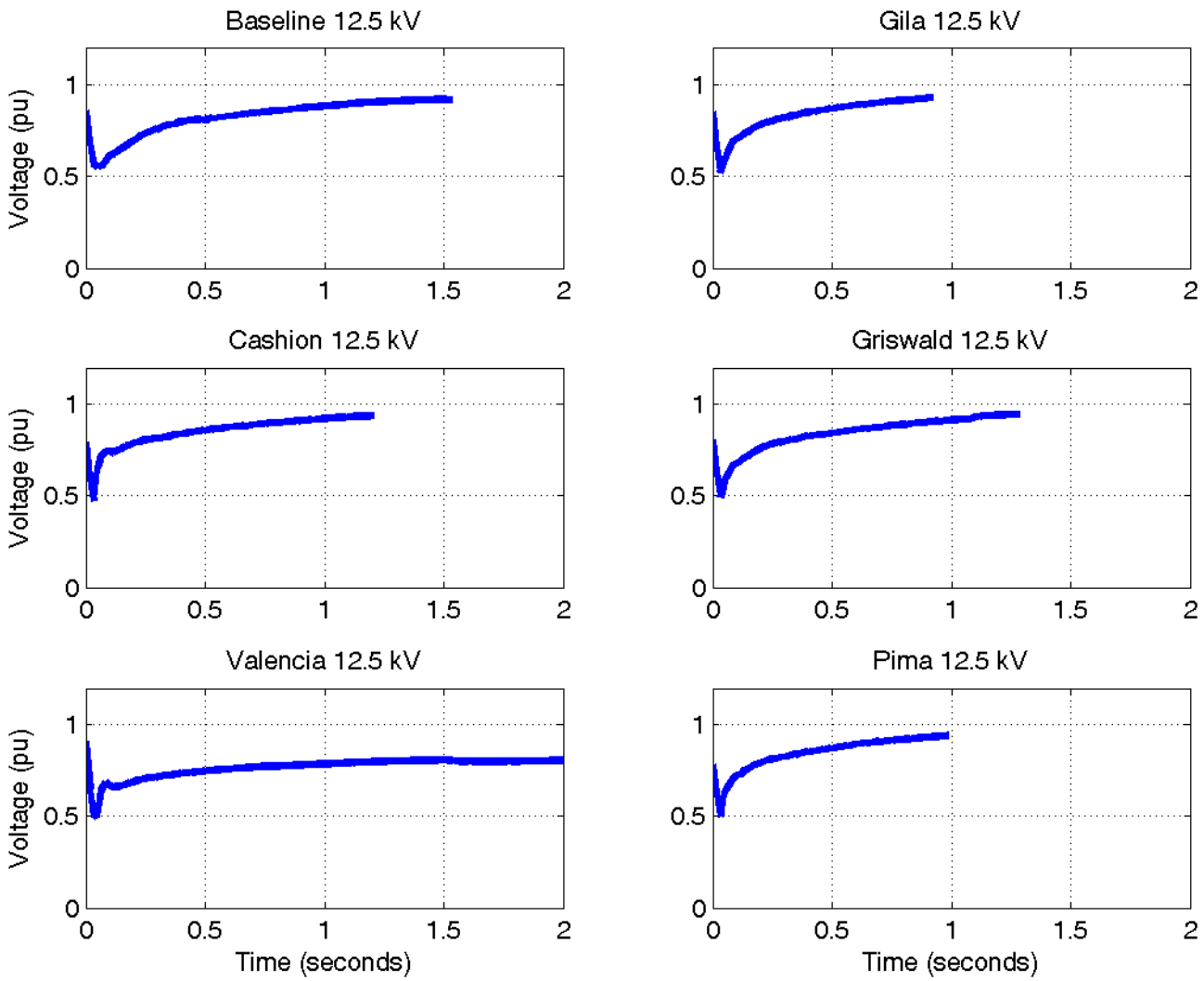
Slow Voltage Recovery

Incident 3

Event Description

- 3-ph fault on Hassayampa 500 kV bus
- Fault cleared in 3 cycles
- 2600 MW of generation tripped
- APS shed 440 MW of load
- 90,000 Customer impacted
- Slow voltage recovery seen in Phoenix area


Hassayampa 500 kV
Voltage (pu)
Time (seconds)
0
0.2
0.4
0.6
0.8
1
0
0.5
1
1.5
2


Baseline 12.5 kV
Gila 12.5 kV
Cashion 12.5 kV
Griswald 12.5 kV
Valencia 12.5 kV
Pima 12.5 kV
Voltage (pu)
Time (seconds)
0
0.5
1
1.5
2

Conclusions

- APS has experienced several slow voltage recovery disturbances
- Residential air-conditioners significantly contribute to the scenario
- APS has installed under-voltage load shedding as an interim safety net
- APS has also added significant new generation in the heart of the city to provide voltage support for the system