

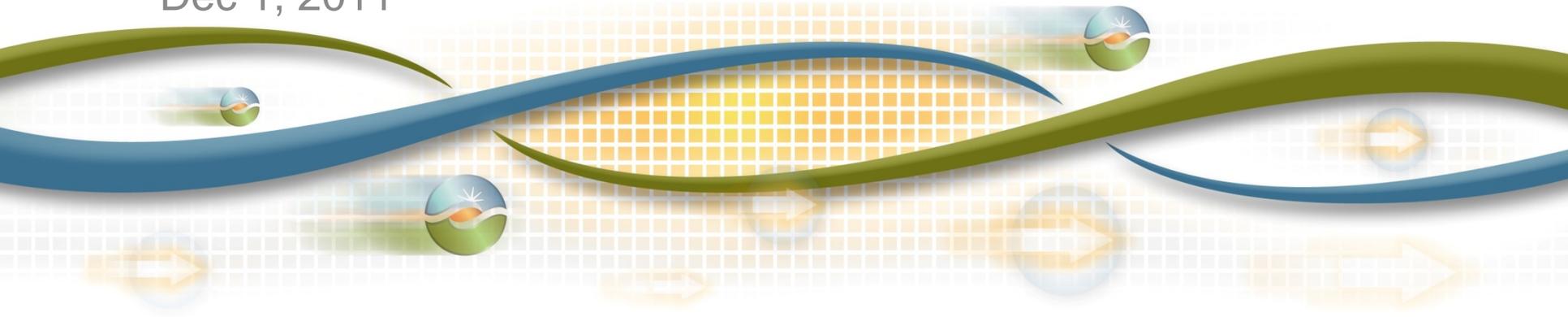
Considerations of Reactive Power/Voltage Control in California ISO Control Center

FERC Workshop: Voltage Coordination on High Voltage Grids

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Reactive Power and Voltage Control

- Reactive Power Management and Voltage control play an important role in supporting the real power transfer across a large scale transmission system
- Voltage profiles may become bottlenecks in transferring increased amount of power across the interfaces
- Reactive power control/optimization determines the sufficient amount and appropriate location of reactive power support in order to maintain a secure voltage profile

Reliability Coordination - Operations Planning

- **NERC Standard IRO-008-1**

- “The WECC Reliability Coordinator (RC) shall conduct Operational Planning Analyses to assess whether the planned operations **for the next day** within its Wide Area, will exceed any of its Interconnection Reliability Operating Limits (IROLs) during anticipated normal and Contingency event conditions. (NERC Standard IRO-008-1 R1). The WECC RC Operational Planning Analyses shall also identify potential exceedances of equipment/facility ratings and/or identified System Operating Limits (SOL).”

Current Voltage and Reactive Power (VAR) Management for CAISO Operations

- CAISO Responsibilities
- Participating Entity Responsibilities
 - Participating generators
 - Participating load/UDC
 - Participating transmission owners (PTOs)

CAISO Responsibilities for VAR Management

- Ensure that participating entities maintain appropriate voltage schedules
- Coordinate switching of voltage support equipment such as shunt capacitors and reactors
- Ensure that participating generating units operate within an appropriate power factor range (0.9 lag and 0.95 lead), exception to this via participating generator agreement
- Coordinate events and changes that impact the voltage support equipment availability, reliability or ability to operate within its applicable power factor range

CAISO Responsibilities for VAR Management

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- Ensure that the grid provides the appropriate reactive power supply and reserves to the interconnected power system
- Coordinate and optimize voltage schedules and VAR flows between Control areas for system stability
- CAISO does not operate a VAR market, the Reactive power and Voltage support are procured and coordinated through long term contracts with Reliability must run units (RMR)

Participating Entity Responsibilities for VAR Management

- Participating generators operate generating units within the established protocols and procedures, specifically normal MW/MVAR capacity profile at the applicable voltage profile
- Participating generators produce or consume reactive power when requested by the ISO
- Participating loads/UDCs operate in accordance with good utility practice within established protocols and operating procedures and adhere to specified voltage schedules

Participating Entity Responsibilities for VAR Management

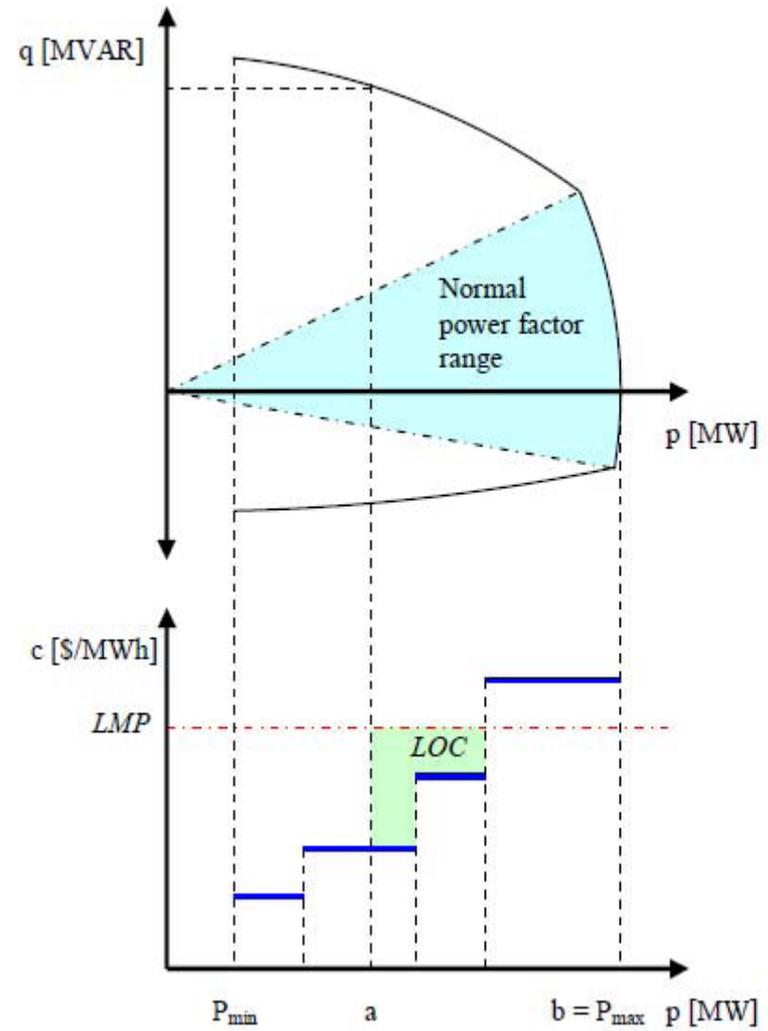
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- Participating load/UDCs maintain reactive power flow at the grid interface points within the applicable power factor range (0.97 lag and 0.99 lead) in operation as well as planning phase
- Participating Transmission Owners (PTO) Operate the system in accordance with good utility practice and in a manner that ensures safe and reliable operation
- PTO maintains appropriate voltage schedules
- PTO notify ISO of any switching events of voltage support equipments

Compensating Reactive Power Support

No remuneration for nominal voltage support from participating generating units while operating within their applicable power factor ranges.

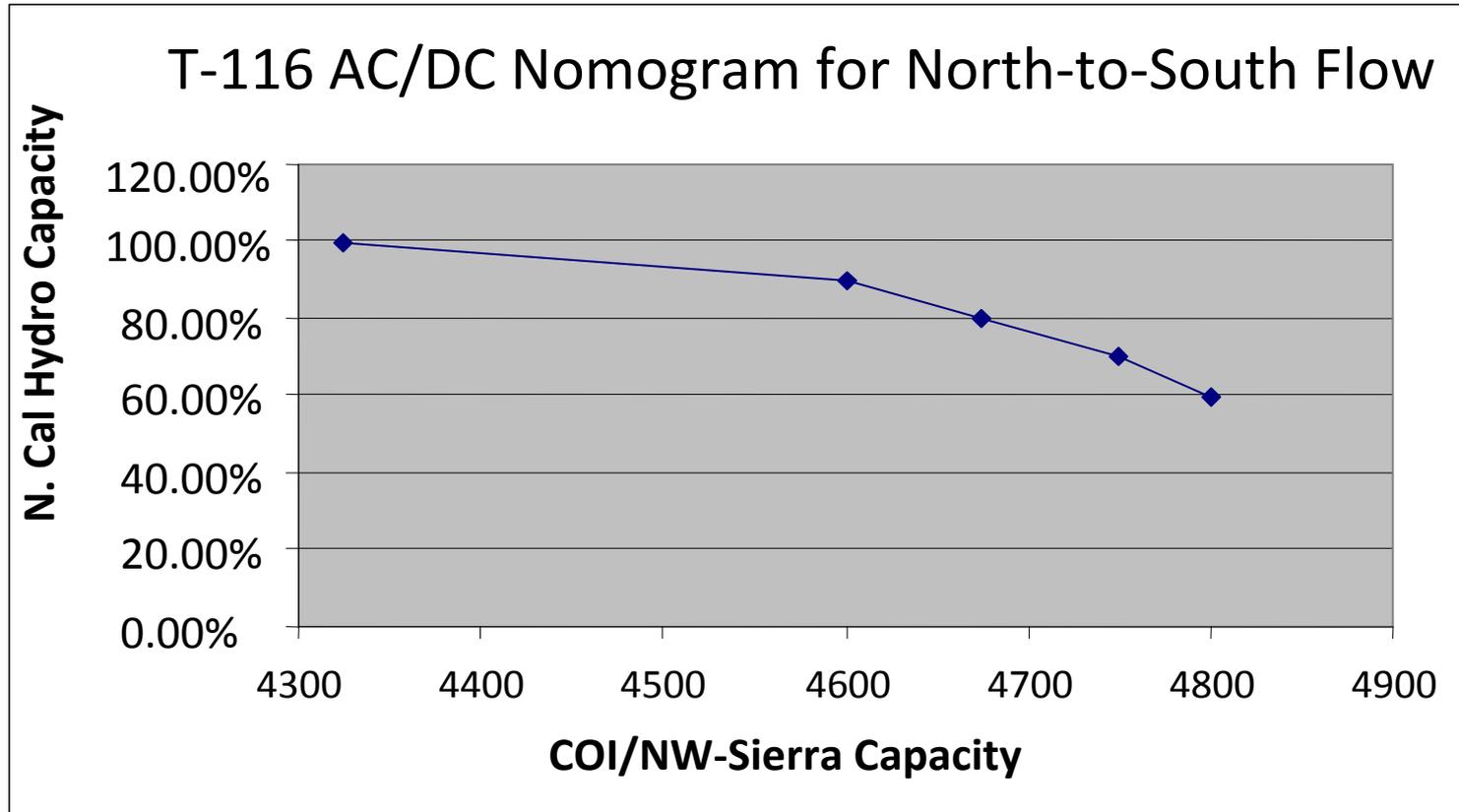
Lost Opportunity Cost (LOC) remunerated to participating units when unit instructed to provide additional voltage support by operating outside of the applicable power factor range (*not a formal reactive power market*)



Transmission Limits and Nomograms

- Dynamic Operating Transfer Capacity (OTC) transmission limits and Nomograms are determined by offline power system analysis studies using the entire WECC interconnected network model with seasonal prediction of operating conditions and a predefined contingency list
- A Nomogram is a set of operating or scheduling rules which are used to ensure that simultaneous operating limits are respected, in order to meet NERC and WECC operating criteria
- Operating within the safe region of a Nomogram ensures that after a contingency event, the resulting flows would not cause a violation of established thermal, voltage and/or stability limits.

Sample Nomogram



Voltage Controls Must be Distributed on the Grid

- Controls: Capacitors, reactors, SVC, LTCs, AVR's fitted with generators, series compensators, voltage source convertors (DC line convertors)
- AVR's are most critical reactive power devices as they are automatic and provide continuous control
- Fast reactive controls are needed to avoid voltage collapse
- Reactive power does not travel over long distance – need distributed reactive power resources for effective voltage control
- Reactive controls must be distributed through out the network

Need for Effective VAR Management

- Increased power transfers across interfaces
- Increased intermittent renewable resources in the grid
- Need effective control tools due to minute by minute decisions in today's electricity market to run the grid reliably and in most economic way
- Limits calculated in planning studies are usually categorized as being “conservative”
- What was called “conservative” is not accurate enough in today's operation of grid with electricity markets where network topology and system conditions may have changed significantly from planning assumptions

Need for Effective VAR Management

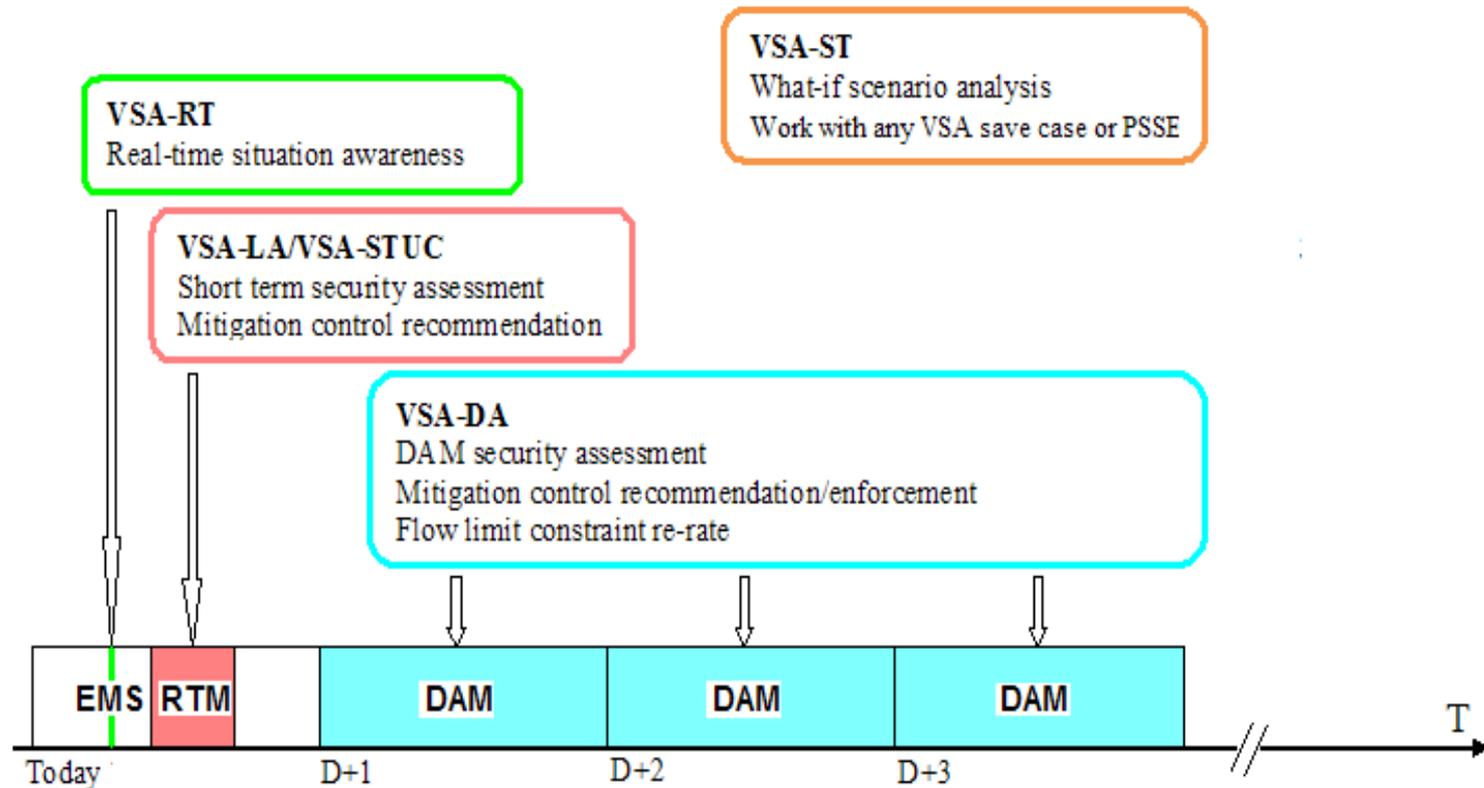
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- Changing system conditions could be due:
 - Unplanned outages in extreme environmental conditions
 - De-ratings
- In sudden fluctuations in planned dispatch due to intermittent renewable generators – System Operator may manually commit units via manual exceptional dispatch
- Need more advanced VAR management tools to deal with sudden fluctuation in generation and abnormal system conditions

On-Line Voltage Stability Analysis

- *Voltage instability* - progressive and uncontrollable decline in voltage after disturbance, increase in load demand, or change in other system conditions, often results in system disintegration or blackout.
- The main cause is the inability of the power system to meet the demand for reactive power.
- The point at which the system becomes unstable is termed the *Point of Collapse*, also called the *nose point*.
- *Voltage stability margin* is a parameter which measures the distance to instability determined for a selected loading or stress direction in MW.
- The voltage magnitude alone is not a good indicator of voltage stability or security.
- Voltage stability margin better describes the ability of a power system to withstand stress to maintain voltage stability.

Roadmap of the Integration of the On-Line Voltage Stability Analysis Application at CAISO



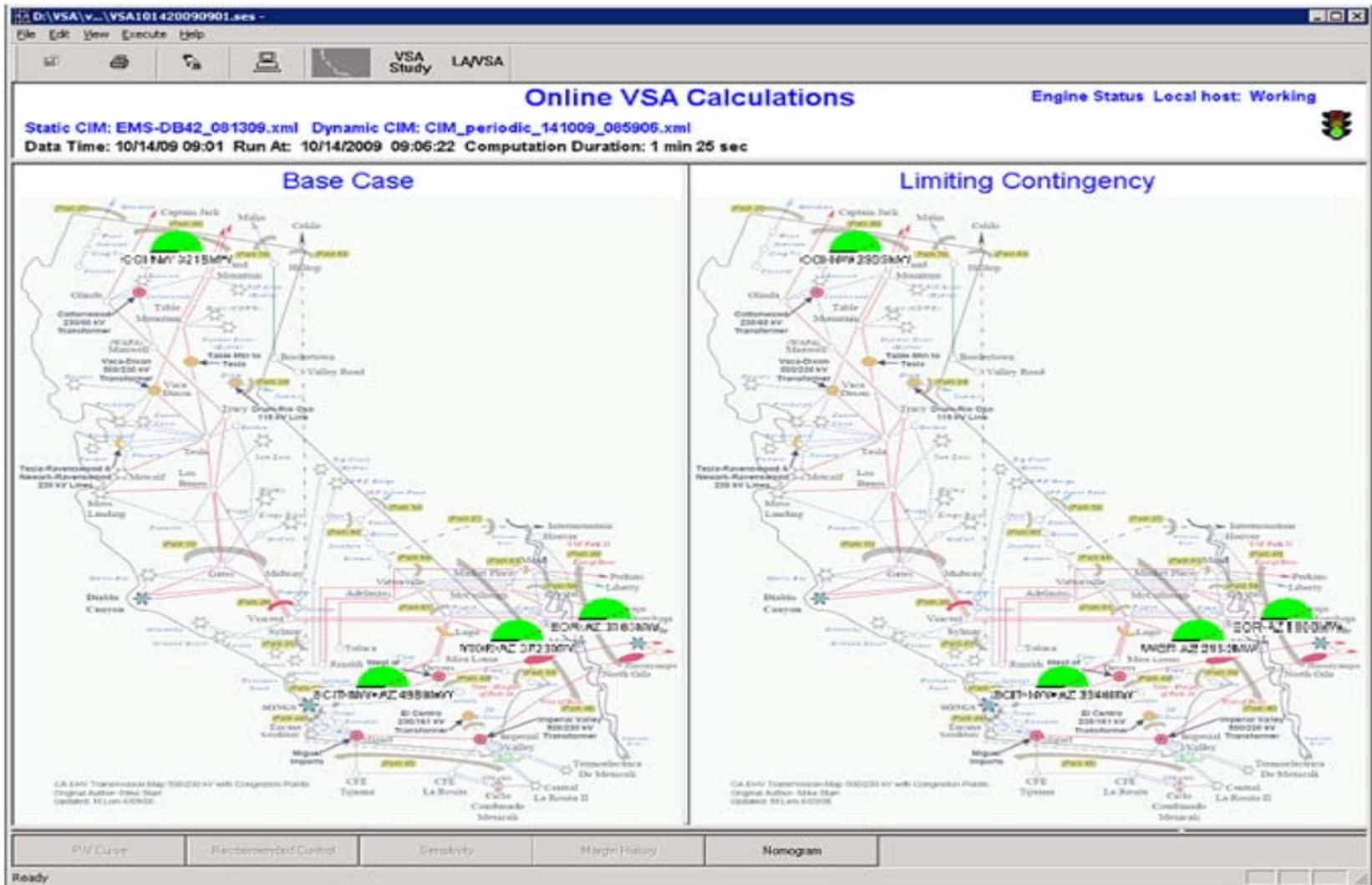
Integration of On-Line VSA with EMS and Market System at CAISO

- VSA and the EMS System Integration
 - Provides Real-time situation awareness
 - SE solutions as base case
 - Fully automatic with High Availability (HA)
 - Software operational since June 2009
- Importance of VSA and Market System Integration
 - Increased renewable penetration level with highly volatile, intermittent nature and their typical remote location from the load centers are detrimental factors to power system reliability
 - Integrated VSA may verify the system conditions as set out in the DAM or RTM to provide better situational awareness of the security of the system and the operating limits in terms of voltage stability margins
 - VSA can potentially allow the transmission limits found in offline studies to be updated based on the current network model conditions, thus allowing the ISO to reliably operate the grid at lower cost, and the consumers to reap the benefit of lower market pricing.
 - Software operational since Nov 2010 for Day-Ahead Market Results

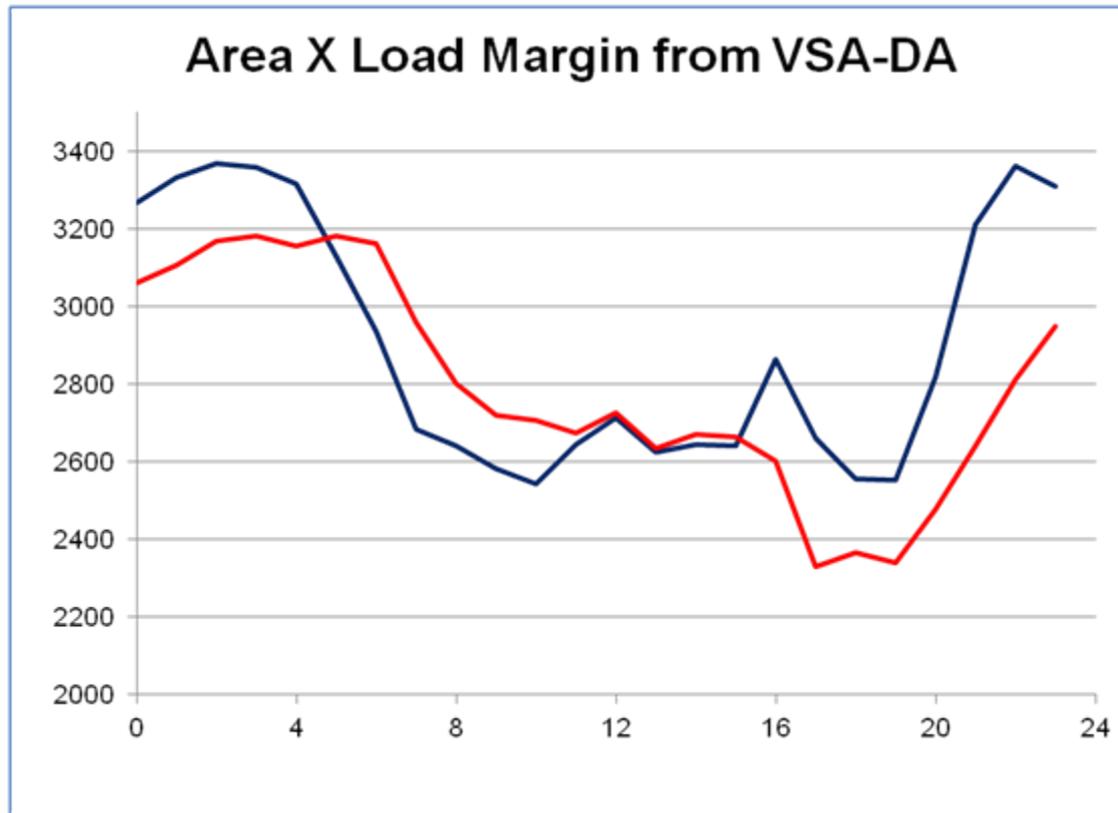
Important VSA Results

- System Load Margin
- Reactive Power Margin
- Interface Flow Limit
- Interface Flow Margin
- Interface Safety Margin
- Limiting Contingency (worst contingency under the given conditions)
- Weakest Bus
- Preventive/Enhancement Control Recommendations

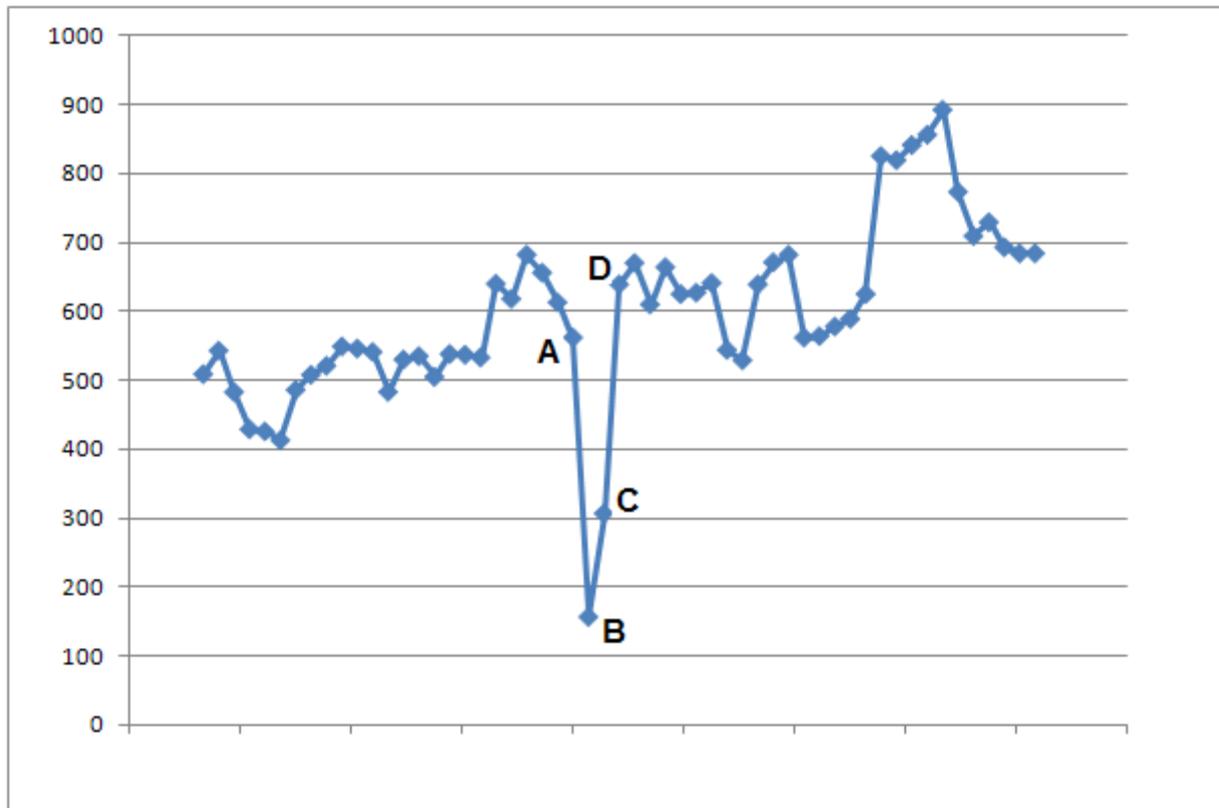
VSA-RT Geographical Interface Margin Display



Sample VSA-DA Results: Area X Load Margin for Two Different Trading Days



Sample Case Study: Area X Load Margin



	Event	Load Margin(MW)
A	Pre-incident	562
B	After units xxx shutdown	157
C	After load shedding	307
D		639

Future Development Work

- Improved incremental loss modeling in optimization algorithm
- VAR Optimization Integration
 - Un-optimized VAR flows can cause or intensify overloads, increase MW losses, or transmission congestions
 - Congestion management based on real power re-distribution may adversely influence system voltage profile
 - AC power flow algorithm supports local VAR controls for voltage regulation
 - Reactive power optimization and compensation - need to solve the congestion problem while considering voltage security within a competitive market environment



California ISO
Shaping a Renewed Future

Thank you

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