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 load
- 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 subtransmission system
- 12 kV distribution system
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

Jul 29, 1995
2:05:12 PM

PH C-NEUT VOLTAGE SAG

77.2 Vrms minimum (64% of Normal)
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
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
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