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

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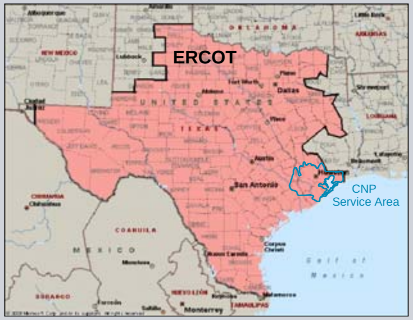
Today’s Agenda

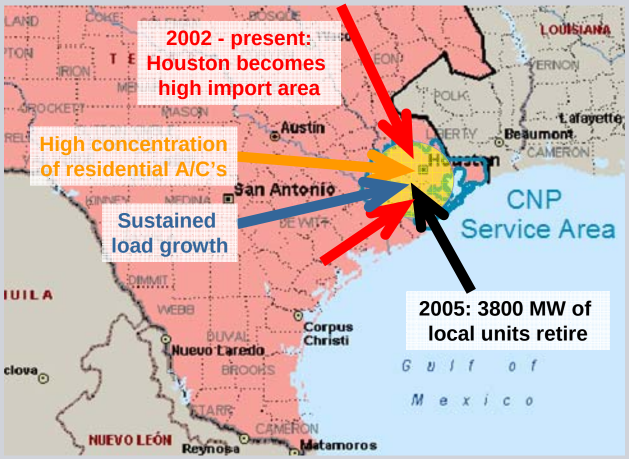
- Introduction
- Background
- Study Methodology and Criteria Used
  - Models Included for Voltage Recovery Studies
  - Disturbances Studied
  - Performance Criteria
  - Dynamic Reactive Device Models and Locations
- Study Results
- SVC Design Considerations
  - SVC Basic Design
  - SVC Control
- Questions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

High concentration of residential A/C's

Sustained load growth

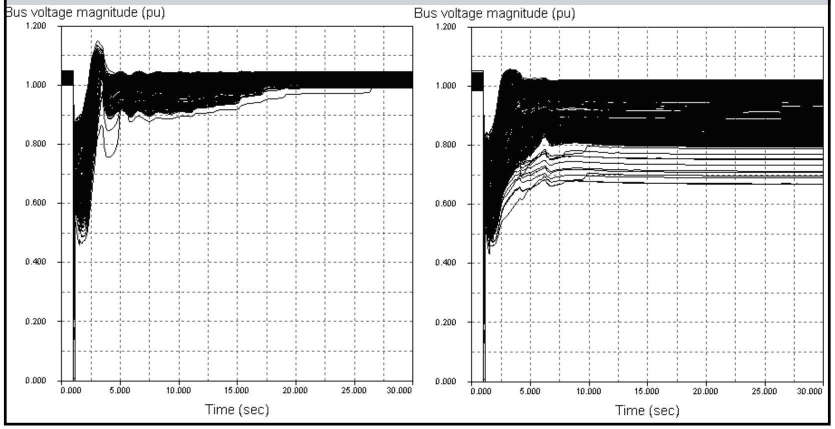
2005: 3800 MW of local units retire

CNP Service Area

Effect of Retiring Local Units

With units on-line

With units off



Study Methodology and Criteria Used

- 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)

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!

Load Composition				
Load Class / Season	**Resistive %**	**Small Motor %**	**Large Motor %**	**Discharge Lighting %**
Residential / summer	25	75	0	0
Commercial / summer	14	51	0	35
Industrial / summer	5	20	56	19

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

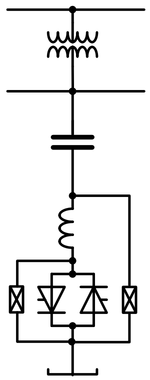
Type of Dynamic Reactive Device	Best Two of the Three Sites	MVA of each Device	Resulting MW Load Shed
Synchronous Condenser	West & Central	70	996
DSTATCOM	Central & East	35	1246
STATCOM	Central & East	85	1226
SVC	Central & East	120	1170
TSC	Central & East	140	1121

CNP TSC Sites

Proposed Technical Solution Highlights

SVC comprising:
- Step down transformer
- TSC

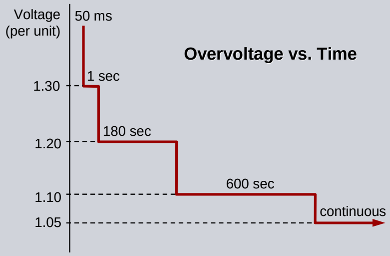
- fast Mvar (<2 cycles response time)
- robust during severe system disturbances
- low minimum operating voltage (0.3 pu)
- extremely low losses during 99% of time
- no harmonic generation
- no radio interference issues



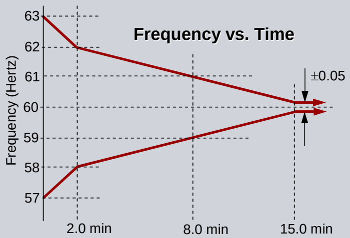
Principle Single Line Diagram

Basic Data for Dynamic Var System Design

Rated Power	140 Mvar at HV 1.0 pu
Nominal system voltage	138 kV (1.0 pu)
Maximum continuous operating voltage	145 kV (1.05 pu)
Minimum continuous operating voltage	41.5 kV (0.3 pu)
Frequency range for continuous operation	59.95 - 60.05 Hz
Basic Insulation Level (BIL)	650 kV

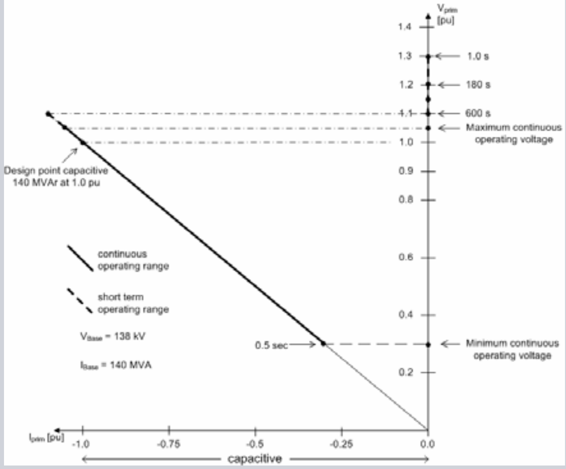


Overvoltage vs. Time



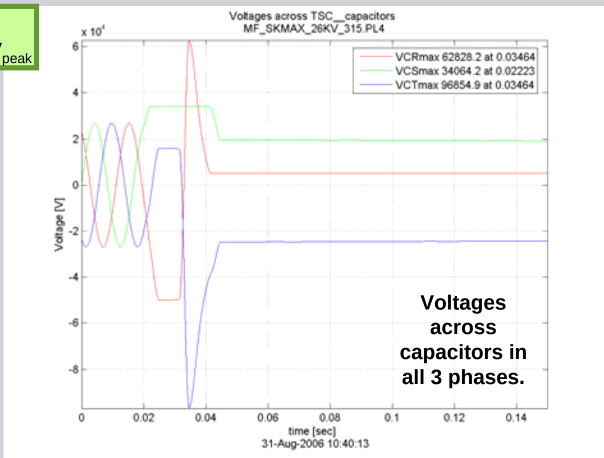
Frequency vs. Time

SVC VI Characteristics



Transient Stresses
Maximum Voltage at TSC Capacitor

Misfiring
V_{CTSC}=96.8 kV_{peak}

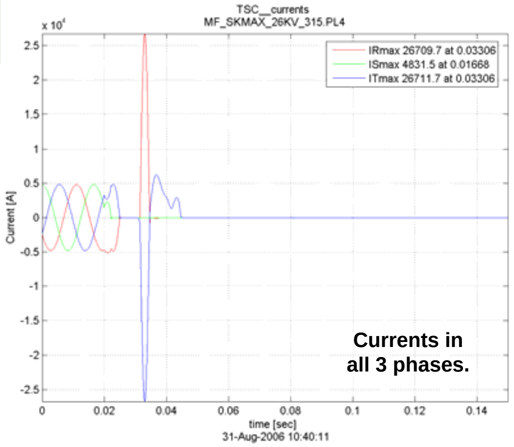


Voltages across capacitors in all 3 phases.

Transient Stresses
Maximum TSC Valve Current

Misfiring
I_{CValve}=26.7 kA_{peak}

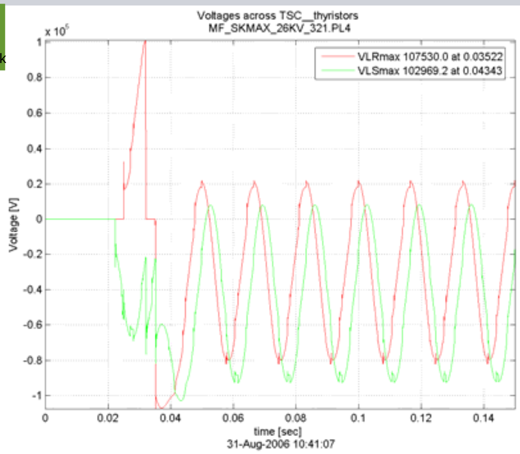
Current through a TSC Valve and Capacitor.



Currents in all 3 phases.

Transient Stresses
Maximum Voltage across TSC Valve

Misfiring
V_{Valve}=107.5 kV_{peak}



Voltages across two TSC Valves.

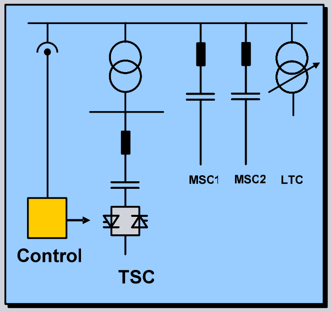
SVC Control System Overview

Controlled Devices at Central Substation

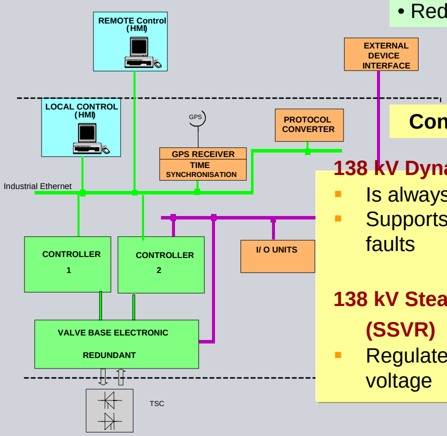
- 1 x TSC Thyristor Switched Capacitor
- 2 x MSC Mechanical switched Capacitor
- 1 x Transformer Tap Changer

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

Control Modes

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

SVC Substation (April 2008)

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Many Thanks ….. Any Questions

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