APS' Protection Philosophy for Lines and Stations

- APS' protection philosophy for lines and stations is to meet or exceed performance requirements of the NERC/WECC Planning Standards.

Lines: 525kV & 345kV

- Three separate strings or relaying schemes, 2-POTT & 1-Current Diff.
  - At least two of the strings have independent communication paths over microwave and/or fiber. The third string will normally share a communication path with one of the "primary" strings. These schemes also incorporate redundant Direct Transfer Tripping (DTT) over independent communication paths.
- One Breaker Failure scheme (two schemes if we are using SEL-421's)
  - The breaker failure relay should be initiated directly from the trip bus of the protection schemes.
- Use of two trip coils

Lines: 525kV & 345kV

- Separate DC sources for each scheme
  - The DC should be wired so that no single DC source breaker trip or failure will disable all of the protection on the line. Our preference is to have two separate DC battery banks. Presently, there is only one battery bank at Navajo and Moenkopi.
- No Automatic Reclosing

Lines: 230kV

- Two separate strings or relay schemes, 2-POTT’s or 1-POTT & 1- Current Diff. or 2-Current Diff.’s
  - Each string will have an independent communication path over microwave or fiber. These schemes also incorporate redundant Direct Transfer Tripping (DTT) over independent communication paths.
- One Breaker Failure scheme (two schemes when available from both line relays)
  - The breaker failure relay should be initiated directly from the trip bus of the protection schemes.

Lines: 230kV

- Use of two trip coils when available
  - We do have breakers with only one trip coil available.
- Separate DC sources for each scheme
  - The DC should be wired so that no single DC source breaker trip or failure will disable all of the protection on the line.
- No Automatic Reclosing

Lines: 69kV

- One string or relay scheme, usually phase step distance and directional ground overcurrent. (when fiber is available, we enable a POTT scheme)
- Breaker Failure is enabled on the microprocessor relays
  - In the older substations with electromechanical relays, we add a breaker failure relay when there are more than two 69kV lines or if the substation is identified as needing it because of the system configuration.
  - The breaker failure relay should be initiated directly from the trip bus of the protection schemes.
- One DC source for each scheme
- No Automatic Reclosing

Stations: 525kV & 345kV

- Two Bus Differential Relay schemes
- One Breaker Column Ground scheme
- One CT Column Ground scheme
- One Breaker Failure scheme on each breaker
  - The breaker failure relay should be initiated directly from the trip bus of the protection schemes.
- Two Leads Differential schemes
- Two Transformer Differential schemes
- Transformer Sudden Fault Pressure relays (1 or 2)

Stations: 525kV & 345kV

- Protection of the cable between the CT Column and Breaker Column
  - We protect this zone using microprocessor relays with separate current inputs. Logic in the relays will be used to determine when a fault exits in this zone and to trip the appropriate backup breakers.

Stations: 230kV

- One Bus Differential Relay scheme.
- One Leads Differential scheme (have sometimes used two when using microprocessor relays)
- One Transformer Differential scheme (may use two when using microprocessor relays)
- One Breaker Failure scheme on each breaker
- Use of two trip coils on each breaker when available.
- Transformer Sudden Fault Pressure relays (1 or 2).

Stations: 230kV

- Use of a backup Phase & Ground Distance, Ground Overcurrent relay
  - This backup relay is set to see faults on both the high and low side of the transformer to provide time delayed backup for faults in the substation and on the lines connected to the 230kV bus.
- Have sometimes used backup Ground Overcurrent relay inside the tertiary delta

Stations: 69/12.47kV

- One Bus Differential Relay scheme for each 69kV bus.
- One Bus Differential Relay scheme for each 12.47kV bus when electromechanical relays are used
- Fast Bus Protection Logic is incorporated on all new 12.47kV buses or when microprocessor relays are used
- One Transformer Differential scheme
- Breaker Failure is enabled on 12.47kV breakers when microprocessor relays are used
- Transformer Sudden Fault Pressure relay

Distribution Feeders: 12.47kV

- Phase and Ground Overcurrent Protection
- Automatic Reclosing
  - One reclosing shot is used on underground feeders.
  - More than one reclosing shot may be used on overhead feeders when necessary
- Breaker Failure
  - Breaker failure is enabled on 12.47kV feeder breakers when microprocessor relays are used
  - No breaker failure is used on 12.47kV feeder breakers on older substations where electromechanical relays are used

Fault Clearing Times:

- At 525kV, 345kV & 230kV, fault clearing times are between 4.0 & 5.0 cycles
- At 69kV, fault clearing times are approximately:
  - 6.0 cycles for Zone 1 and other instantaneous trips
  - 20.0 cycles for Zone 2 trips
  - 60.0 cycles for Zone 3 trips
  - Normally up to 60.0 cycles for directional ground overcurrent time dial trips
- At 12.47kV, fault clearing times are approximately:
  - 6.0 cycles for instantaneous trips.
  - Normally up to 120.0 cycles for phase & ground time dial trips based on the fault magnitude (we are allowed to go up to 180.0 cycles in remote areas of the state).

Under Frequency Load Shedding:

- APS has an Under Frequency Load Shedding Scheme that complies with the WECC guidelines
- The under frequency function is enabled on our microprocessor relays when they are used
- We use a separate under frequency relay that is connected to our 12.47kV busses at substations where we still have electromechanical relays

Under Frequency Analysis:

• Total APS 2009 Projected Coincident MW Load	7266.00	
• Total APS MW Load that can be tripped by U/F	6655.01	
• MW tripped @ 59.5 Hz with 60 seconds delay	145.3	2.0%
• MW tripped @ 59.5 Hz with 30 seconds delay	123.4	1.7%
• MW tripped @ 59.3 Hz with 15 seconds delay	167.5	2.3%
• MW tripped @ 59.5 Hz with 0.1 seconds delay	351.9	4.8%
• MW tripped @ 59.1 Hz with 0.1 seconds delay	31.0	0.4%
• MW tripped @ 58.9 Hz with 0.1 seconds delay	429.3	5.9%
• MW tripped @ 58.7 Hz with 0.1 seconds delay	470.8	6.5%
• MW tripped @ 58.5 Hz with 0.1 seconds delay	487.1	6.7%
• MW tripped @ 58.3 Hz with 0.1 seconds delay	486.7	6.7%
• MW tripped @ 57.9 Hz with 0.1 seconds delay	937.2	12.9%
• Total tripped MW load (of 2009 projected coincident MW load)	3630.3	50.0%

Under Voltage Load Shedding:

- APS has an Under Voltage Load Shedding Scheme that complies with the WECC guidelines
- The under voltage function is enabled on all feeders that have microprocessor relays

Under Voltage Analysis:

- Total APS 2009 Projected Coincident MW Load 7266.00
- Total APS MW Load that can be tripped by U/V 6655.01
- Total Metro Area MW Load that can be tripped U/V relays 5392.57
- Total State Area MW Load that can be tripped U/V relays 1262.43

	METRO AREA		STATE AREA	
MW tripped @ 0.5 PU (60 volts) @ 2 seconds	372.75	6.9%	51.54	4.1%
MW tripped @ 0.7 PU (84 volts) @ 4 seconds	344.18	6.4%	36.84	2.9%
MW tripped @ 0.8 PU (96 volts) @ 6 seconds	370.91	6.9%	36.37	2.9%
MW tripped @ 0.9 PU (108 volts) @ 2 seconds	326.33	6.1%		
MW tripped @ 0.9 PU (108 volts) @ 10 seconds	340.02	6.3%	24.17	1.9%
Total tripped MW load	1754.2	32.5%	148.9	11.8%

Transmission Metering

- APS uses redundant substation meters and redundant RTU’s to meter transmission lines and to send the billing quality metering data to our EMS.
- There is also telemetering data on the transmission lines that is sent back to EMS which is used to operate the system.
  - The present standard is to use the microprocessor relays to send the telemetering data to EMS through the main RTU.
  - Some of the older substations may use transducers to send the telemetering data to EMS through the main RTU.