Arizona Public Service Company and the Transmission Partnership for National Electric Power Company of Jordan

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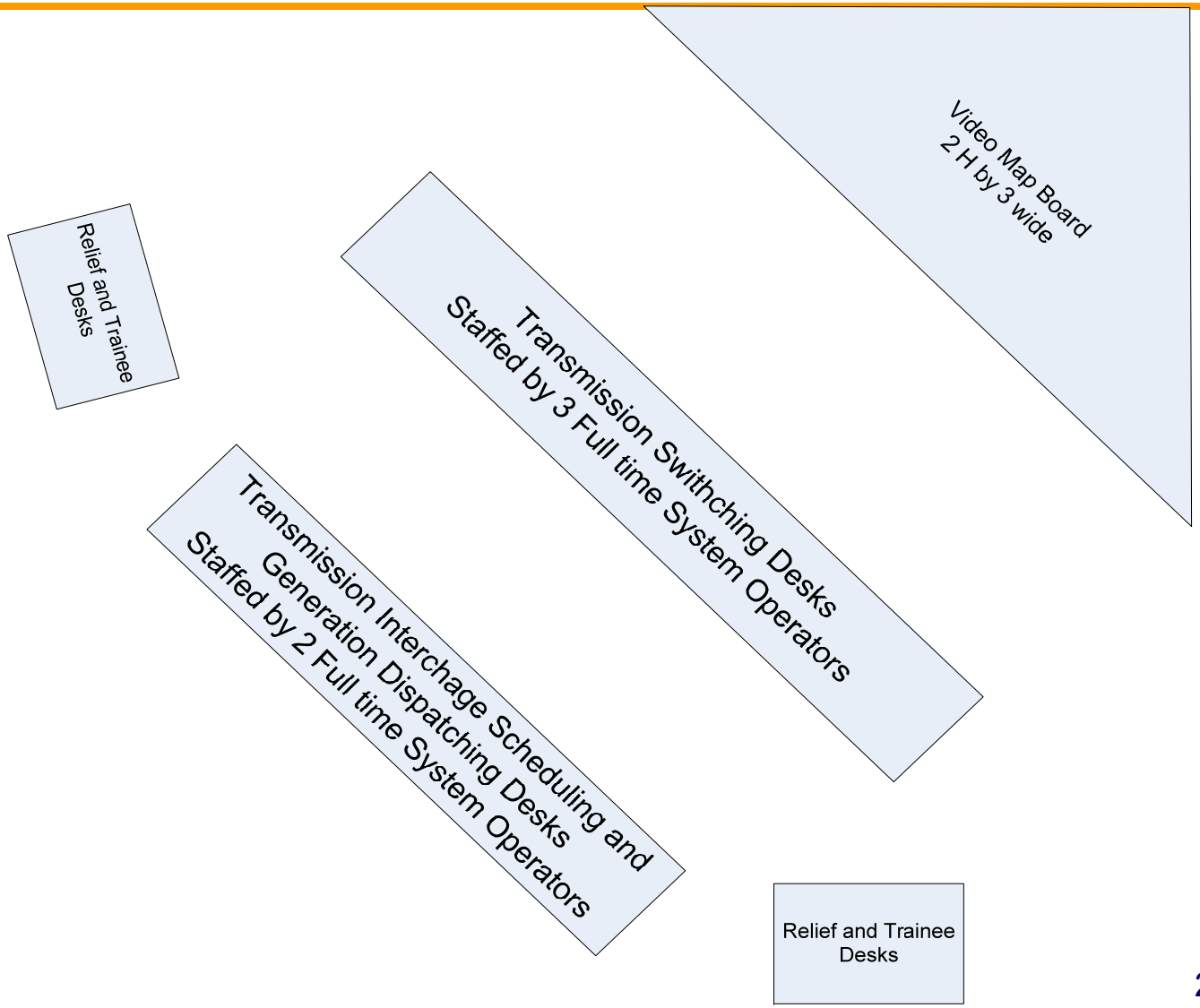
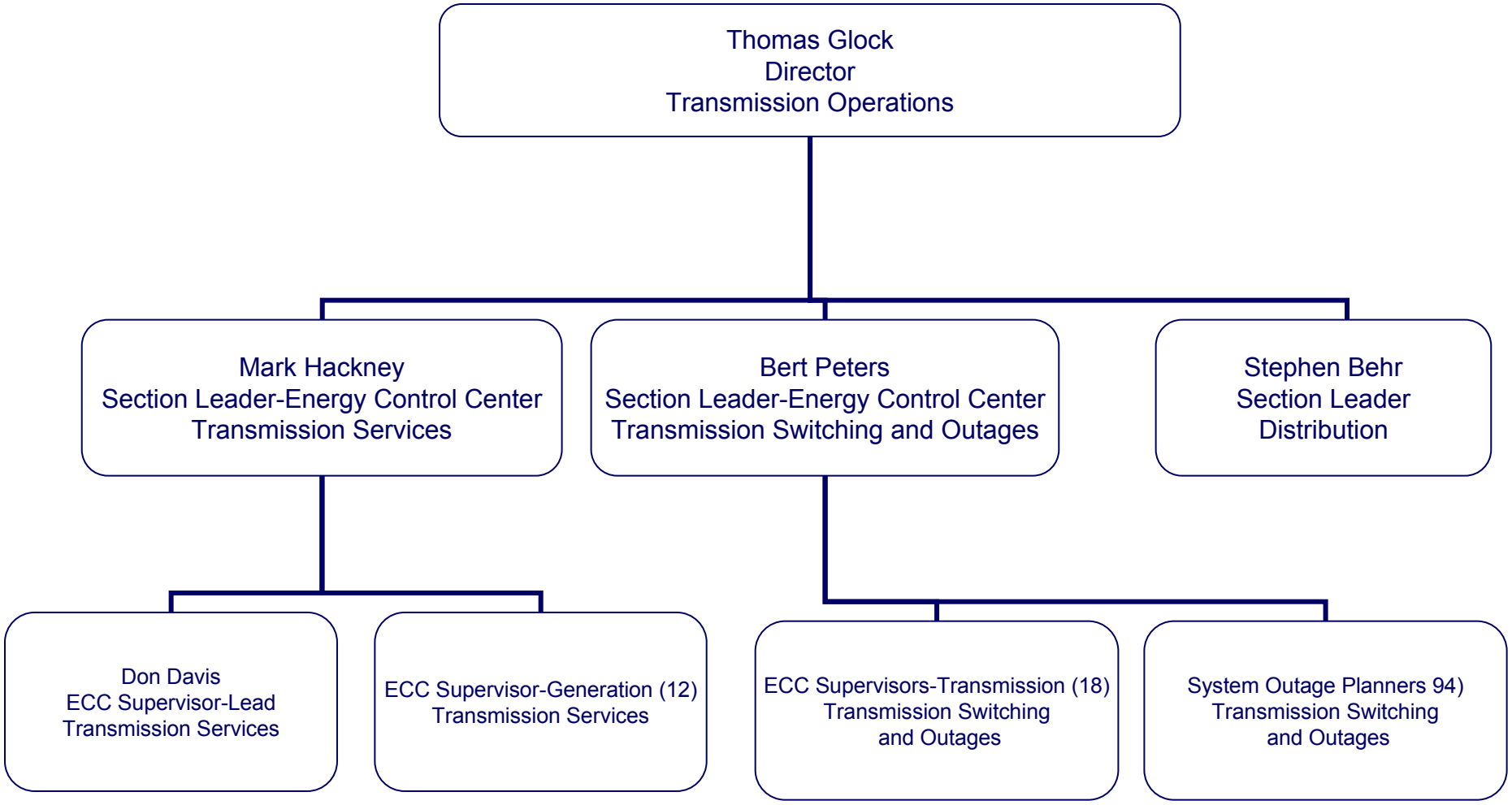
Energy Control Center Layout



Energy Control Center Organization Structure



Relationship/Interaction

- Short term system planning (operations planning) and the Real-time control room operations
  - Ops planning supports out of base case scenarios
    - Fire within right of way of transmission lines
    - Losses of multiple sub transmission (69 kV) facilities
    - Loss of series capacitors/line reactors
    - Loading nomograms for load pocket and parallel lines
    - Coordination with System Outage Planners
    - On call to the Operators 24x7

Training Requirements

- Requirement for System Operators
  - North American Electric Reliability Council (NERC) Certified
    - Understanding and Comprehension of standards via online testing with score of 75% or better
    - Various Certification exams
      - Reliability Coordinator
      - Transmission Operators
      - Balancing and Interchange Operator
      - Transmission, Balancing and Interchange

NERC Certification Overview

- **The NERC System Operator Certification Program is a 3-year certification program. Initial certification is obtained by passing one of four examinations: Balancing, Transmission, Combined Balancing and Transmission, and Reliability. These examinations are based on content outlines derived from job analyses conducted every three to five years.**

NERC Certification Overview

- **The Reliability examination is designed for system operators working in Reliability Coordinator control centers. The specifications for this examination are such that 75% of the questions are on subjects related to the operation of generation equipment, scheduled interchange, and the operation of transmission equipment; 25% are on subjects related to the reliability of the Interconnection.**

NERC Certification Overview

- **The Transmission examination is designed for those system operators working in control centers from which transmission is controlled. The specifications for this examination are such that 75% of the questions are on subjects related to the operation of transmission equipment and 25% are on subjects related to the operation of generation equipment and scheduled interchange.**

NERC Certification Overview

- **The Balancing examination is designed for those system operators working in control centers from which generation is controlled. The specifications for this examination are such that 75% of the questions are on subjects related to the operation of generation equipment and scheduled interchange and 25% are on subjects related to the operation of transmission equipment.**

NERC Certification Overview

- **The Combined Balancing and Transmission examination is designed for system operators working in control centers from which both generation and transmission are controlled. The specifications for this examination are such that 50% of the questions are on subjects related to the operation of generation equipment and scheduled interchange and 50% are on subjects related to the operation of transmission equipment.**

NERC Certification Overview

- After initial certification is obtained, the credential is maintained only through earning of Continuing Education Hours. Continuing Education (CE) Hours are earned by participating in NERC Approved Learning Activities. However, those system operators whose certificates expire before October 1, 2009 have the option of re-certifying by passing an examination again.

Program Mission

- **Produce and maintain adequately trained, well-qualified, competent personnel to operate system components in a safe and reliable manner.**

Program Objectives

- **Ensure that operators are adequately instructed on:**
  - **Electrical concepts**
  - **Power operation theory**
  - **Accident prevention and safety**
  - **Our electrical interconnection**
  - **Standards and regulations**
  - **Policies and procedures**

Operations Personnel Participating in Training Program

- Certified
  - Transmission Operators
    - Duties
  - Balance and Interchange Operators
    - Duties
- Uncertified
  - Distribution Operation Specialists
    - Duties
  - Distribution Dispatchers
    - Duties

NERC Standards

- PER-001
- PER-002
- PER-003
- PER-004

Initial Training

- Curriculum designed via the Systematic Approach to Training (SAT)
  - Analyze job/task
  - Design syllabus
  - Develop training
  - Implement
  - Evaluate for effectiveness/revise as needed
- Some classroom, some on-the-job training

Continuing Training

- Designed to maintain and enhance the initial training
- Topics are selected based on:
  - Regulatory requirements
  - Job performance trends
  - Industry issues/lessons learned
  - New equipment or procedures
- NERC-required 200 Continuing Education Hours every 3 years
  - 30 of the 200 must pertain to NERC standards
  - 30 of the 200 must involve simulations
  - Each year operators must receive 32 hours of emergency operations training

Instructional Staff

- Subject matter experts
- Experienced vendors
- Engineers
- Operators
- Technical Trainers
- Supervision

Transmission Operator Training

- Typical enrollee
  - Generation operator
  - Protective relay technician
  - Electrician
- Training
  - Distribution operations
  - Sub-transmission operations
  - Transmission operations and Certification
- Approximately two years to complete

Balance and Interchange Operator Training

- Typical enrollee
  - Generation operator
  - Controls technician
  - Engineer
- Training
  - Theory and applications
  - Certification training
  - On the Job Training
- Approximately one year to complete

Distribution Operation Specialist

- Typical enrollee
  - Distribution dispatcher
- Training (draft)
  - Theory and application
  - Field installations and work processes
  - Department policies and procedures
  - On the Job Training
- Approximately two years to complete

Distribution Dispatcher

- Typical enrollee
  - Meter reader or non-skilled trades
  - New hire
- Training
  - Electrical theory and application
  - Computer applications
  - Field equipment and work processes
  - Clearances
  - Department policies and procedures
  - Switching and Loading
  - Off-normal operations
  - On the Job Training
- Approximately two years to complete

Simulations and Simulators

- Table top “what-if?” drills with documentation
  - e.g. Protective relay applications
- EPRI Power Simulator
  - e.g. Decision making
- Spectrum Operator Training Simulator (OTS)
  - e.g. Load shedding

APS Training Department

- NERC Approved Training Provider
- Transmission Operator program approved by US Veterans' Affairs for GI Bill benefits
- Currently nine Transmission Operators in various stages of program completion

Emergency Transmission Restoration Procedure

- Emergency Operations
  - Load and Generator Imbalance
    - Assistance from interconnected systems
    - Emergency start of nat gas and/or oil turbines
  - Restoration Practices
    - Training on the Operator Training Simulator
      - Load Shed and Restoration practice
  - Emergency Standards – NERC Emergency Operation Planning
    - Backup Center Activation – Practical testing once year
    - Emergency plans with neighboring system

Emergency Transmission Restoration Procedure (continued)

- Emergency Operations
  - Emergency Standards – NERC Emergency Operation Planning
    - Emergency Assistance (energy) from any provider
    - System Restoration Coordination (more than one system was affected)
    - Black Start plans and units

Use of Relays and Other Equipment

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

APS' Protection Philosophy for Lines and Stations

- **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**
  - **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**

APS' Protection Philosophy for Lines and Stations

- 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.
  - 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

APS' Protection Philosophy for Lines and Stations

- **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**

APS' Protection Philosophy for Lines and Stations

- 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)
  - 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.

APS' Protection Philosophy for Lines and Stations

- **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).**
  - **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.**

APS' Protection Philosophy for Lines and Stations

- **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**

APS' Protection Philosophy for Lines and Stations

- 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.

APS' Protection Philosophy for Lines and Stations

- 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 distance 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).

APS' Protection Philosophy for Lines and Stations

- **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	3630.3	50.0% (of 2009 projected coincident MW load)

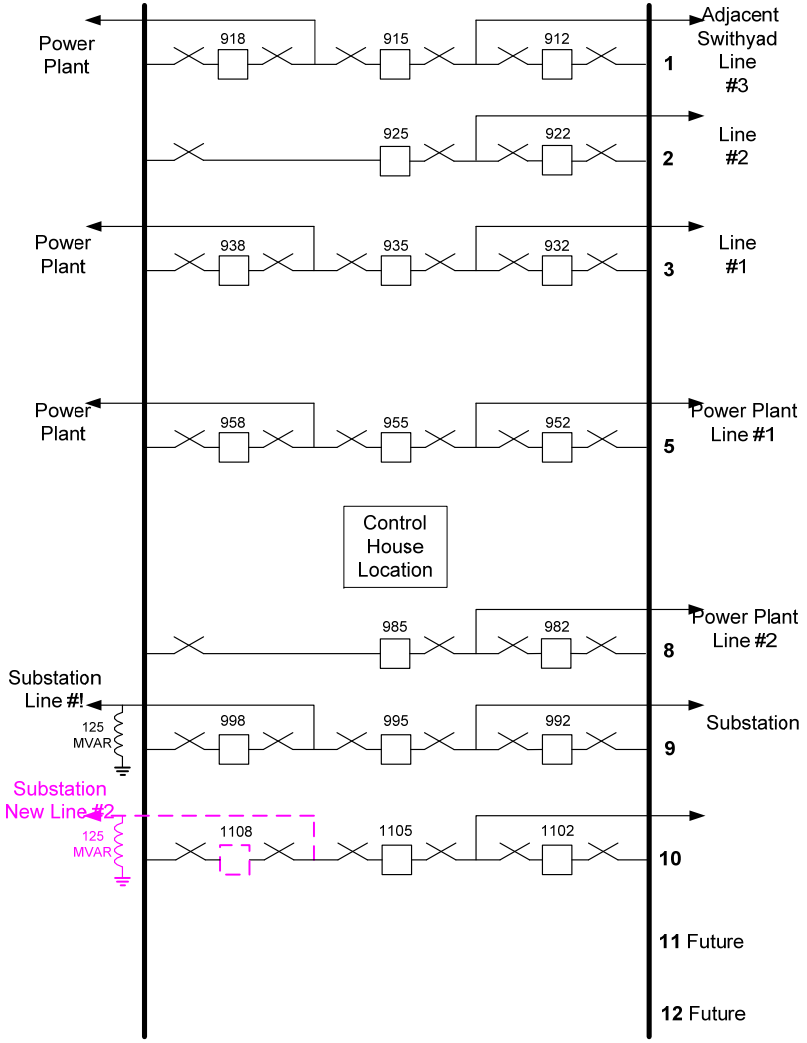
APS' Protection Philosophy for Lines and Stations

- **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:**

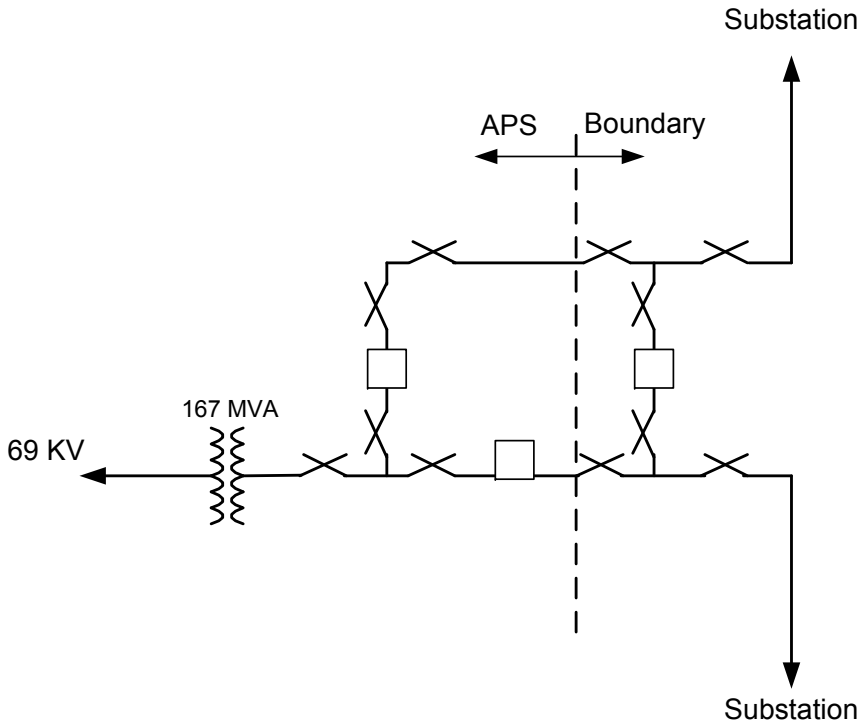
Total APS 2009 Projected Coincident MW Load	7266.00
Total APS MW Load that can be tripped by U/V	6655.01
Total Metro Area MW Load that can be tripped U/V relays	5392.57
Total State Area MW Load that can be tripped U/V relays	1262.43

	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%

Typical Breaker and one-half Station



Typical Ring Bus Station



Typical Main and Transfer Station