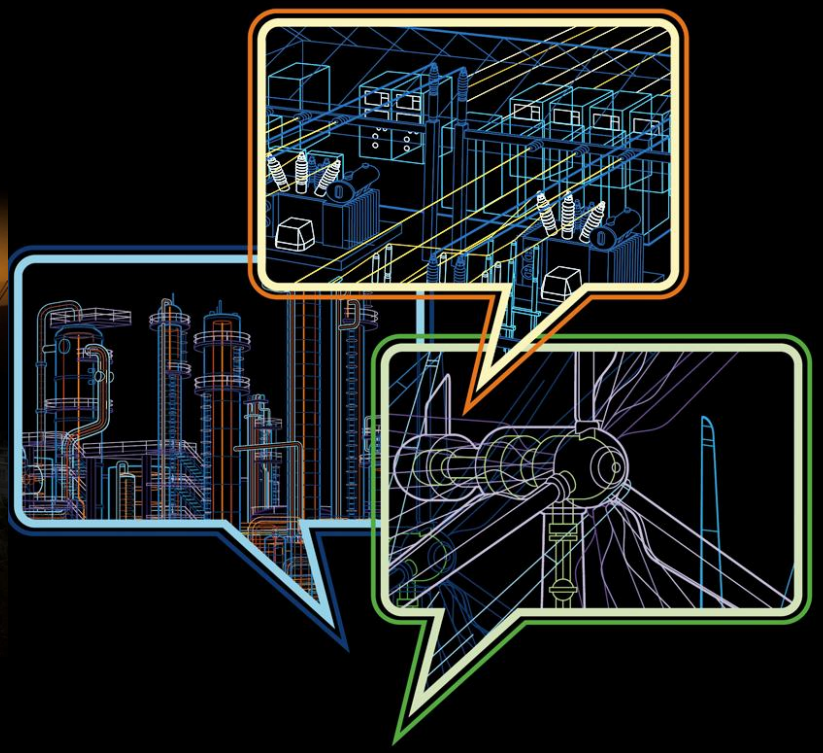


ABB Automation & Power World: April 18-21, 2011

WPS-141-1A

Static var compensator (SVC) applications for improving transmission system performance

WCS-120-1
Static Var Compensator Applications

Agenda

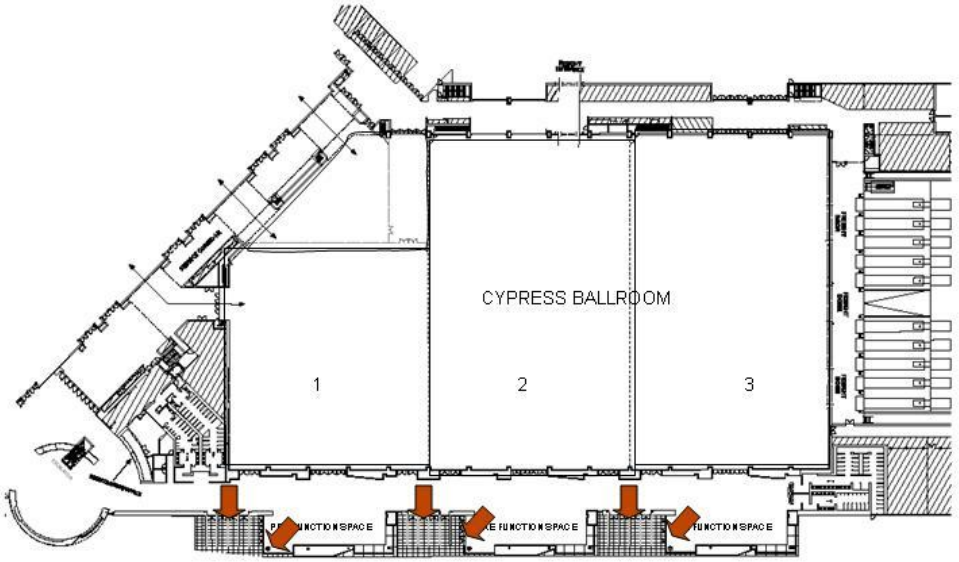
- Introduction & FACTS (Flexible AC Transmission Systems) Overview
- System Study Consideration – Steady State vs Dynamic
- SVC Technology Overview & Applications

- 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

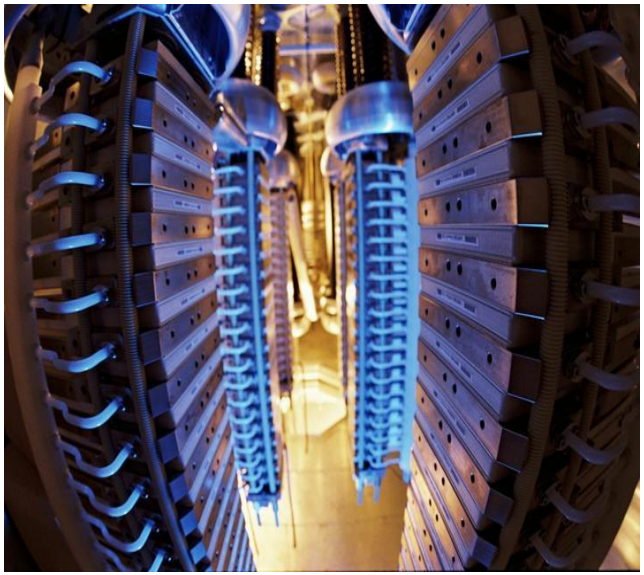
- SVC
- STATCOM (SVC Light)
- Battery Energy Storage

Series Compensation

- Fixed
- Controllable

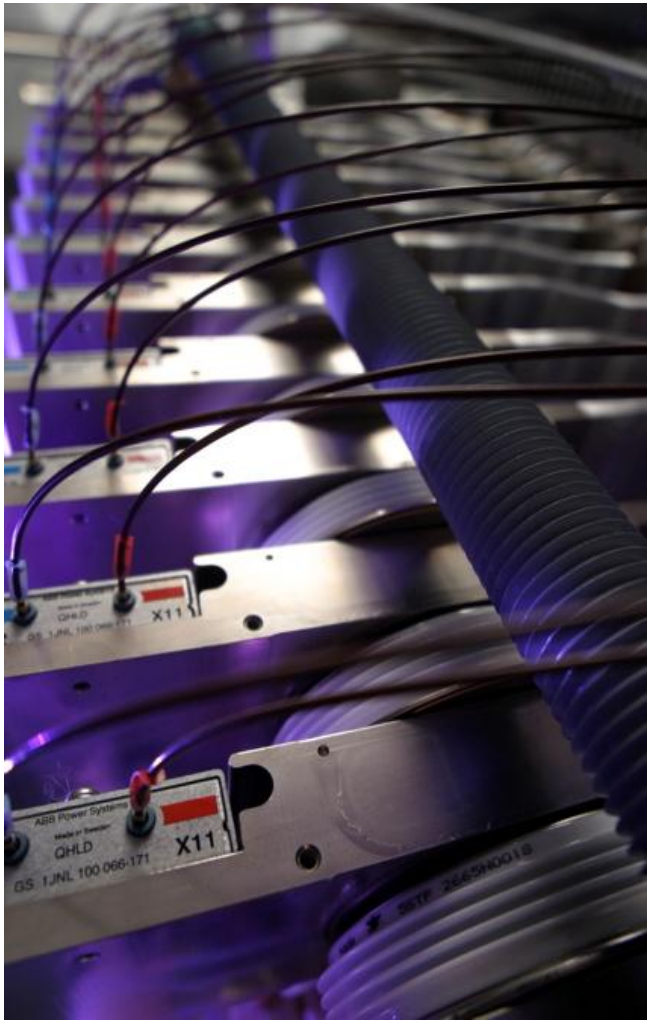
Typical Drivers for Dynamic Reactive Support (FACTS)

- **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

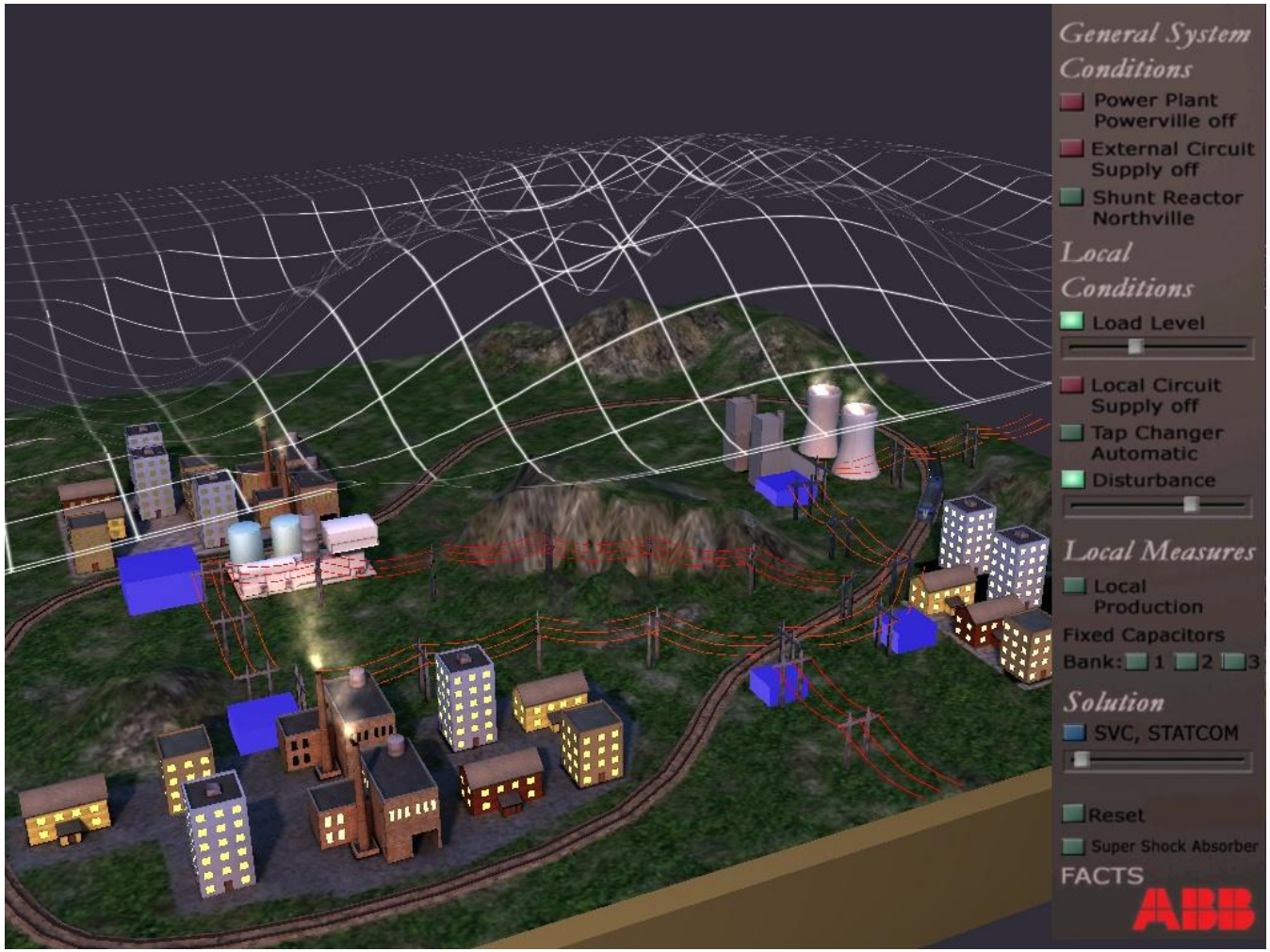
Static Compensator (STATCOM) / SVC Light

- **First units installed:** 1990's
- **Simplified:** Variable Voltage Source
- **Technology:** VSC (Voltage Source Converter)

Series Capacitor (SC)

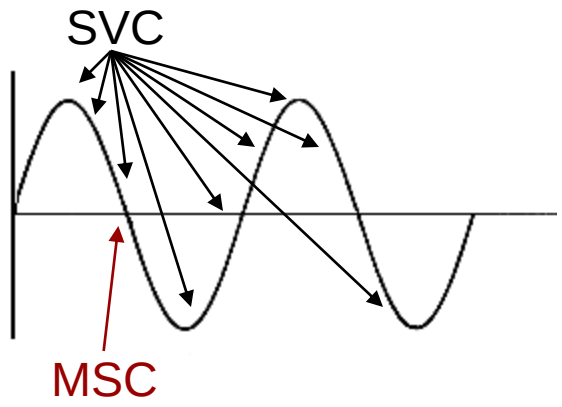
- **First units installed:** 1950
- **ABB Installations:** More than 400 globally
- **Simplified:** Offset's inductance of line to "appear" shorter
- **Technology:** Fixed, Staged/Stepped, Thyristor Controlled

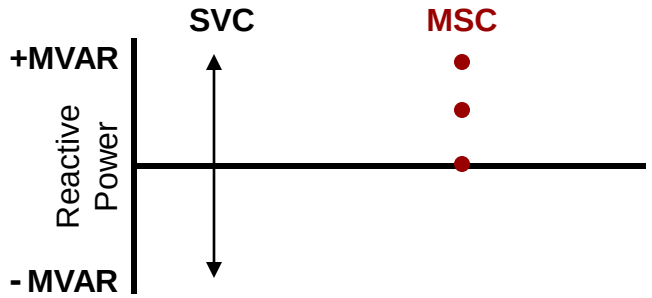
SVC Demo



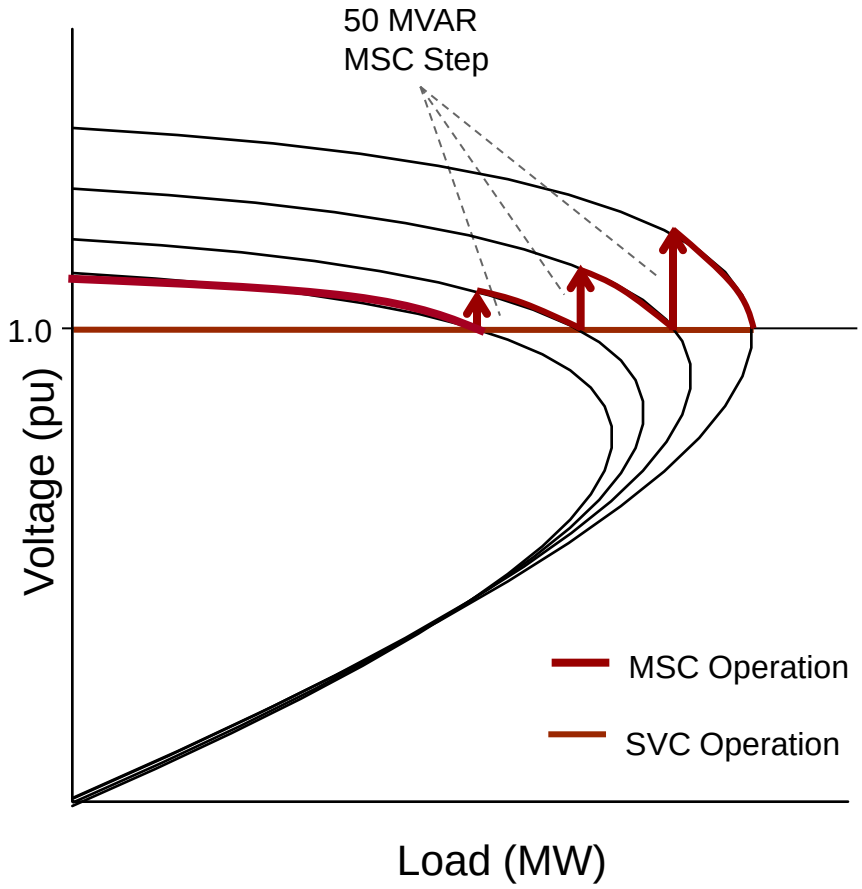
SVC vs. Shunt Capacitors

OPERATION	SVC	MSC
Switch-in Time	At most 3 ms	~50 - 200 ms
Discharge Time	None needed	5 – 15 min
Point of Wave	Any	zero crossing desired
Control Type	Continuous	Stepwise





SVC Vs. MSC
Practical Operation

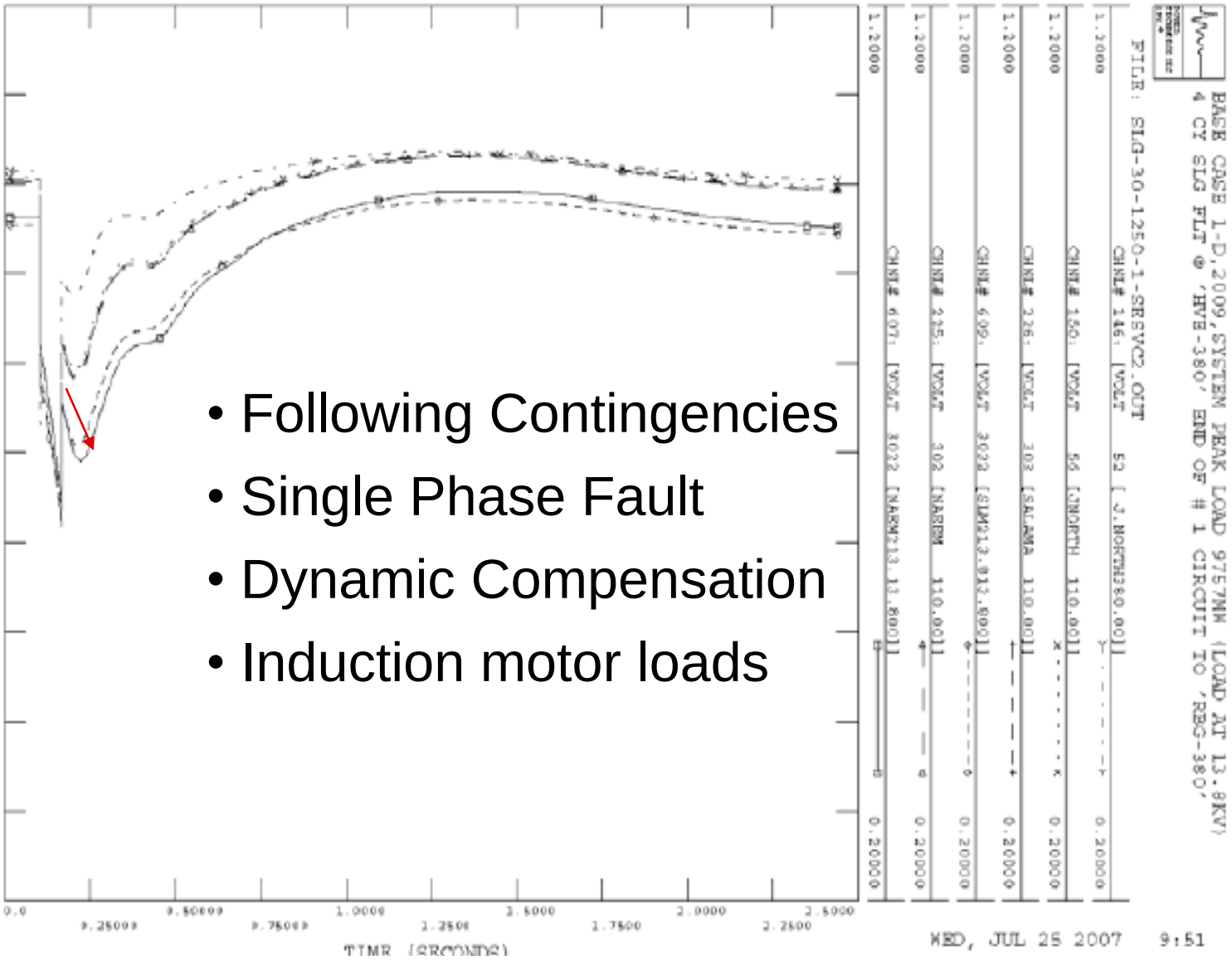


- Systems heavily compensated with shunt capacitor banks are more sensitive to changes in reactive power
- SVC's can provide continuous range, therefore limiting the effects of capacitor bank switching
- For this reason, using an SVC to automatically control MSC banks can be very effective.

SVC Design Studies
Specification Development

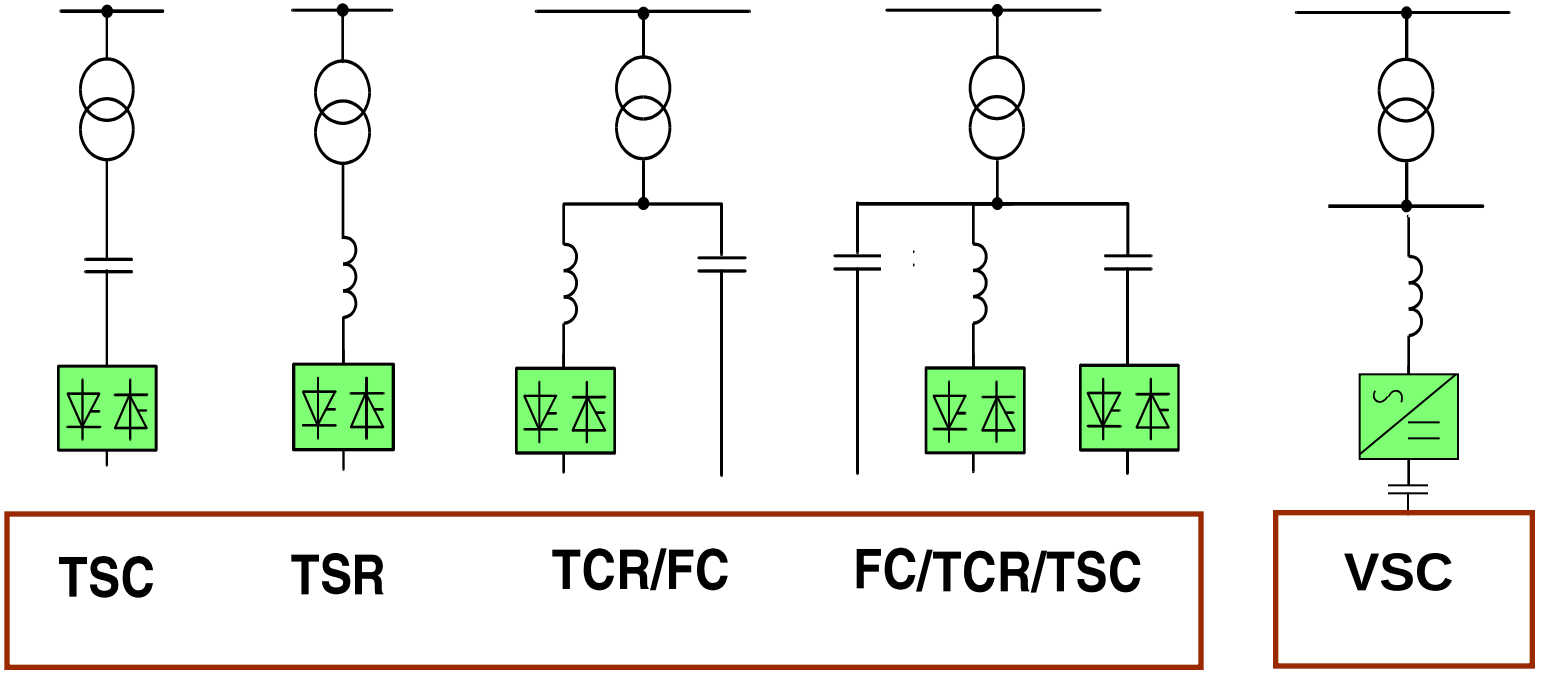
- SVC sizing studies
  - Steady state load flow studies
    - Different load levels and generation scenarios, voltage profiles
    - Short circuit levels
  - Dynamic Studies
    - Post contingency behavior
    - Load modeling important, ie fraction of motor load
    - Requirements on SVC control response
- 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



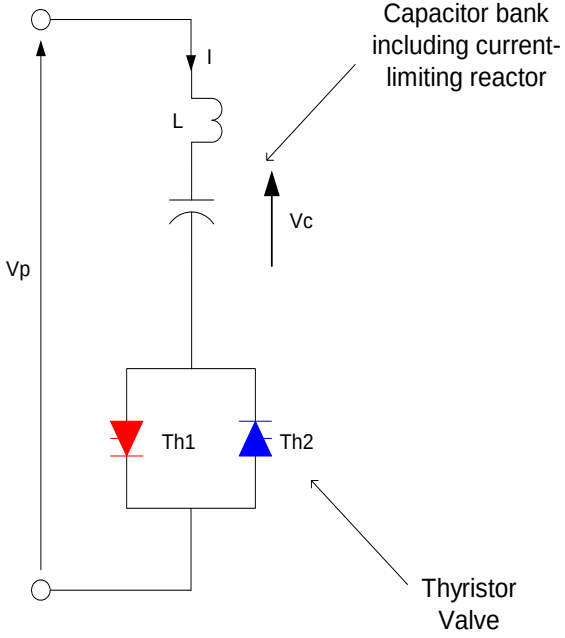
Classical switched and continuous phase control

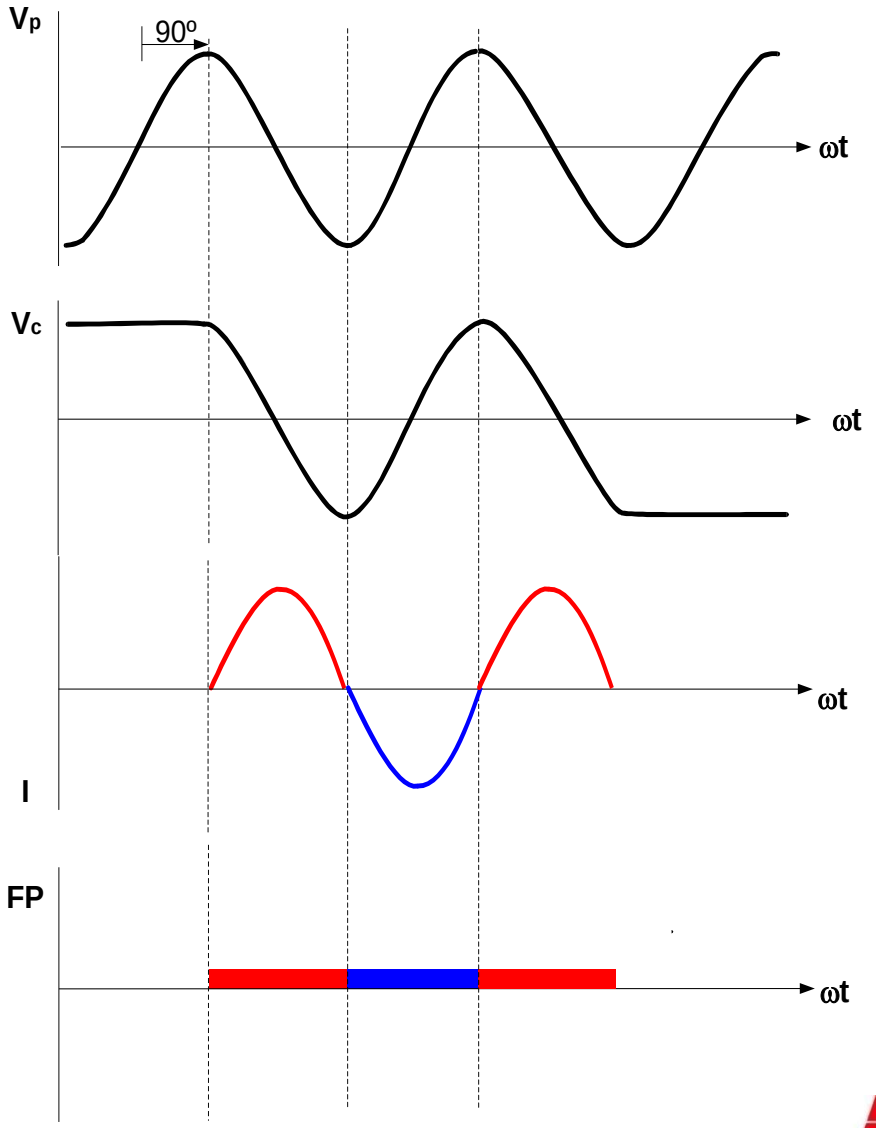
SVC Light®
STATCOM
Continuous control

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

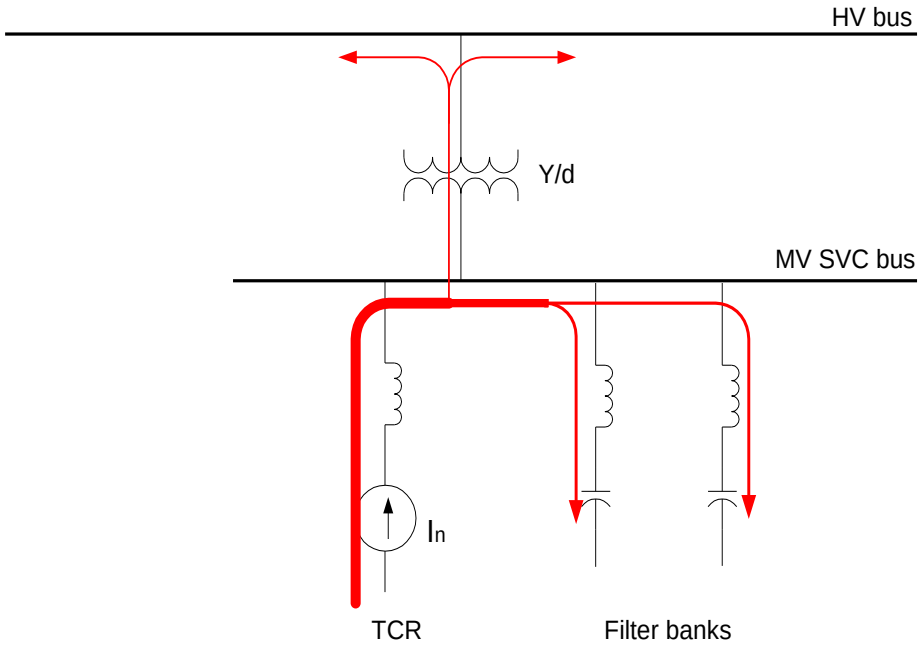
FC: Fixed/Filter Capacitor
VSC: Voltage Source Converter

Thyristor Switched Capacitor

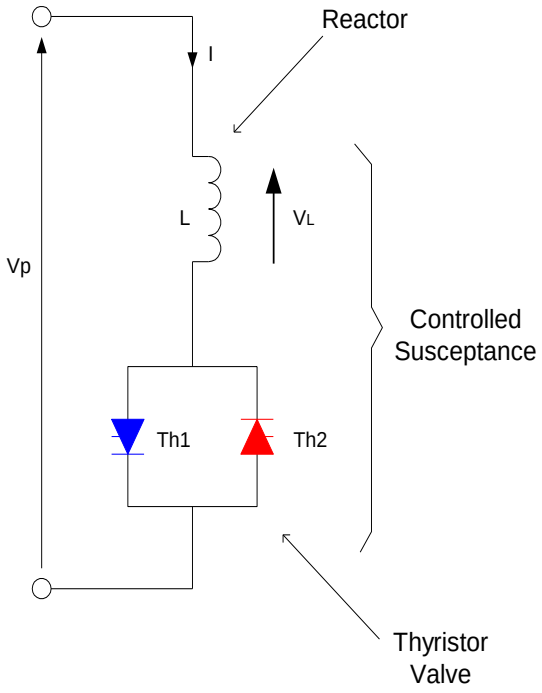


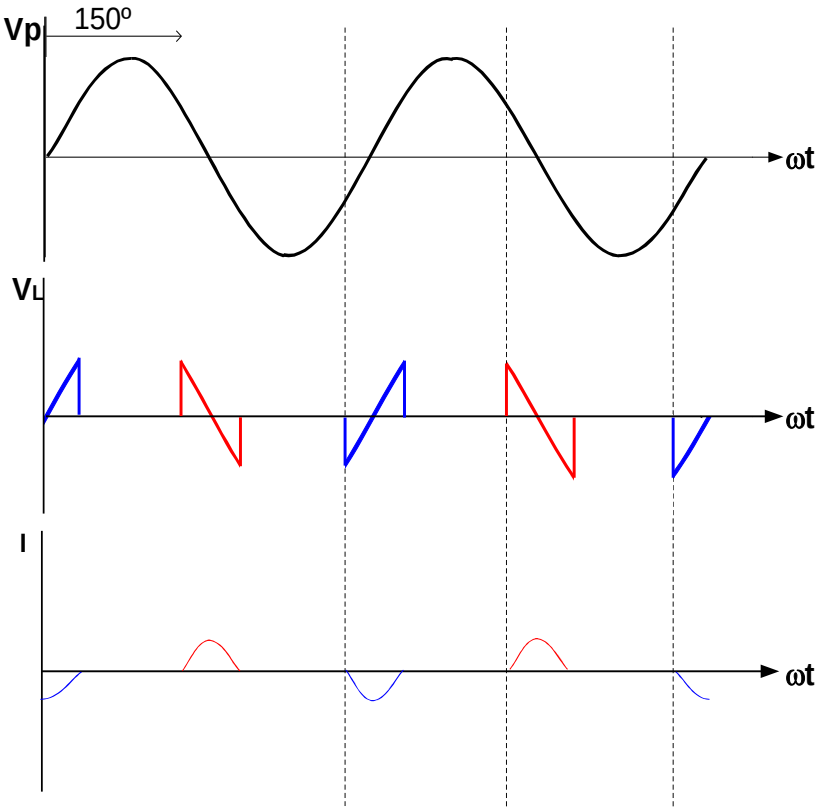


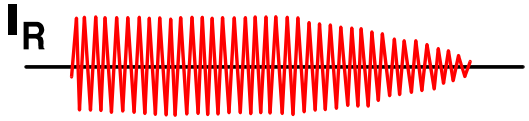
TCR Harmonics & Filters



Thyristor Controlled Reactor







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

* Identified in previous white paper: Pourbeik, A. Meyer, and M. A. Tilford, "Solving a Potential Voltage Stability Problem with the Application of a Static VAr Compensator", Proceedings of the IEEE PES General Meeting, June 2007, Tampa, FL.

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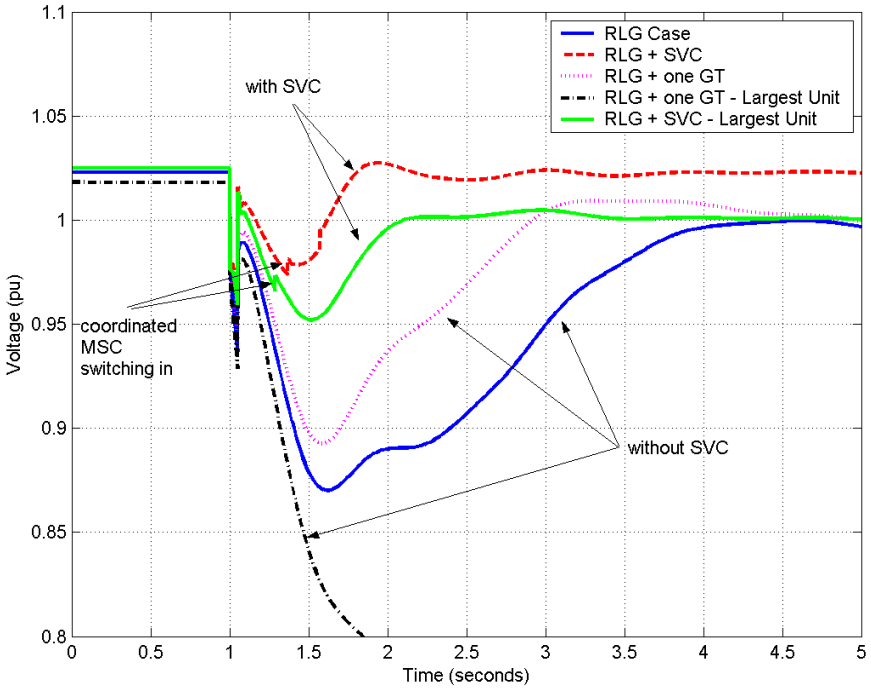

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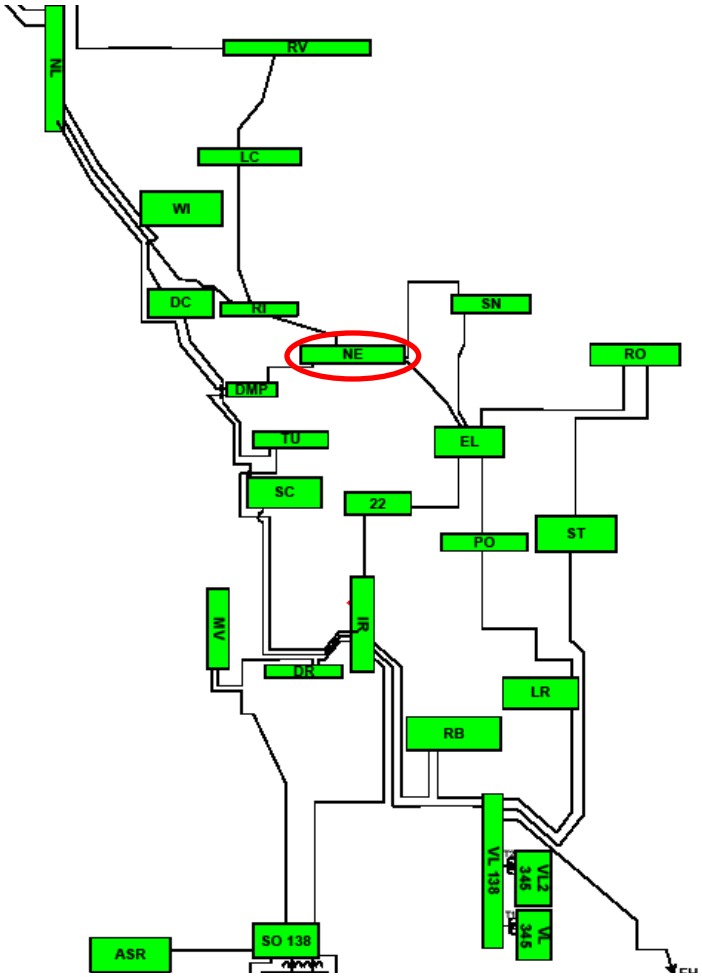
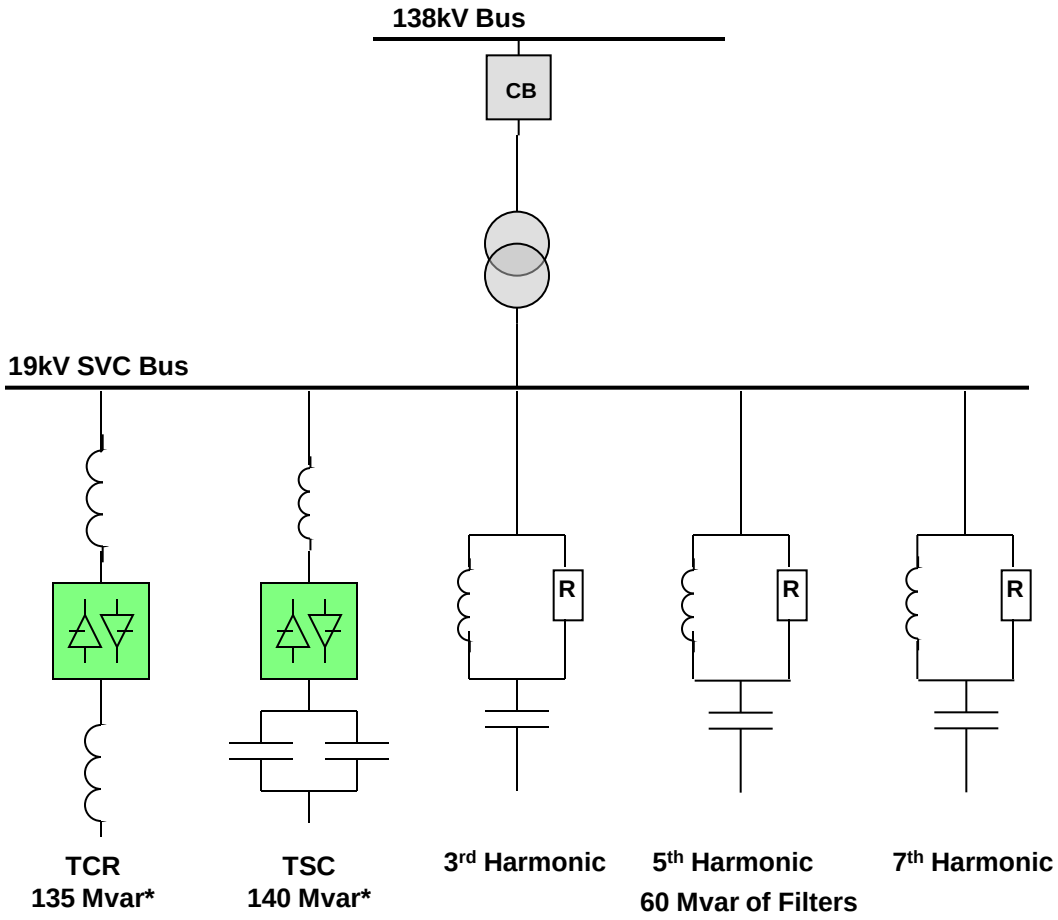
Local TEP 138 kV System



Reason For Chosen Location:

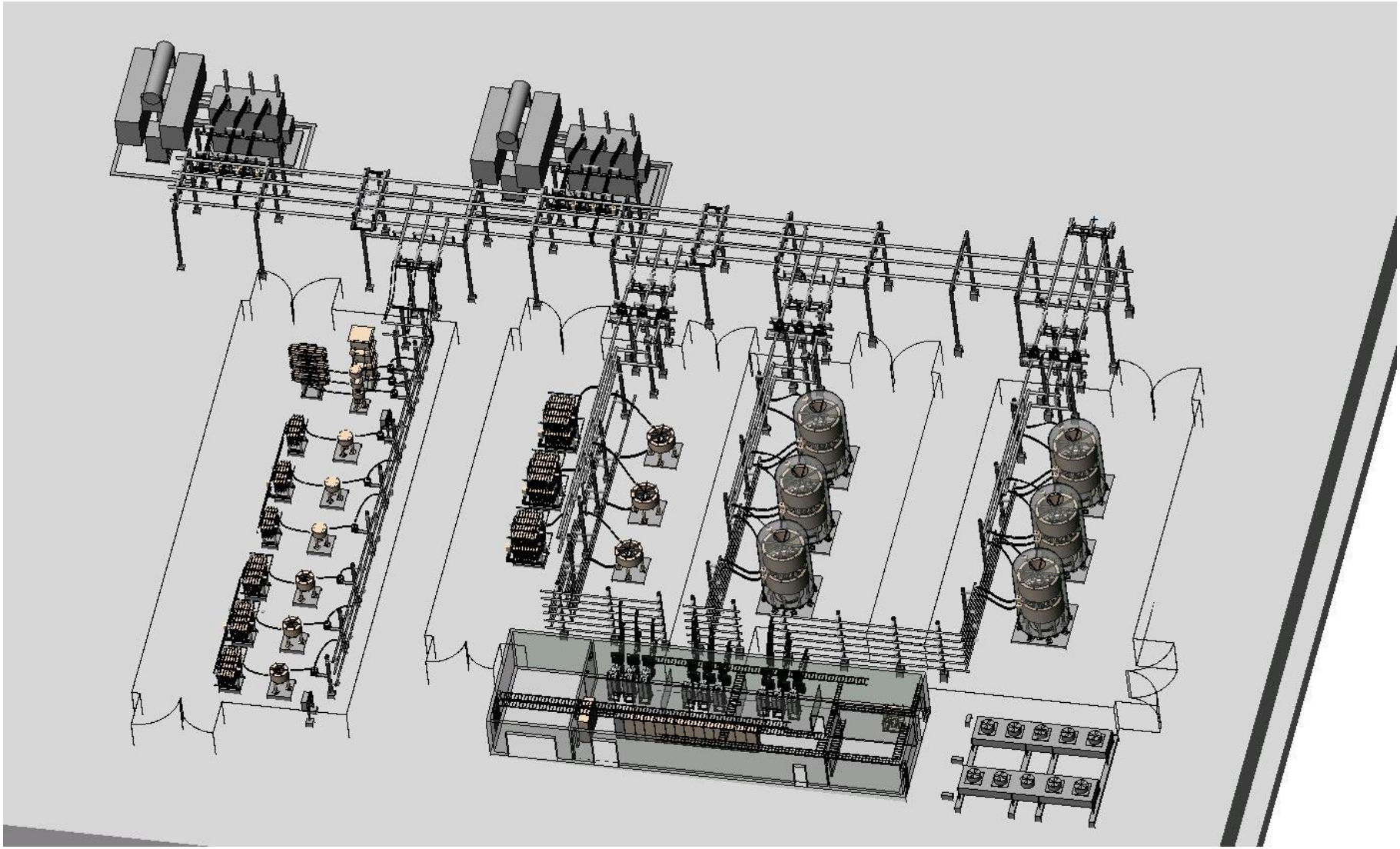
- Proximity to city of Tucson
- Multiple lines converge
- Cost optimal location considering…
  - Required SVC size
  - Available footprint
  - Available connection points

TEP SVC
Single Line Diagram

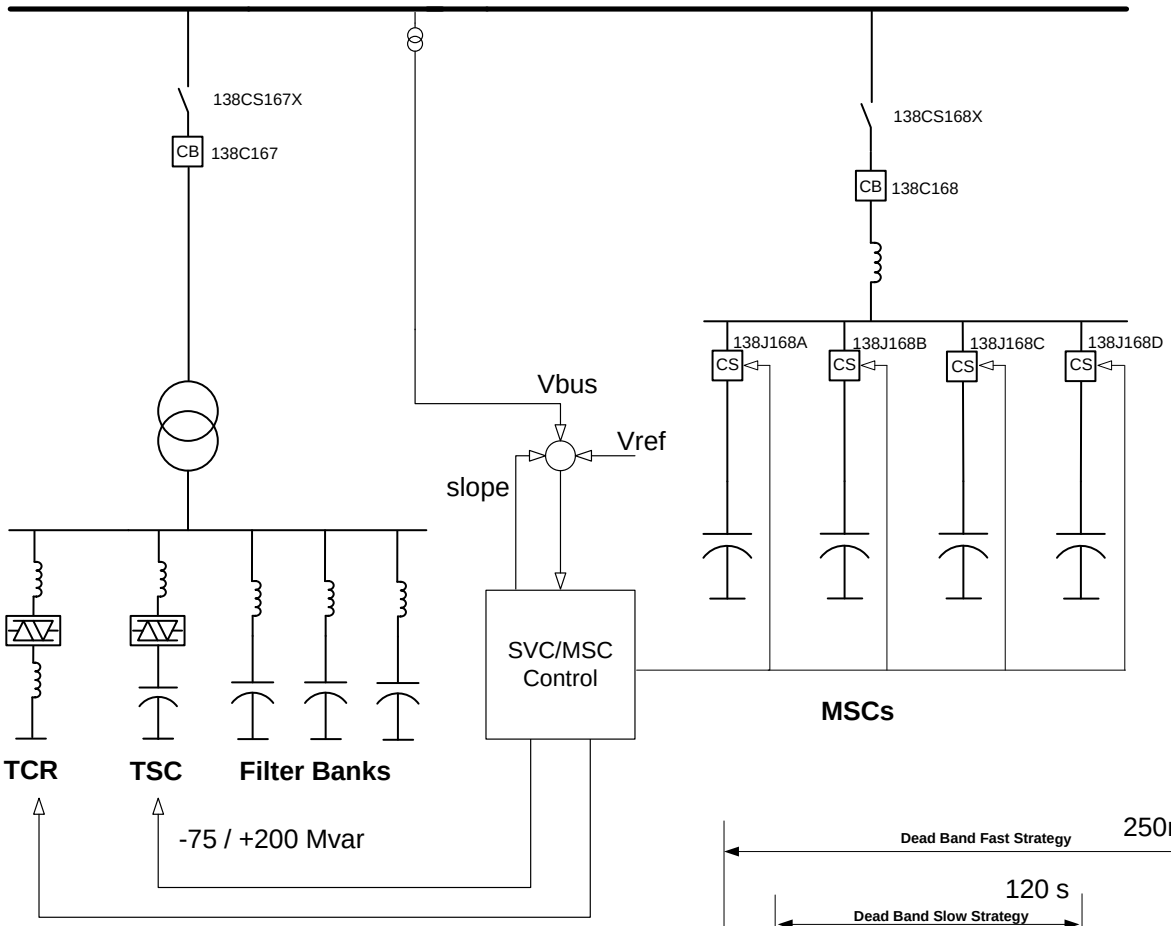


TCR: Thyristor Controlled Reactor
TSC: Thyristor Switched Capacitor

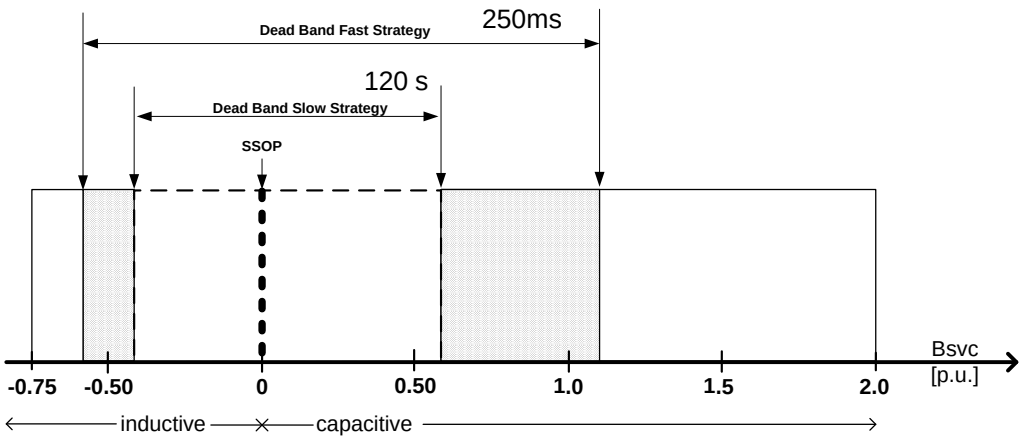
SVC Layout



Control of Mechanically Switched Capacitor Banks

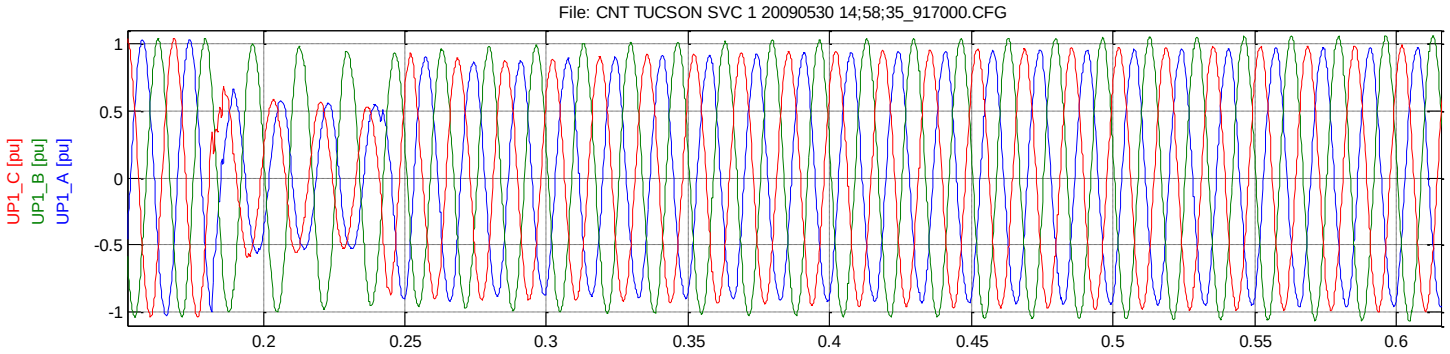


- MSC's ~50 Mvar each
- 2 MSC's always reserved for contingency operation
- If the wide dead band is exceeded for a short time, an MSC will be switched
- If the narrow dead band is exceeded for a longer time, an MSC will be switched

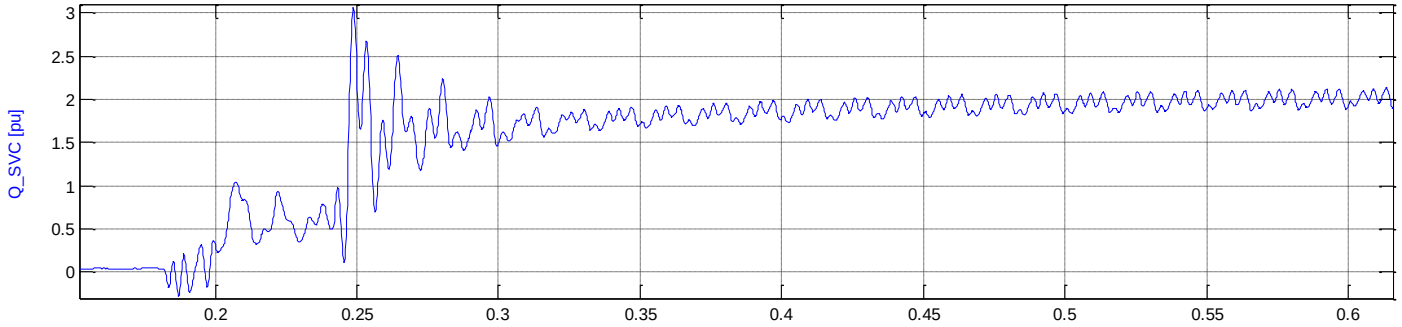


138 kV Phase to Phase Fault
SVC Transient Fault Recorder

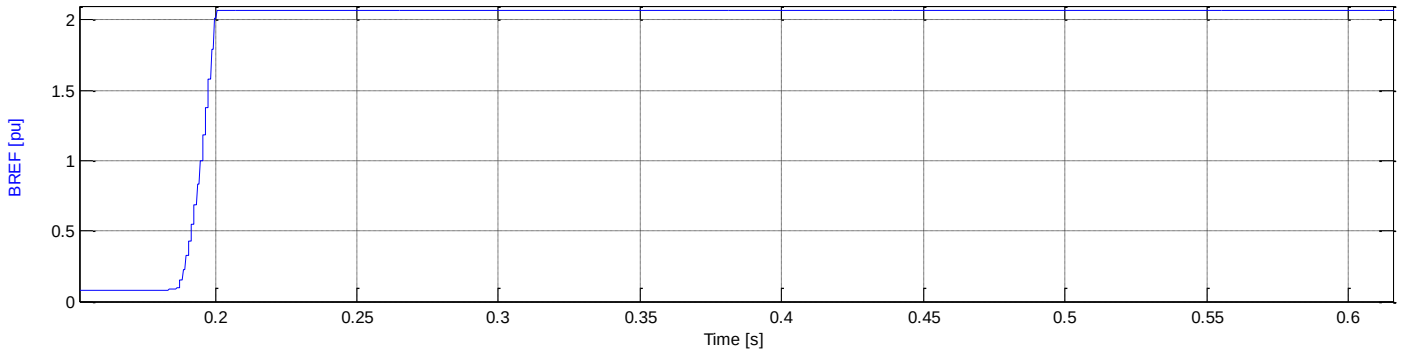
System Voltage



SVC Mvar Output



Suseptance Reference



138 kV Phase to Phase Fault
SVC Transient Fault Recorder

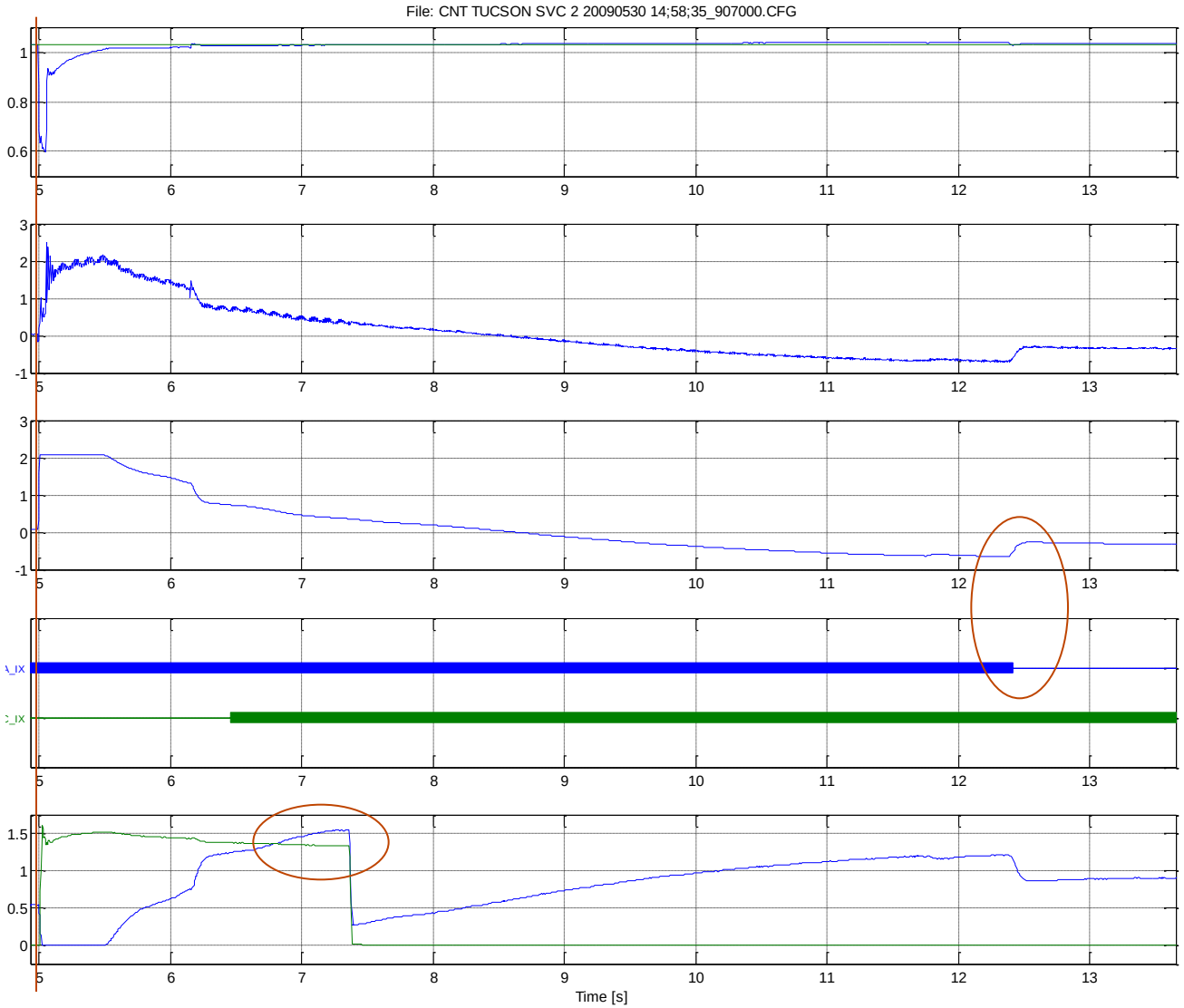
System Voltage

SVC Mvar Output

Suseptance Reference

MSC #1
MSC #3

I TCR
I TSC




WARNING
DO NOT ENTER WITHOUT A CLEARANCE FROM SYSTEMS SUPERVISORS OFFICE
WARNING
DO NOT ENTER WITHOUT A CLEARANCE FROM SYSTEMS SUPERVISORS OFFICE
ORTA
888-1880
DANGER
HIGH VOLTAGE

Predicted SVC Sound Propagation

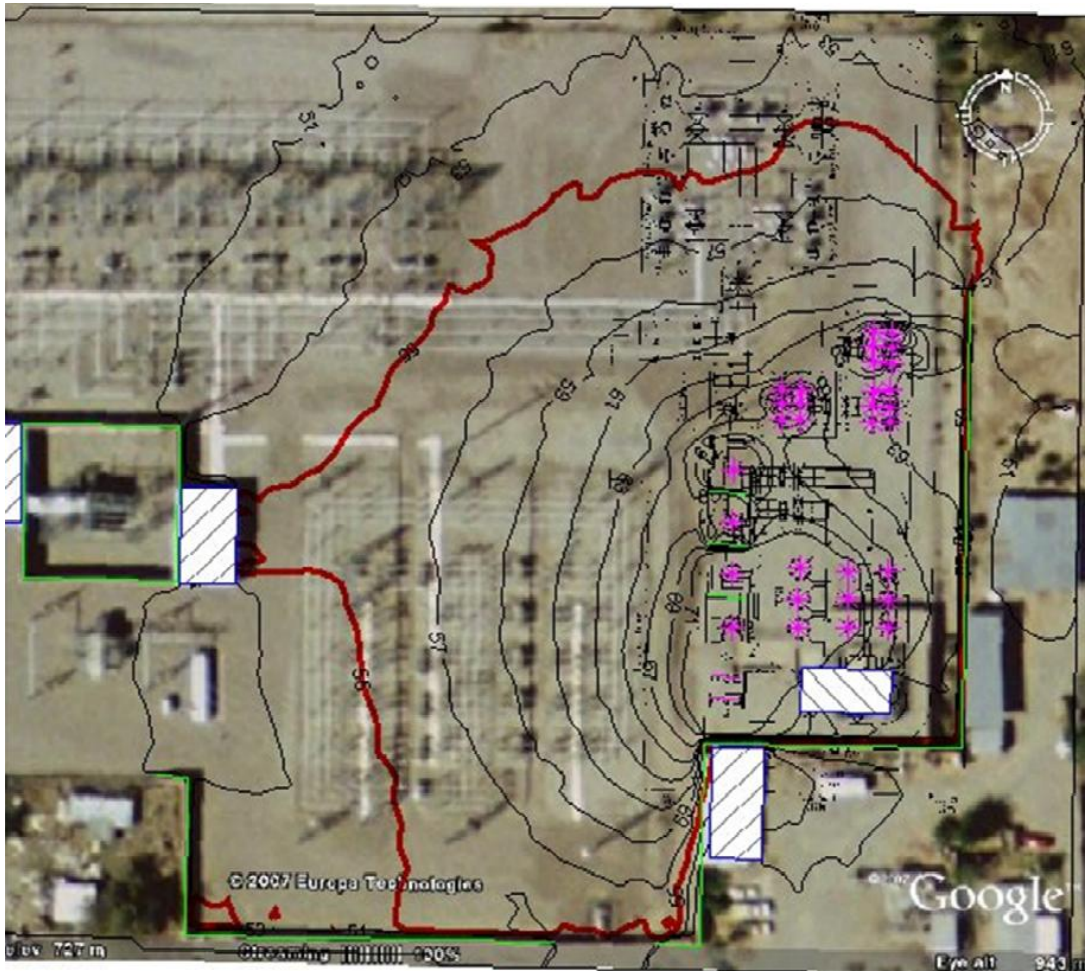
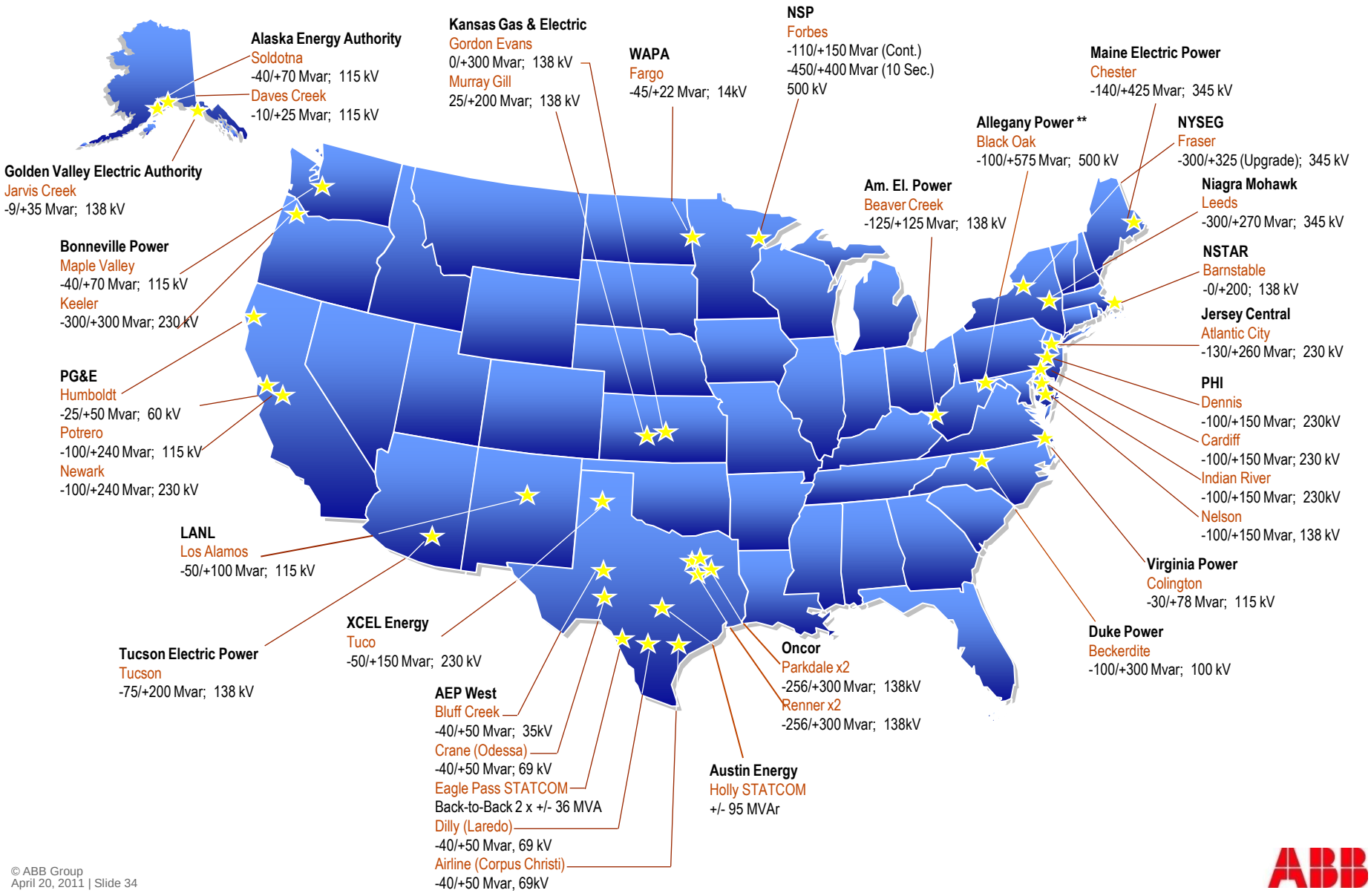
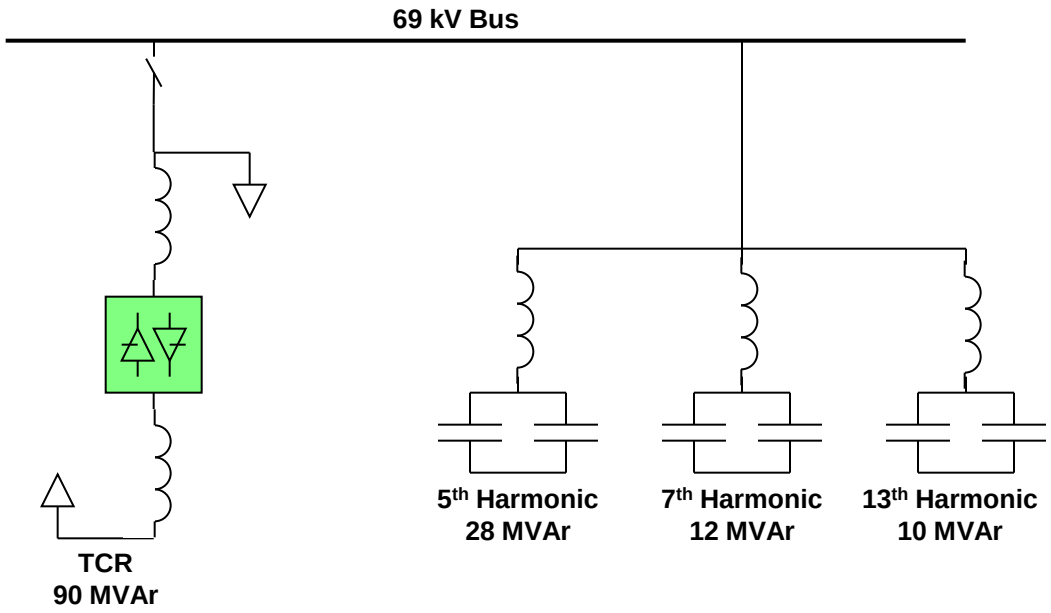


ABB SVC & STATCOM Utility Installations in the US

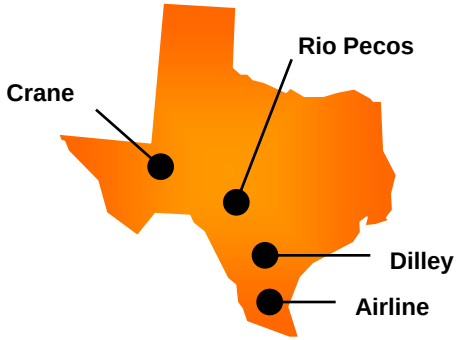


AEP Direct Connect - Single Line Diagram

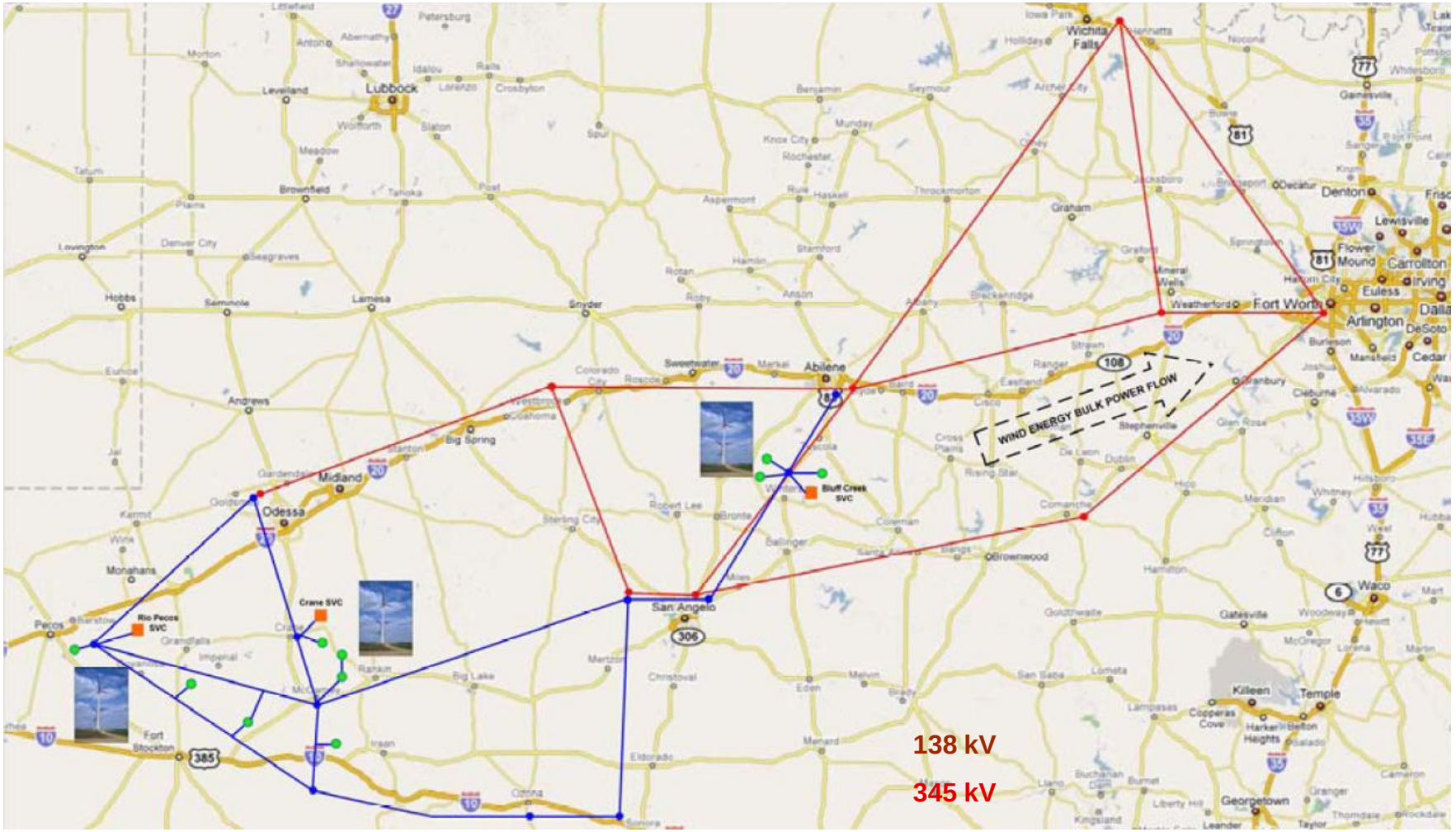
- **Benefits**
- Reduced Losses
- Smaller Footprint
- Reduced Delivery Time
- Reduced Maintenance Costs
- Reduced Equipment Delivery Risk
- Higher availability/reliability (w/o spare transformer)



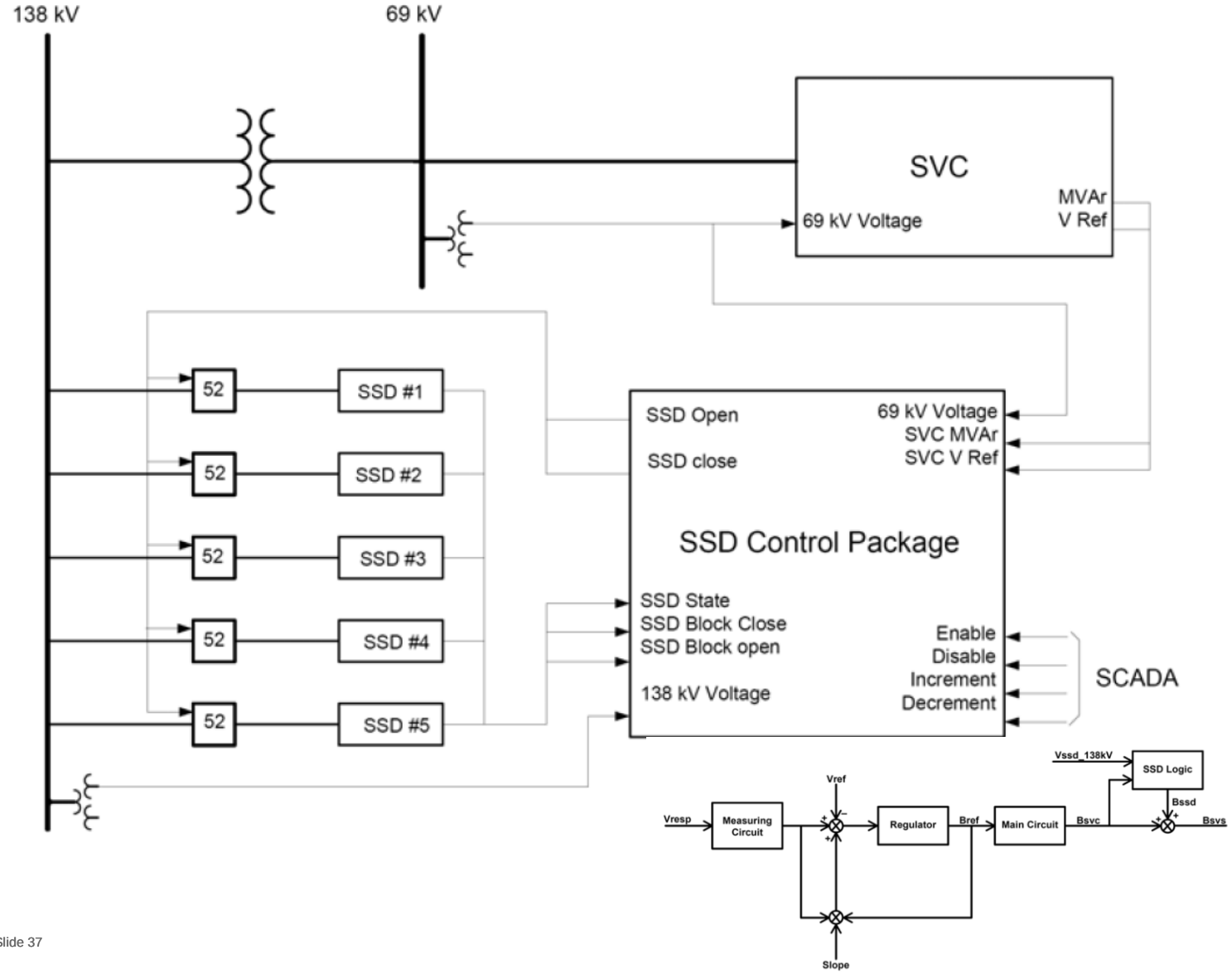
Rating: -40/+ 50 MVAr @ 69 kV



AEP Direct Connect
SVC & Static Shunt Device Locations



AEP Direct Connect
SVC & Static Shunt Device Control Logic



AEP Direct Connect Site Photos, Texas

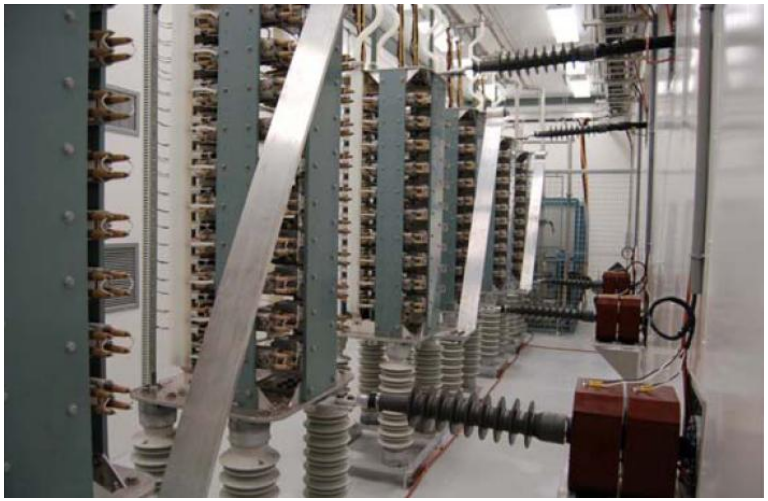

TCR Reactors


Inst. Transformers


Harmonic Filters

Valve Hall / Control Enclosure

AEP Direct Connect Site Photos, Texas



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for a better world™

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Automation & Power World 2011

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- Professional Development Hours (PDHs) and Continuing Education Credits (CEUs):
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  - 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.