WPS-141-1A
Static var compensator (SVC) applications for improving transmission system performance
WCS-120-1
Static Var Compensator Applications

Agenda
- Introduction & FACTS (Flexible AC Transmission Systems) Overview
- System Study Consideration – Steady State vs Dynamic
- SVC Technology Overview & Applications

- Brian Scott
- Sales Mgr FACTS US, ABB Inc.
- Raleigh, NC
Your safety is important to us
Please be aware of these emergency procedures

- In the event of an emergency please dial ext. 55555 from any house phone. Do not dial 9-1-1.

- In the event of an alarm, please proceed carefully to the nearest exit. Emergency exits are clearly marked throughout the hotel and convention center.

- Use the stairwells to evacuate the building and do not attempt to use the elevators.

- Hotel associates will be located throughout the public space to assist in directing guests toward the closest exit.

- Any guest requiring assistance during an evacuation should dial “0” from any house phone and notify the operator of their location.

- Do not re-enter the building until advised by hotel personnel or an “all clear” announcement is made.
Your safety is important to us
Convention Center exits in case of an emergency

Know your surroundings:
- Identify the meeting room your workshop is being held in
- Locate the nearest exit
FACTS Portfolio – Two main areas
Flexible AC Transmission Systems

Shunt Compensation
- SVC
- STATCOM (SVC Light)
- Battery Energy Storage

Series Compensation
- Fixed
- Controllable
Typical Drivers for Dynamic Reactive Support (FACTS)

- Support Load Centers Importing Remote Generation
- Provides Stability During Dynamic Events
- Retire RMR or High Emission Generation
- Improve Power Quality & Mitigate Flicker
- Replace Synchronous Condensers
- Increase Transmission Capacity
- Power Oscillation Damping
- Phase Unbalance Control
- Improve Grid Reliability
- Voltage Recovery
- Voltage Profile

FACTS Offers a Toolbox of Solutions for Transmission Challenges
FACTS in Brief

**Static Var Compensator (SVC)**
- **First units installed:** Mid 1970’s
- **ABB Installations:** More than 400 globally
- **Simplified:** Variable Shunt Impedance
- **Technology:** Fixed Capacitors (Filters), TCR/TSR, TSC

**Static Compensator (STATCOM) / SVC Light**
- **First units installed:** 1990’s
- **Simplified:** Variable Voltage Source
- **Technology:** VSC (Voltage Source Converter)

**Series Capacitor (SC)**
- **First units installed:** 1950
- **ABB Installations:** More than 400 globally
- **Simplified:** Offset’s inductance of line to “appear” shorter
- **Technology:** Fixed, Staged/Stepped, Thyristor Controlled
SVC Demo
SVC vs. Shunt Capacitors

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>SVC</th>
<th>MSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch-in Time</td>
<td>At most 3 ms</td>
<td>~50 - 200 ms</td>
</tr>
<tr>
<td>Discharge Time</td>
<td>None needed</td>
<td>5 – 15 min</td>
</tr>
<tr>
<td>Point of Wave</td>
<td>Any</td>
<td>zero crossing desired</td>
</tr>
<tr>
<td>Control Type</td>
<td>Continuous</td>
<td>Stepwise</td>
</tr>
</tbody>
</table>

SVC

MSC
• Systems heavily compensated with shunt capacitor banks are more sensitive to changes in reactive power

• SVC’s can provide continuous range, therefore limiting the effects of capacitor bank switching

• For this reason, using an SVC to automatically control MSC banks can be very effective.
SVC Design Studies
Specification Development

- SVC sizing studies
  - Steady state load flow studies
    - Different load levels and generation scenarios, voltage profiles
  - Short circuit levels
- Dynamic Studies
  - Post contingency behavior
  - Load modeling important, ie fraction of motor load
  - Requirements on SVC control response
    - Harmonic impedance study
    - Background harmonics (measurement)
    - Power oscillation damping requirements
Example Simulation
Dynamic vs. Steady State Vars

- Following Contingencies
- Single Phase Fault
- Dynamic Compensation
- Induction motor loads
SVC & SVC Light
Building Blocks

Classical switched and continuous phase control

**TCR**: Thyristor Controlled Reactor
**TSR**: Thyristor Switched Reactor
**TSC**: Thyristor Switched Capacitor

**FC**: Fixed/Filter Capacitor
**VSC**: Voltage Source Converter

SVC Light®
STATCOM
Continuous control
Thyristor Switched Capacitor

Capacitor bank including current-limiting reactor

Thyristor Valve

\[ V_p \]

\[ V_c \]

\[ I \]

\[ FP \]
TCR Harmonics & Filters
Thyristor Controlled Reactor

Thyristor Controlled Reactor

Reactor

Controlled Susceptance

Thyristor Valve
Drivers for the Tucson Electric Power SVC

**Problem:**
- Potential for voltage collapse, especially during warm summer months

**Causes:**
- High concentration of air conditioning motor loads
- Heavy loading conditions
- Minimal local generation
- Outages of critical EHV infrastructure

**Solution:**
- 138 kV, -75 / +200 Mvar Static Var Compensator (SVC)
- Commissioned Summer of 2008

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Local TEP 138 kV System

Reason For Chosen Location:

- Proximity to city of Tucson
- Multiple lines converge
- Cost optimal location considering…
  - Required SVC size
  - Available footprint
  - Available connection points
TEP SVC
Single Line Diagram

138kV Bus

CB

19kV SVC Bus

TCR
135 Mvar*

TSC
140 Mvar*

3rd Harmonic

R

5th Harmonic

R

60 Mvar of Filters

R

7th Harmonic

TCR: Thyristor Controlled Reactor
TSC: Thyristor Switched Capacitor
SVC Layout
Control of Mechanically Switched Capacitor Banks

- MSC's ~50 Mvar each
- 2 MSC's always reserved for contingency operation
- If the wide dead band is exceeded for a short time, an MSC will be switched
- If the narrow dead band is exceeded for a longer time, an MSC will be switched
138 kV Phase to Phase Fault
SVC Transient Fault Recorder

System Voltage

SVC Mvar Output

Susceptance Reference
138 kV Phase to Phase Fault SVC Transient Fault Recorder

System Voltage

SVC Mvar Output

Susceptance Reference

MSC #1
MSC #3

I TCR
I TSC

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Predicted SVC Sound Propagation
ABB SVC & STATCOM Utility Installations in the US

Alaska Energy Authority
- Soldotna: 40/+70 Mvar, 115 kV
- Daves Creek: -10/+25 Mvar, 115 kV

Golden Valley Electric Authority
- Jarvis Creek: -9/+35 Mvar, 138 kV

Bonneville Power
- Maple Valley: -40/+70 Mvar, 115 kV
- Keeler: -300/+300 Mvar, 230 kV

PG&E
- Humboldt: -25/+50 Mvar, 60 kV
- Potro: -100/+240 Mvar, 115 kV
- Newark: -100/+240 Mvar, 230 kV

LANL
- Los Alamos: -50/+100 Mvar, 115 kV

Tucson Electric Power
- Tucson: -75/+200 Mvar, 138 kV

Kansas Gas & Electric
- Gordon Evans: 0/+300 Mvar, 138 kV
- Murray Gill: 25/+200 Mvar, 138 kV

WAPA
- Fargo: -45/+22 Mvar, 14 kV

NSP
- Forbes: -110/+150 Mvar (Cont.), -450/+400 Mvar (10 Sec.), 500 kV

Maine Electric Power
- Chester: -140/+425 Mvar, 345 kV

Allegany Power
- Black Oak: -100/+575 Mvar, 500 kV

Virginia Power
- Colington: -30/+78 Mvar, 115 kV

Am. El. Power
- Beaver Creek: -100/+575 Mvar, 138 kV

AEP West
- Bluff Creek: -40/+50 Mvar, 35 kV
- Crane (Odessa): -40/+50 Mvar, 69 kV
- Eagle Pass STATCOM: Back-to-Back 2 x +/- 36 MVA
- Dilly (Laredo): -40/+50 Mvar, 69 kV
- Airline (Corpus Christi): -40/+50 Mvar, 69 kV

XCEL Energy
- Tuco: -50/+150 Mvar, 230 kV

Oncor
- Parkdale x2: -256/+300 Mvar, 138 kV
- Renner x2: -256/+300 Mvar, 138 kV

Austin Energy
- Holly STATCOM: +/- 95 MVAR

AEP West
- Bluff Creek: -40/+50 Mvar, 35 kV
- Crane (Odessa): -40/+50 Mvar, 69 kV
- Eagle Pass STATCOM: Back-to-Back 2 x +/- 36 MVA
- Dilly (Laredo): -40/+50 Mvar, 69 kV
- Airline (Corpus Christi): -40/+50 Mvar, 69 kV

Nyseg
- Fraser: -300/+325 (Upgrade), 345 kV

Niagra Mohawk
- Leeds: -300/+270 Mvar, 345 kV

NSTAR
- Barnstable: -60/+200, 138 kV

Jersey Central
- Atlantic City: -130/+260 Mvar, 230 kV

PHI
- Dennis: -100/+150 Mvar, 230 kV
- Cardiff: -100/+150 Mvar, 230 kV
- Indian River: -100/+150 Mvar, 230 kV
- Nelson: -100/+150 Mvar, 138 kV

Virginia Power
- Colington: -30/+78 Mvar, 115 kV

Duke Power
- Beckerdite: -100/+300 Mvar, 100 kV

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AEP Direct Connect - Single Line Diagram

AEP, Texas

- **Benefits**
  - Reduced Losses
  - Smaller Footprint
  - Reduced Delivery Time
  - Reduced Maintenance Costs
  - Reduced Equipment Delivery Risk
  - Higher availability/reliability (w/o spare transformer)

**Rating:** -40/+ 50 MVAr @ 69 kV

69 kV Bus

- TCR 90 MVAr
- 5th Harmonic 28 MVAr
- 7th Harmonic 12 MVAr
- 13th Harmonic 10 MVAr

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AEP Direct Connect
SVC & Static Shunt Device Locations

138 kV
345 kV
AEP Direct Connect
SVC & Static Shunt Device Control Logic
AEP Direct Connect
Site Photos, Texas

TCR Reactors

Inst. Transformers

Harmonic Filters

Valve Hall / Control Enclosure
AEP Direct Connect
Site Photos, Texas

Thyristor Valve Hall
Wall Bushings
Control Enclosure
Power and productivity for a better world™
Reminders
Automation & Power World 2011

- Please be sure to complete the workshop evaluation
- Professional Development Hours (PDHs) and Continuing Education Credits (CEUs):
  - You will receive a link via e-mail to print certificates for all the workshops you have attended during Automation & Power World 2011.
  - BE SURE YOU HAVE YOUR BADGE SCANNED for each workshop you attend. If you do not have your badge scanned you will not be able to obtain PDHs or CEUs.