Power Electronics/FACTS Installations to Improve Power System Dynamic Performance

Panel Session Presentation on

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

Presented by

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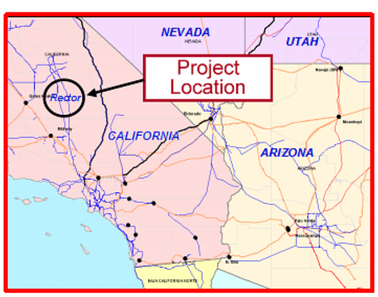
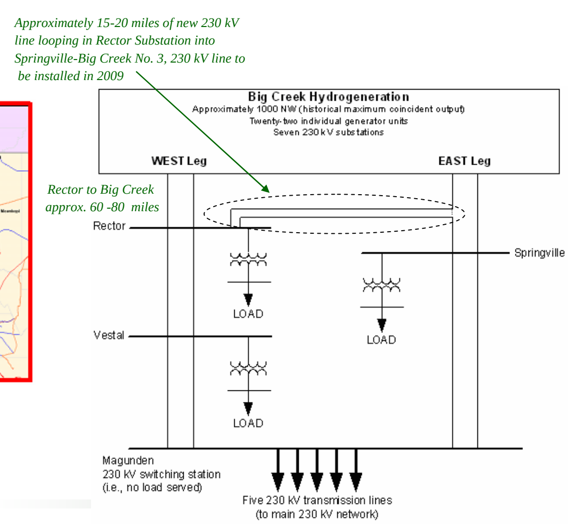
April 23, 2008

2008 IEEE/PES Transmission and Distribution Conference & Exposition

Chicago, Illinois

Transmission System in Big Creek Corridor





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

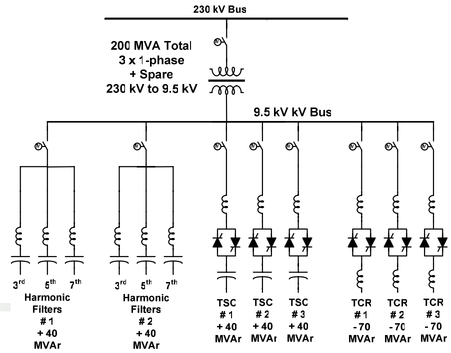
- ***200 Mvar SVC for dynamic voltage support and coordinated voltage control***
  - ***Loop the Big Creek-Springville 230 kV line through Rector substation***

Requirements for Voltage Control

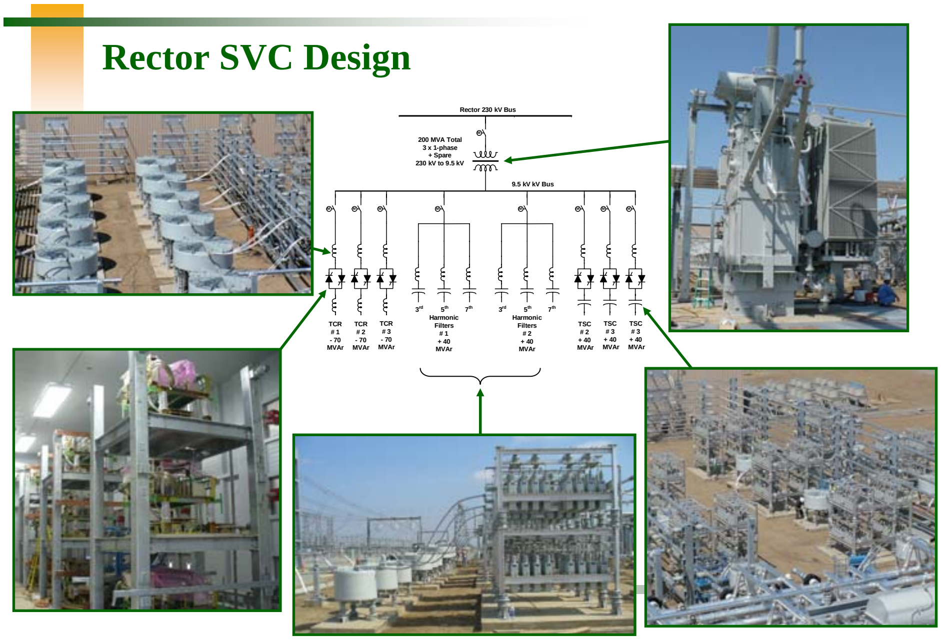
- Limit the transient voltage dips during major system disturbances
- Regulate the 230 kV steady-state voltage at Rector while preserving sufficient SVC dynamic range
- Control a local 230 kV, 79 Mvar capacitor bank
- Coordinate the 230 kV Big Creek Generating Station operating voltage with the SVC's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

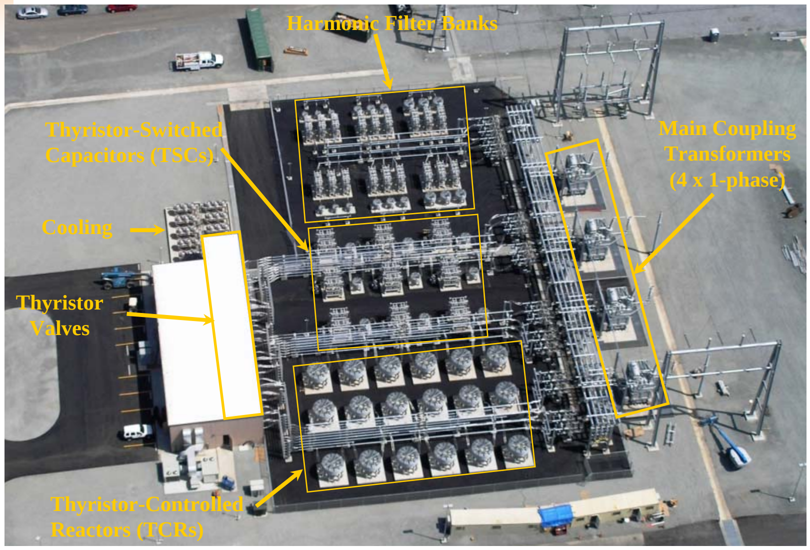


Rector SVC Design



Rector SVC Site

Yard Area - 255 ft x 200 ft
(Excluding Building)

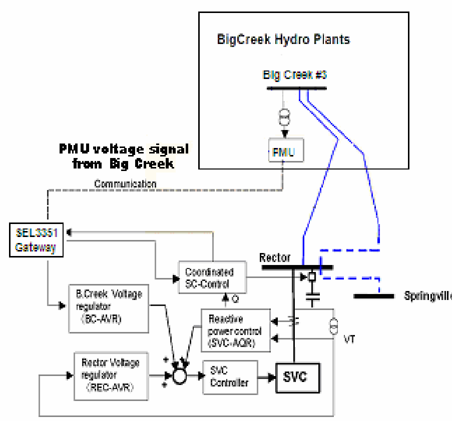


Rector SVC Site

Rector SVC Site

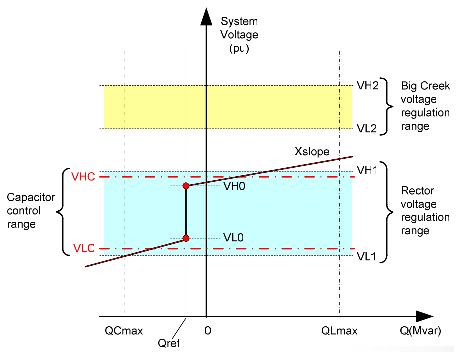
Coordinated Voltage/Var Control Scheme

- 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:

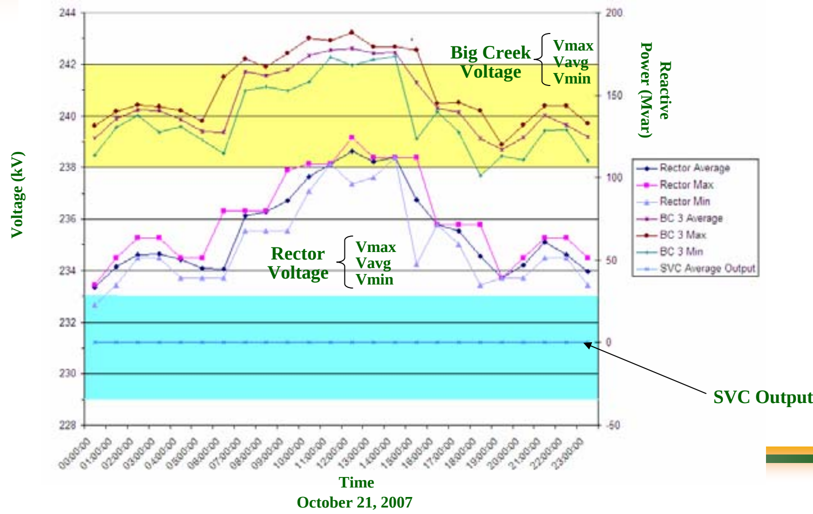


1) *Maintain Big Creek #3's 230 kV bus voltage within its upper (VH2) and lower (VL2) limits (BC-AVR) and SVC steady-state output within QCmax and QLmax (SVC-AQR)*
2) *Maintain Rector 230 kV bus voltage within its upper (VH1) and lower (VL1) limits with Priority #1 maintained (REC-AVR)*
3) *If Big Creek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

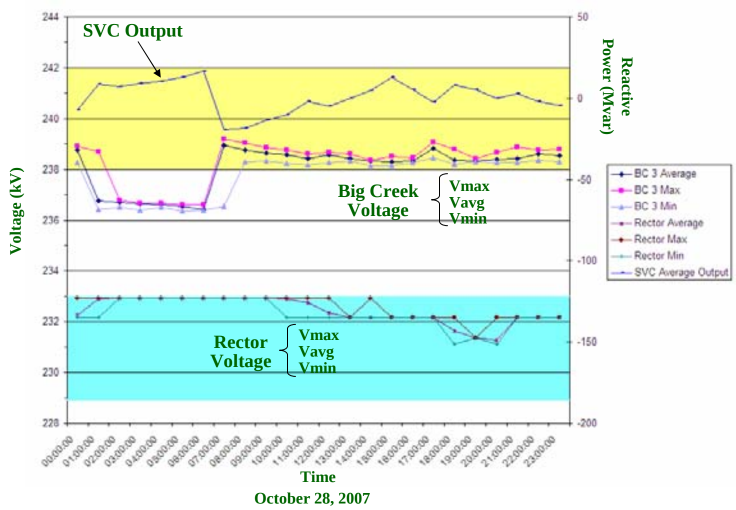
Conclusion

- 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.

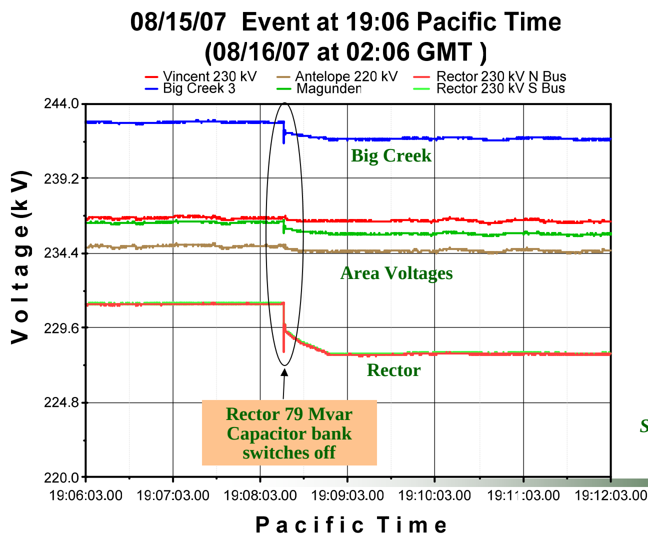
Rector and Big Creek Voltage Profile with the SVC Out-of-Service



Rector and Big Creek Voltage Profile with the SVC In-Service



Impact of SVC on Capacitor Switching

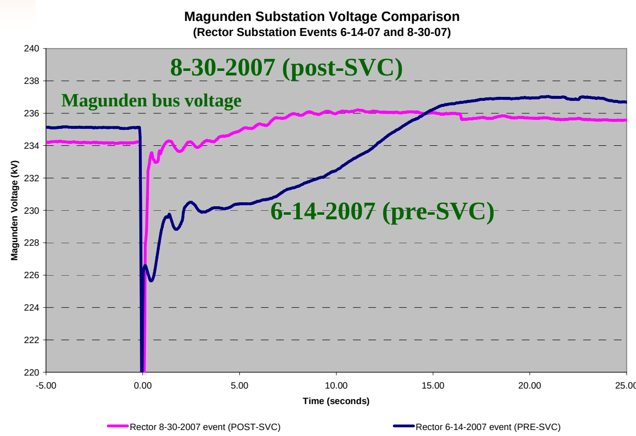


SVC is in-service

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

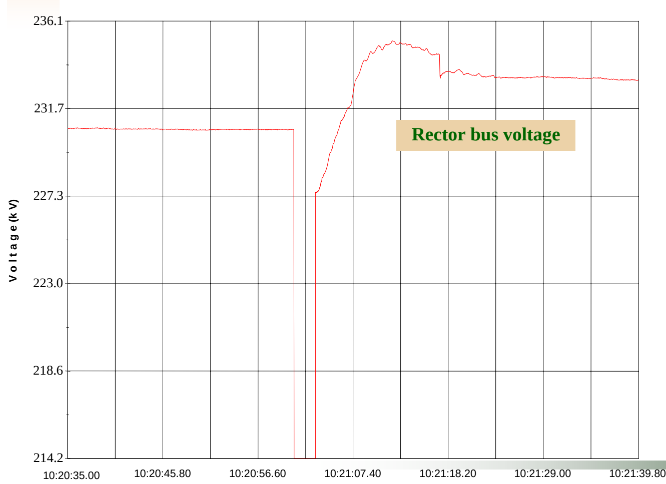
Impact of the Rector SVC:
6-14-07 (pre-SVC) vs. 8-30-07 (post-SVC)



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

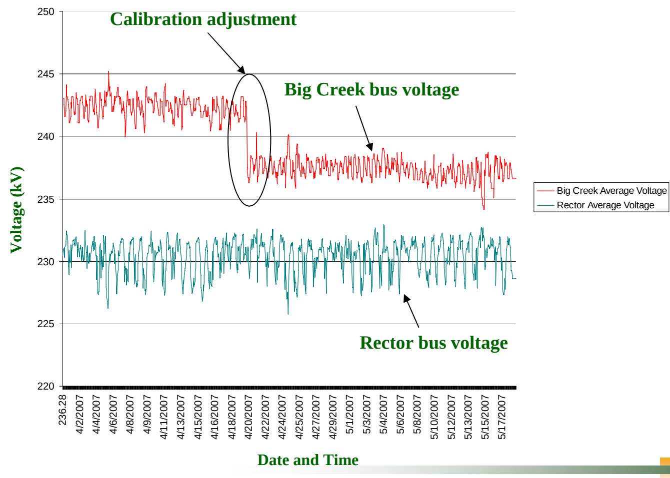
The Rector SVC had the apparent effect of reducing the magnitude & duration of the fault-induced slow voltage recovery

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



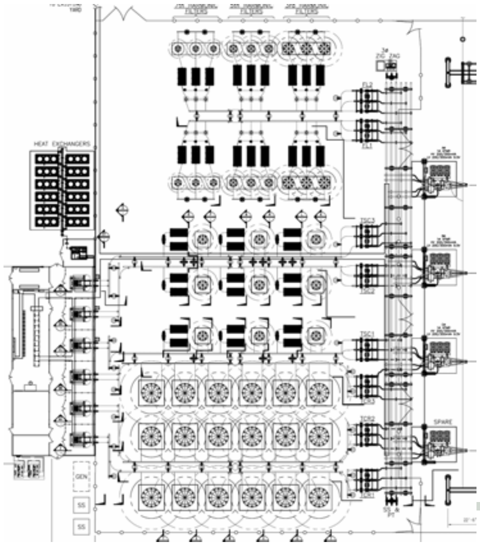
Questions?

Reference Slides

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



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