Application of SVCs by CenterPoint Energy to Address Voltage Stability Issues: Planning and Design Considerations

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Today's Agenda

- Introduction
- Background
- Study Methodology and Criteria Used
  - Models Included for Voltage Recovery Studies
  - Disturbances Studied
  - Performance Criteria
  - Dynamic Reactive Device Models and Locations
- Study Results
- SVC Design Considerations
  - SVC Basic Design
  - SVC Control
- Questions & Answers

Introduction – CenterPoint Energy

- Unbundled “Wires” company that delivers power to over 1.8 million metered customers.
- Highly industrialized, 5000 sq. Mile service area which includes Houston and 102 surrounding communities.
  - Approximately 3,600 miles of transmission lines.
  - Approximately 16,000 MW peak demand.
  - About 25% of the ERCOT load with less than 10% of ERCOT transmission circuit-miles.
Background

2002 - present: Houston becomes high import area

2005: 3800 MW of local units retire

High concentration of residential A/C's

Sustained load growth

Effect of Retiring Local Units

With units on-line

With units off
Models Included for Voltage Recovery Studies
- Load model includes explicit motor models
- Undervoltage Load Shedding (UVLS)
- Large motor contactor drop-out
- Generator Over-excitation Limiters (OEL)

Study Methodology and Criteria Used

Load Model

- Accurate load modeling is important
  - Used 2003 load model provided by ERCOT and Powertech
  - Load modeling can mean the difference between a stable system and a voltage collapse
  - Percentage of constant impedance, small motor load, large motor, and discharge lighting
  - Air-conditioner stalling is not modeled!

<table>
<thead>
<tr>
<th>Load Class/ Season</th>
<th>Resistive %</th>
<th>Small Motor %</th>
<th>Large Motor %</th>
<th>Discharge Lighting %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential / summer</td>
<td>25</td>
<td>75</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Commercial / summer</td>
<td>14</td>
<td>51</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Industrial / summer</td>
<td>5</td>
<td>20</td>
<td>56</td>
<td>19</td>
</tr>
</tbody>
</table>
Additional Models

- UVLS
  - 25% of CNP distribution load
  - Voltage trigger = 0.91 pu
  - Blocks at 3, 5, and 8 seconds

- Large motor contactor drop-out
  - When voltage drops below 0.6pu for 0.5 sec, load drops out
  - Load reconnected after voltage rises above 0.8pu for 1 sec
  - First CNP studies without contactor dropout showed fast voltage collapse.

- OEL models
  - Represents a 'best-case' scenario
  - Assumes generators are meeting ERCOT Operating Guide requirements at a minimum
  - Results very sensitive to OEL models

Disturbances Studied

- Disturbance studied: 3-phase fault cleared by breaker failure relaying taking two elements out of service
  - CNP System Design Criteria
  - NERC Category D
  - These disturbances do occur!
Performance Criteria

- Performance requirements:
  - Transmission system voltages must recover so that no generator terminal voltage remains below 90% of rated voltage for more than 10 seconds. (Based on ERCOT Op Guides Sec 3.1.4.6)
  - No more than 1250 MW of UVLS should be lost - Reserve a portion of UVLS as safety net for residential air conditioner stalling (not modeled) and avoid over-frequency excursions.

Dynamic Reactive Device Models and Locations

- Determine size of various technologies required
  - Synchronous Condenser
  - Distribution Static Compensator (DSTATCOM)
  - Static Synchronous Compensator (STATCOM)
  - Static VAR Compensator (SVC)
  - Thyristor-Switched Capacitors (TSC)
- Determine optimum locations: 2 locations, same device of equal size
## Study Results

<table>
<thead>
<tr>
<th>Type of Dynamic Reactive Device</th>
<th>Best Two of the Three Sites</th>
<th>MVA of each Device</th>
<th>Resulting MW Load Shed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous Condenser</td>
<td>West &amp; Central</td>
<td>70</td>
<td>996</td>
</tr>
<tr>
<td>DSTATCOM</td>
<td>Central &amp; East</td>
<td>35</td>
<td>1246</td>
</tr>
<tr>
<td>STATCOM</td>
<td>Central &amp; East</td>
<td>85</td>
<td>1226</td>
</tr>
<tr>
<td>SVC</td>
<td>Central &amp; East</td>
<td>120</td>
<td>1170</td>
</tr>
<tr>
<td>TSC</td>
<td>Central &amp; East</td>
<td>140</td>
<td>1121</td>
</tr>
</tbody>
</table>

## CNP TSC Sites

![CNP TSC Sites Map](image)
Proposed Technical Solution

Highlights

SVC comprising:
- Step down transformer
- TSC

- fast Mvar (<2 cycles response time)
- robust during severe system disturbances
- low minimum operating voltage (0.3 pu)
- extremely low losses during 99% of time
- no harmonic generation
- no radio interference issues

Basic Data for Dynamic Var System Design

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Rated Power</td>
<td>140 Mvar at HV 1.0 pu</td>
</tr>
<tr>
<td>Nominal system voltage</td>
<td>138 kV (1.0 pu)</td>
</tr>
<tr>
<td>Maximum continuous operating voltage</td>
<td>145 kV (1.05 pu)</td>
</tr>
<tr>
<td>Minimum continuous operating voltage</td>
<td>41.5 kV (0.3 pu)</td>
</tr>
<tr>
<td>Frequency range for continuous operation</td>
<td>59.95 - 60.05 Hz</td>
</tr>
<tr>
<td>Basic Insulation Level (BIL)</td>
<td>650 kV</td>
</tr>
</tbody>
</table>
SVC VI Characteristics

Transient Stresses
Maximum Voltage at TSC Capacitor

Misfiring
$V_{\text{CTSC}}=96.8 \text{ kV}_{\text{peak}}$

Voltages across capacitors in all 3 phases.
Transient Stresses
Maximum TSC Valve Current

Current through a TSC Valve and Capacitor.

Currents in all 3 phases.

Misfiring $I_{\text{Valve}}=26.7 \text{ kA}_{\text{peak}}$

Transient Stresses
Maximum Voltage across TSC Valve

Voltages across two TSC Valves.

Misfiring $V_{\text{Valve}}=107.5 \text{ kV}_{\text{peak}}$
SVC Control System Overview

Controlled Devices at Central Substation
- 1 x TSC Thyristor Switched Capacitor
- 2 x MSC Mechanical switched Capacitor
- 1 x Transformer Tap Changer

Controlled Devices at Eastern Substation
- 1 x TSC Thyristor Switched Capacitor
- 1 x MSC Mechanical Switched Capacitor
- 1 x MSR Mechanical Switched Reactor

SVC Control - Basic Functions

• Redundant Controller Structure

138 kV Dynamic Voltage Support Mode (DVS)
- Is always active
- Supports the system voltage during network faults

138 kV Steady State Voltage Regulation (SSVR)
- Regulates the system voltage to the reference voltage
Many Thanks ..... Any Questions

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