REACTIVE (VAR) RESERVE MARGIN

NARUC

JOINT MEETING
ELECTRIC RELIABILITY STAFF SUBCOMMITTEE
ELECTRICITY STAFF SUBCOMMITTEE

November 13, 2005

Chifong Thomas

Pacific Gas and Electric Company™
WE DELIVER ENERGY.℠

Topics

- Reactive Power Fundamentals
- Study Methodology
- WECC Standards
- Reactive Power Market?

Reactive Power Fundamentals

- Total Power (MVA) consists of
  - Real Power (MW)
  - Reactive Power (MVAR)

  $|MVA| = (MW^2 + MVAR^2)^{1/2}$

- Like Real Power, Reactive Power needs to be controlled for voltage regulation:
  - To deliver quality power to load customers
  - For system reliability

- Unlike Real Power, Reactive Power cannot be effectively transmitted over long distances

Reactive Power Fundamentals

- At a system node:
  - Too much Reactive Power injection
    => high voltages => Flashovers, safety issues
  - Too little Reactive Power injection
    => low voltages => Equipment problems
  - Not enough reactive power reserve
    => voltage instability
    => blackout
- VAR needs are location-specific
- VAR needs must be met locally

Reactive Power Fundamentals

- VAR Producing Devices
  - Static
    - Lightly loaded lines
    - Shunt capacitors (load p.f., MSC, fixed)
    - Series capacitors
  - Dynamic
    - Synchronous Condensers
    - FACTS (e.g., SVC, STATCOM)
    - Generators

- VAR Absorbing Devices
  - Static
    - Heavily loaded lines
    - Shunt reactors
    - Series reactors
  - Dynamic
    - Synchronous Condensers
    - FACTS (e.g., SVC, STATCOM)
    - Generators

Decreasing Real Power transfer can increase voltage at the receiving end

Both Static and Dynamic Devices are needed

- Static devices to produce VARs + Static devices to absorb VARs
- Variable Reactive power sources can include both dynamic and static devices
- Dynamic Devices should not operate at their limits under normal conditions (i.e., must have reserves)
- Static Devices enable full range of operation from Dynamic Devices when needed

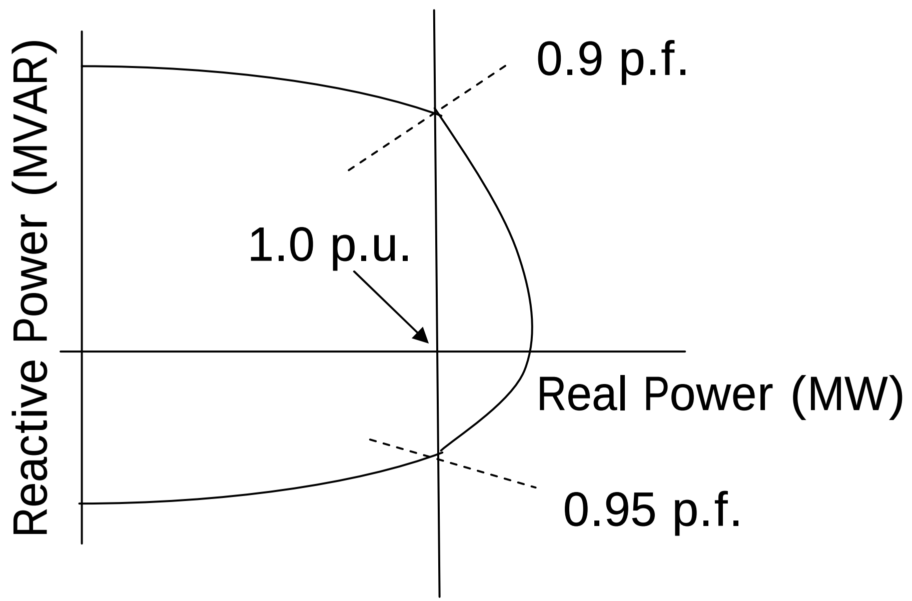
Response to Voltage Variations

- Load (Distribution)
  - Constant Power ($\propto$MVA)
  - Constant Current ($\propto$V)
  - Constant Impedance ($\propto V^2$)

Sequence of events when Transmission voltage drops
=> Distribution voltage drops
=> Voltage sensitive loads decrease
=> Increase Transmission voltage
=> LTC restores distribution voltage
=> Restores distribution loads
=> Decreases Transmission voltage
=> ...... LTC reaches limit

Window of opportunity to take corrective action

- Generator (Transmission)



Designed to operate within VAR Range and to have short-time over-excitation capability at no added cost

Reactive Power Supply Strategy

- Transmission system
  - Normal Conditions
    - Correct load p.f. with distribution capacitors before adding transmission voltage support devices
    - Shunt reactors to remove VAR in remote area with excessively high voltage
    - Shunt capacitors in load centers
    - Series capacitors to increase stability for heavy power transfer
    - Supply load from generators closer to load centers <u>if economic</u>
  - Emergency conditions
    - Generators
    - MSC
    - SVC
    - Generator Tripping at sending end and/or load shedding at receiving end to decrease power transfer

WECC Efforts since 1996 Disturbances

- TSS formed the Reactive Reserve Working Group (RRWG) in 1996
- Developed voltage stability methodology (P-V, V-Q analyses)
- Examine system performance after automatic devices have completed action, but before operator intervention

1996 RRWG Members

- Abbas Abed (SDG&E, Chair)
- Joaquin Aquilar (EPE)
- Nick Chopra (BCH)
- Peter Krzykos (APS)
- Andy Law (WWP)
- Brian Lee (BCH)
- Frank McElvain (TSGT)
- Saif Mogri (LADWP)
- Les Pereira (NCPA)
- Craig Quist (NPC)
- Ronald Schellberg (IPC)
- Joe Seabrook (PSE)
- Chifong Thomas (PG&E)
- Boris Tumarin (EPE)

WECC Reactive Reserve Documents

- 1996 RRWG Report:
  - *Voltage Stability Criteria, Undervoltage Load Shedding Strategy and Reactive Power Reserve Monitoring Methodology*, May 1998
  http://www.wecc.biz/documents/library/procedures/operating/PCC_ReactiveReserve_07-11-03.pdf

- Other WECC Reactive Power related documents:
  - *Undervoltage Load Shedding Guidelines*, 1999
  http://www.wecc.biz/documents/library/procedures/operating/Undervoltage_Load_Shedding_Guidelines.pdf
  - *Summary of WECC Voltage Stability Assessment Methodology*, 2001
  http://www.wecc.biz/documents/library/procedures/operating/WECC_Voltage_Stability_Methodology_7-11-01.pdf

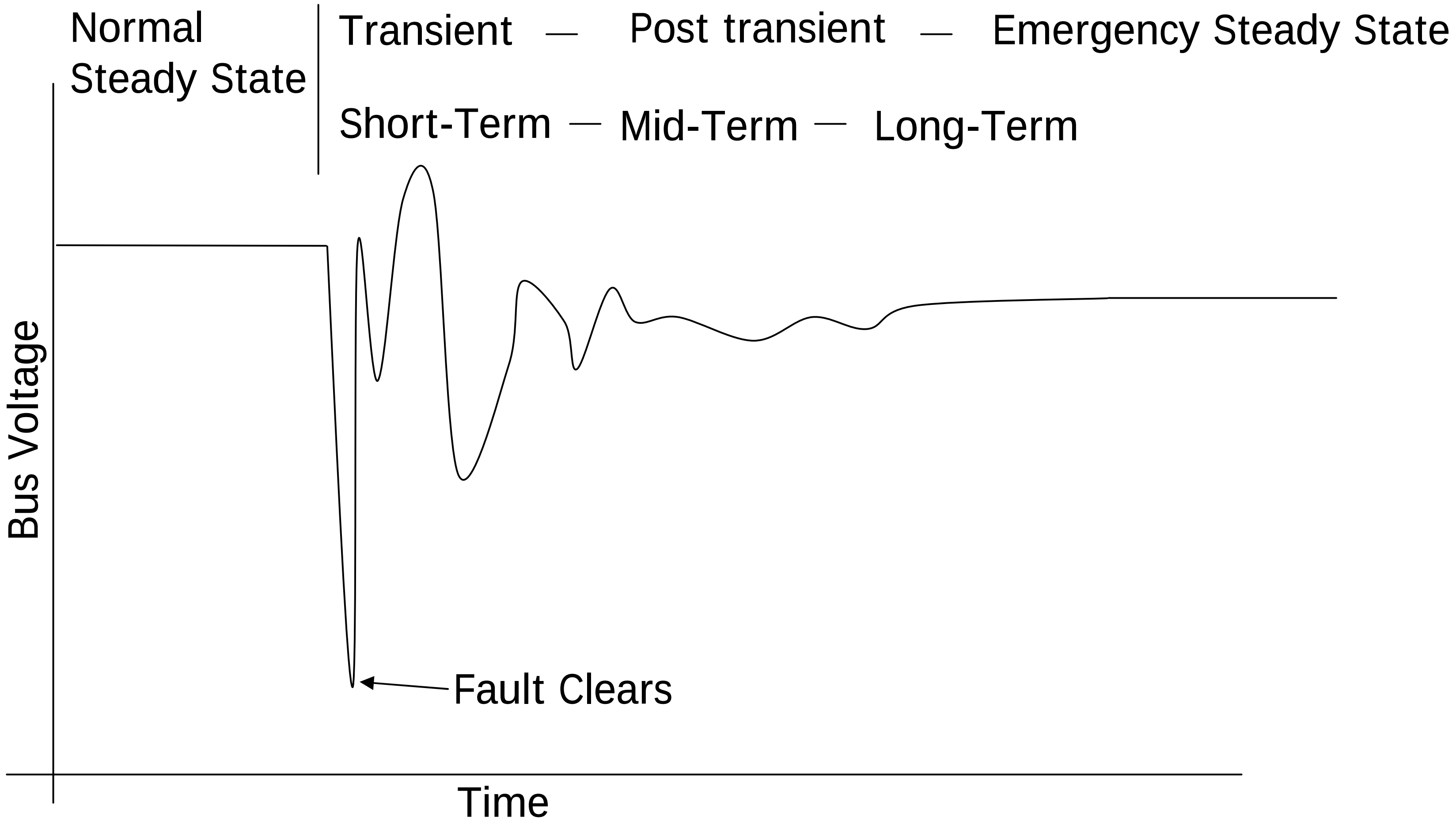
- WECC Planning Standards 1.D.
  WECC-S1; WECC-S2; WECC-S3 and WECC-S4
  http://www.wecc.biz/documents/library/procedures/planning/WECC-NERC_Planning%20Standards_4-10-03.pdf

2004 RRWG

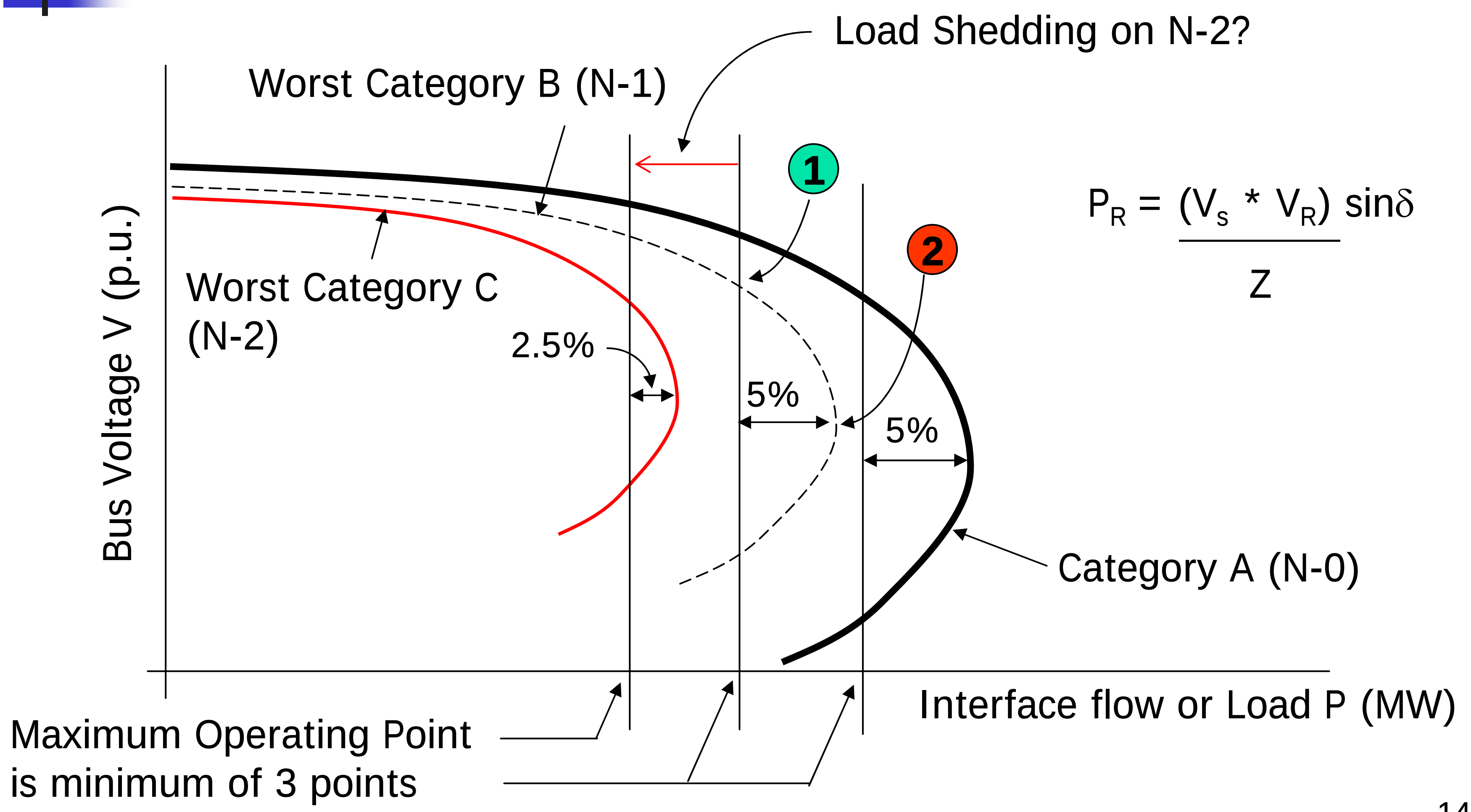
Availability of updated information
=>TSS Re-established RRWG

- Bring the existing documents and guidelines in line with the NERC/WECC Planning Standards
- Provide WECC members with a guide in implementing Planning Standard 1.D
- 2004 RRWG Members:
  - Shamir S. Ladhani, ENMAX Power Corporation (Chair)
  - Craig Quist, PacifiCorp
  - Joe Seabrook, Puget Sound Energy Inc.
  - Chifong Thomas, Pacific Gas & Electric Company

Time Frames in Voltage Stability Studies

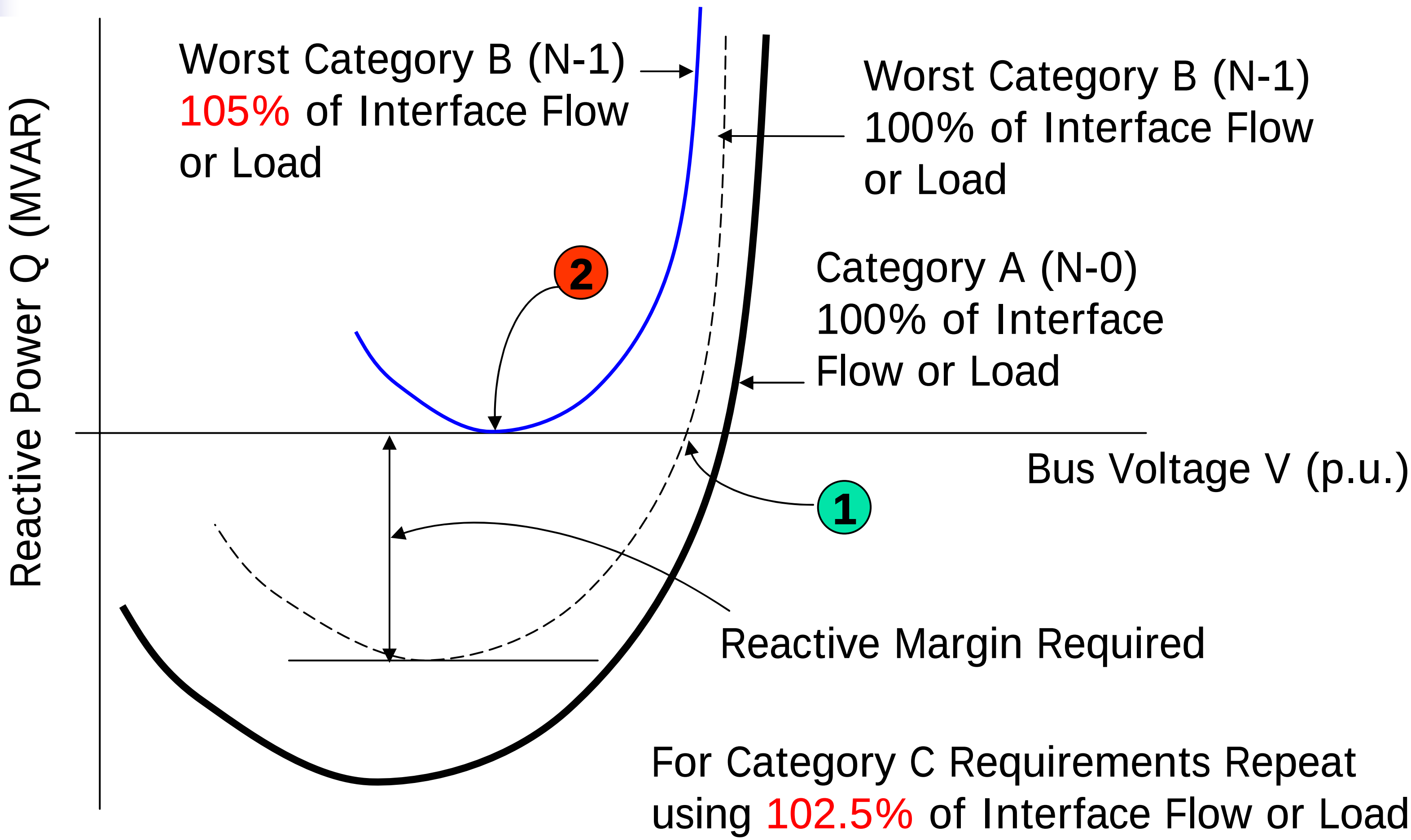


P-V Analysis



Load Shedding on N-2?
Worst Category B (N-1)
1
2
$P_R = \frac{(V_s * V_R) \sin\delta}{Z}$
Worst Category C
(N-2)
2.5%
5%
5%
Bus Voltage V (p.u.)
Category A (N-0)
Interface flow or Load P (MW)
Maximum Operating Point
is minimum of 3 points

V-Q Analysis



Worst Category B (N-1)
105% of Interface Flow
or Load
Worst Category B (N-1)
100% of Interface Flow
or Load
2
Category A (N-0)
100% of Interface
Flow or Load
Reactive Power Q (MVAR)
Bus Voltage V (p.u.)
1
Reactive Margin Required
For Category C Requirements Repeat
using 102.5% of Interface Flow or Load

Consideration of Uncertainties

- Customer real and reactive power demand greater than forecasted
- Approximations in studies (Planning and Operations)
- Outages not routinely studied on the member system
- Outages not routinely studied on neighboring systems
- Unit trips following major disturbances
- Lower voltage line trips following major disturbances
- Variations on neighboring system dispatch
- Large and variable reactive exchanges with neighboring systems
- More restrictive reactive power constraints on neighboring system generators than planned

Consideration of Uncertainties (2)

- Variations in load characteristics, especially in load power factors
- Risk of the next major event during a 30-minute adjustment period
- Not being able to readjust adequately to get back to a secure state
- Increases in major path flows following major contingencies due to various factors such as on-system undervoltage load shedding
- On-system reactive resources not responding
- Excitation limiters responding prematurely
- Possible Remedial Action Scheme failure
- Prior outages of system facilities
- More restrictive reactive power constraints on internal generators than planned.

WECC Planning Standards I.D

- WECC-S1
  For transfer paths, post-transient voltage stability is required with the path modeled at a minimum of 105% of the path rating (or Operational Transfer Capability) for system normal conditions (Category A) and for single contingencies (Category B). For multiple contingencies (Category C), post-transient voltage stability is required with the path modeled at a minimum of 102.5% of the path rating (or Operational Transfer Capability).

WECC Planning Standards I.D

- WECC-S2
  For load areas, post-transient voltage stability is required for the area modeled at a minimum of 105% of the reference load level for system normal conditions (Category A) and for single contingencies (Category B). For multiple contingencies (Category C), post-transient voltage stability is required with the area modeled at a minimum of 102.5% of the reference load level. For this standard, the reference load level is the maximum established planned load limit for the area under study.

WECC Planning Standards I.D

- WECC-S3
  Specific requirements that exceed the minimums specified in I.D WECC-S1 and S2 may be established, to be adhered to by others, provided that technical justification has been approved by the Planning Coordination Committee of the WECC.

- WECC-S4
  These Standards apply to internal WECC Member Systems as well as between WECC Member Systems.

Reactive Power Market?

Considerations:

- Local supply – Market Power Issue?
- Cost to supply reactive power is low compared to real power
- Interdependency between Real and Reactive Power
- Under normal conditions system reliability requires devices
  - To supply and absorb reactive power at different locations <u>and</u>
  - Reactive Reserves (i.e., ideally minimum VARs from variable VAR devices, e.g. synchronous condensers, generators, SVC, MSC, etc.)
- Correct mix of dynamic vs. static VARs
- Coordination between reactive power sources
- Impacts on time to install new facilities -- how would reliability be affected?

Questions?