Dynamic Voltage Support with the Rector SVC in California’s San Joaquin Valley

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Transmission System in Big Creek Corridor

- Approximately 15-20 miles of new 230 kV line looping into Rector Substation into Springville-Big Creek No. 3, 230 kV line to be installed in 2009
- Project Location
System Assessment

- **Corridor Limitations**
  - Age related reliability issues
  - Large number of splices in transmission conductors are failing
  - Absence of transmission towers mean imbalanced loading between phases
  - Transmission losses during peak utilization
  - Bi-directional power flows in system designed for delivery of hydro power to southern area

- **Transient Voltage Stability Limitations**
  - Outage of either line between Rector and Big Creek causes low transient voltage at Rector under heavy load conditions
  - Low transient voltage due to a high percentage of induction motor load served by Rector
  - Without mitigation the low-voltage condition may violate WECC transient voltage dip reliability requirements

**Solution**

- 200 Mvar SVC for dynamic voltage support and coordinated voltage control
- Loop the Big Creek-Springville 230 kV line through Rector substation

Requirements for Voltage Control

- Limit the transient voltage dips during major system disturbances
- Regulate the 230 kV steady-state voltage at Rector while preserving sufficient SVC dynamic range
- Control a local 230 kV, 79 Mvar capacitor bank
- Coordinate the 230 kV Big Creek Generating Station operating voltage with the SVC’s control
Rector SVC Rating and Design

- **Rating**
  - -120/+200 Mvar continuous at 230 kV
  - Loss of one TCR branch does not reduce the SVC inductive Mvar output by more than 50% (i.e. -60 MVar)
  - Largest TSC branch shall not result in a voltage rise (at Rector 230 kV) greater than 2.0% under minimum fault duty
  - Availability: 98.5% forced outage

- **TCR/TSC/FC Based Design**
  - Direct LTT-based TCR/TSC valves
  - 3rd, 5th, 7th harmonic filters
  - Auto-reconfigurable degraded mode

- **Application**
  - Dynamic voltage/var control

- **Coordinated Control**
  - Local 79 Mvar, 230 kV shunt capacitor
  - 230 kV Big Creek Generating Station operating voltage

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Rector SVC Design
Coordinated Voltage/Var Control Scheme

- The SVC’s primary function is to control the dynamic voltage change at the Rector 230 kV bus (REC-AVR).
- The SVC steady-state control:
  - Operates the steady-state reactive power output (SVC-AQR),
  - Provides supplementary regulation of the 230 kV Big Creek #3 bus voltage via phasor measurement unit (PMU) (BC-AVR), and
  - Controls a 79 MVAR, 230 kV shunt capacitor in the Rector substation (SC-Control).
V-Q Characteristics of the Rector SVC Coordinated Control

Since three different control loops (REC-AVR, SVC-AQR, and BC-AVR) function together in the steady-state coordinated control, the steady-state SVC output should be controlled based on the V-Q characteristics, in the following order of priority:

1) Maintain Big Creek #3’s 230 kV bus voltage within its upper (VH2) and lower (VL2) limits (BC-AVR) and SVC steady-state output within QCmax and QLmax (SVC-AQR)
2) Maintain Rector 230 kV bus voltage within its upper (VH1) and lower (VL1) limits with Priority #1 maintained (REC-AVR)
3) If Big Creek #3 230 kV bus voltage goes lower than VL2, the SVC should control it within VL2 while maintaining the first two priorities

Conclusion

- The Rector SVC was successfully designed, installed, tested, and commissioned in approximately 14 months with an in-service date of June 2007.
- The application of the Rector SVC and steady-state coordinated controls provide improved short-term voltage stability and dynamic voltage support in the Big Creek Corridor.
Rector and Big Creek Voltage Profile with the SVC Out-of-Service

Rector and Big Creek Voltage Profile with the SVC In-Service
Impact of SVC on Capacitor Switching

08/15/07 Event at 19:06 Pacific Time
(08/16/07 at 02:06 GMT)

- Vincent 230 kV
- Antelope 220 kV
- Rector 230 kV N Bus
- Big Creek
- Rector 79 Mvar Capacitor bank switches off
- SVC is in-service

Rector Example:
6-14-07 (pre-SVC) vs. 8-30-07 (post-SVC)

- Rector 6-14-2007
  - 66-kV fault triggered (breaker internal fault)
  - 150 MW load reduction (125 MW w/no apparent CB operation)
  - Disturbance isolated to Rector radial subtransmission system

- Rector 8-30-2007
  - 66-kV fault triggered (lightning)
  - 120 MW load reduction (w/no apparent CB operation)
  - Disturbance isolated to Rector radial subtransmission system
  - Rector SVC (+200/-120 MVAR) was in service and operated as designed during the Rector system disturbance:
    - Reached full boost (+200 MVAR) during low voltage event
    - Reached full buck (-120 MVAR) during post-event overvoltage
**Impact of the Rector SVC: 6-14-07 (pre-SVC) vs. 8-30-07 (post-SVC)**

**Magunden Substation Voltage Comparison**
(Rector Substation Events 6-14-07 and 8-30-07)

**NOTE:** Voltages shown were measured ~70 miles south of Rector Substation (actual low voltage event was of greater magnitude at Rector substation itself)

The Rector SVC had the apparent effect of reducing the magnitude & duration of the fault-induced slow voltage recovery.

**August 30, 2007 AC Stall Event: Rector Voltage**

The PMU at Rector was installed as part of the SVC installation. Therefore, events prior to the installation do not have the Rector voltage available.
Voltage Calibration Need

![Voltage Calibration Diagram]

Questions?
Transmission System Conditions

- Transmission Line Voltage:
  - 230 kV, (0.96 PU to 1.04 PU)

- Short Circuit MVA:
  - Maximum = 3,625
  - Minimum = 2,151

- Allowed Max. Switching Step
  - 2% (0.02 x 2,151 = 43 Mvar max.)

- Ambient Conditions:
  - Elevation: 350 Feet
  - Maximum Temperature: 50 Degrees C (45 Deg. 24 hr. Avg.)
  - Minimum Temperature: -20 Degrees C
Rector SVC Site

Yard Area
255 ft x 200 ft
(Excluding Building)