

Panel on Voltage Management

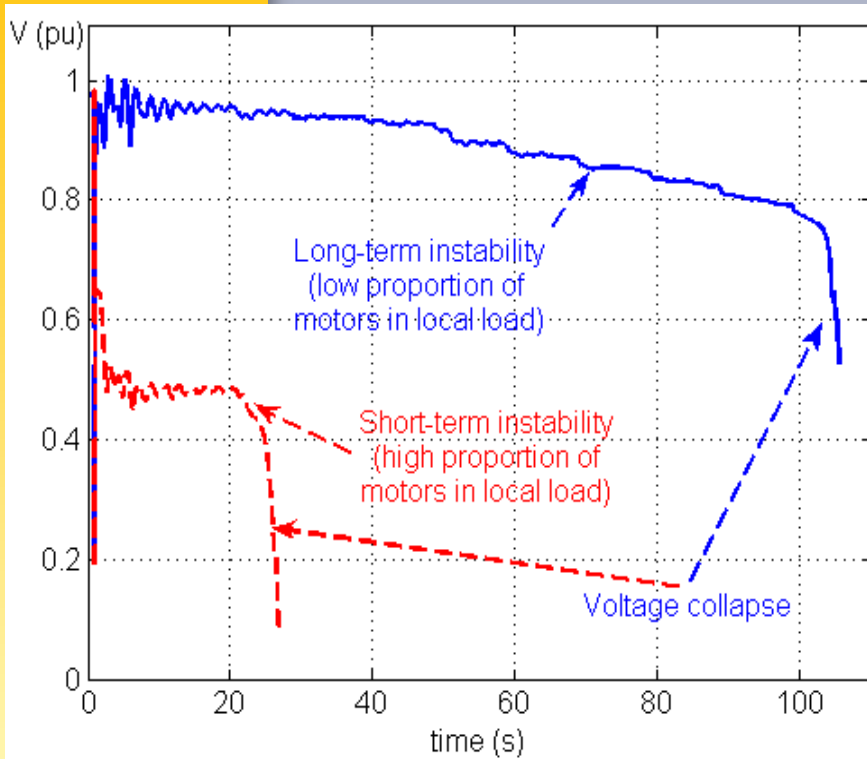
- Introduction – Damir Novosel
- Gordon Matthews – BPA Operational Aspects and Solutions
- Ron Markham - PG&E Operational Aspects
- Bharat Bhargava - EPG Solutions
- Yuri Makarov - PNNL Solutions
- Jay Giri - Alstom Grid Solutions
- Dejan Sobajic – EI Aspects

***i*-PCGRID Workshop 2013**

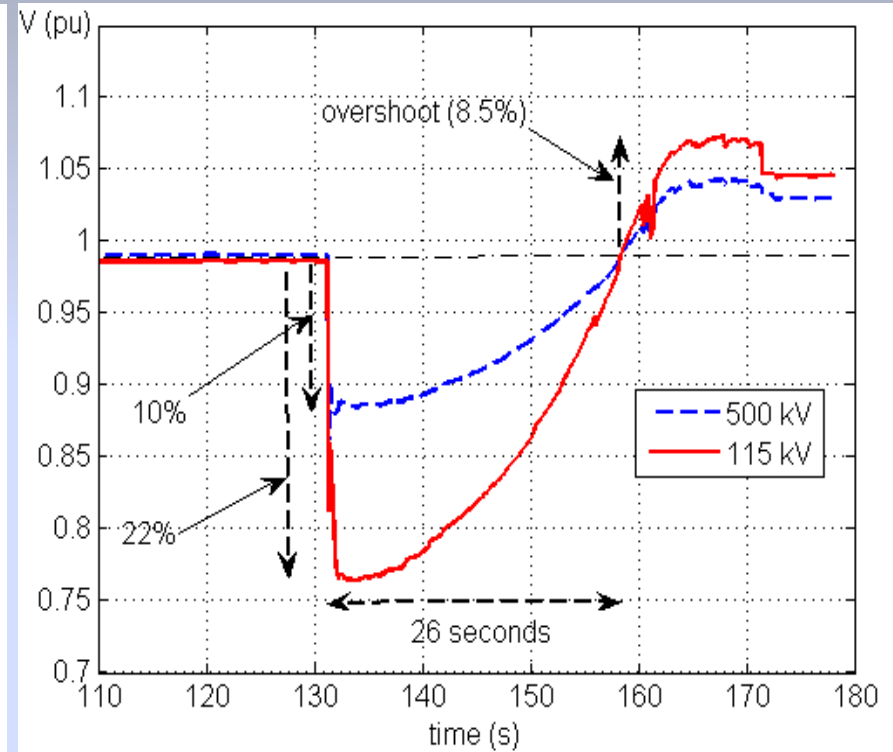
Innovations in Protection & Control for Greater Reliability Infrastructure Development

Voltage Related Issues

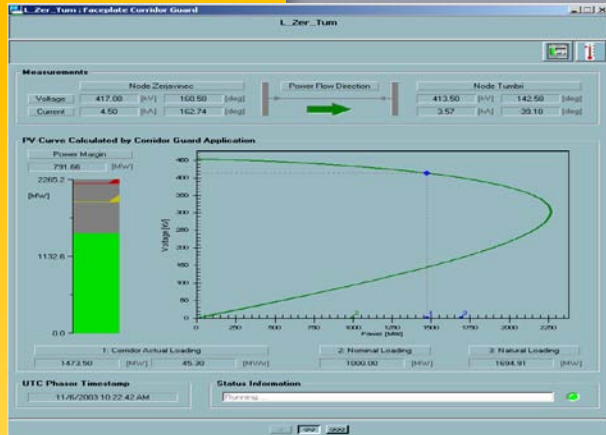
Voltage Instability: Short- and Long- Term



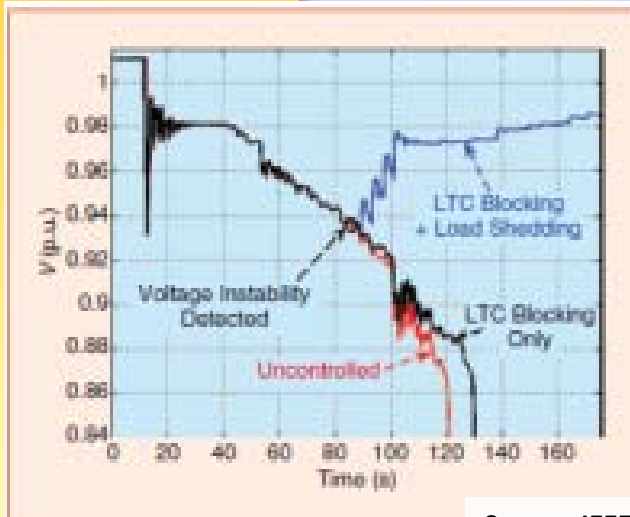
Fault Induced Delayed Voltage Recovery (FIDVR)



Voltage Stability Assessment



Source: ABB



Source: IEEE
P&E Magazine

Model-based simulation tools:

- Voltage Stability Assessment (VSA) based on State Estimation contingency analysis
- Tracking the relative distance from voltage instability continually in real-time
 - Distance to the nose of the PV curve
 - State Estimation based stability boundary
- Sensitive to model accuracy and dynamic system changes

Measurement-based indicators:

- Monitor available reactive power levels (capacitor/reactor reserves, tap-changers)
- Singular Value Decomposition (SVD)/Sensitivity
- Distance of the load's apparent impedance to the Thevenin impedance – Real-time voltage instability indication (VIP, REI, VIP Improved/RVII)

High-Level Method Assessment

Measurement-Based

Advantage

Moderate

None

	Accuracy	Easy to Interpret	Data Req.	Comput. Burden	Local/ WA/ FIDVR
<i>VIP improved</i> [^]	Moderate	Advantage	Advantage	Advantage	Advantage
<i>VIP</i> [^]	None	Advantage	Advantage	Advantage	Moderate
<i>REI</i> [^]	None	Advantage	Advantage	Advantage	Moderate
SVD	Advantage	Moderate	Moderate	Moderate	None
Sensitivity	Moderate	Moderate	Advantage	Advantage	Moderate
Time Series	Moderate	Moderate	Advantage	Moderate	None

* [^] Pilot or Product Installation

WA – Wide Area

High-Level Method Assessment

Model-Based

Advantage

Moderate

None

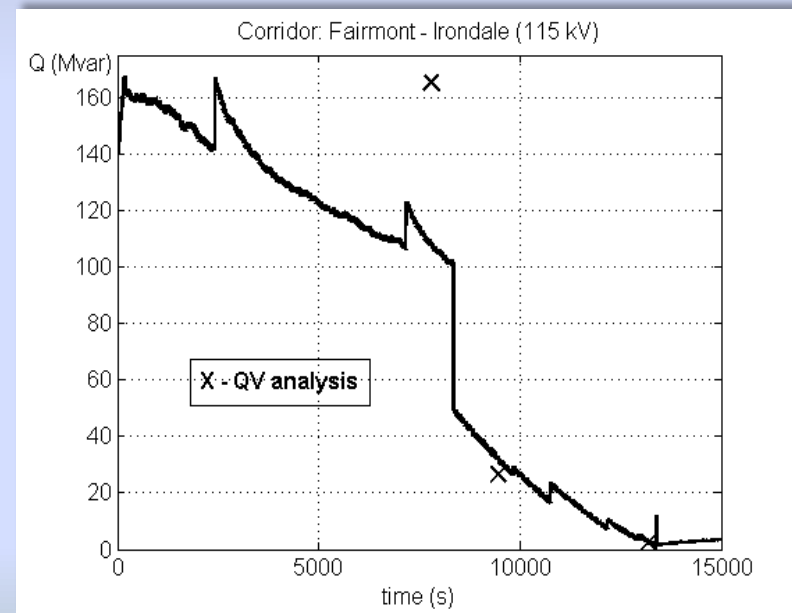
	Accuracy	Easy to Interpret	Data Req.	Comput. Burden	Local/ WA/ FIDVR
<i>RT Nomogram</i> ^{**^}	Advantage	Advantage	None	Moderate	None
<i>Contingency VSA</i> [^]	Advantage	Advantage	None	None	Moderate
<i>Cont. Power Flow</i> [^]	Moderate	Advantage	None	None	None
<i>Reactive Reserve</i> [^]	Moderate	Moderate	Moderate	Moderate	Moderate
Decision Trees	Advantage	Moderate	None	Moderate	None
Sensit./Eigenval.	Advantage	Moderate	None	Moderate	None

* ^ *Pilot or Product Installation*

WA – Wide Area

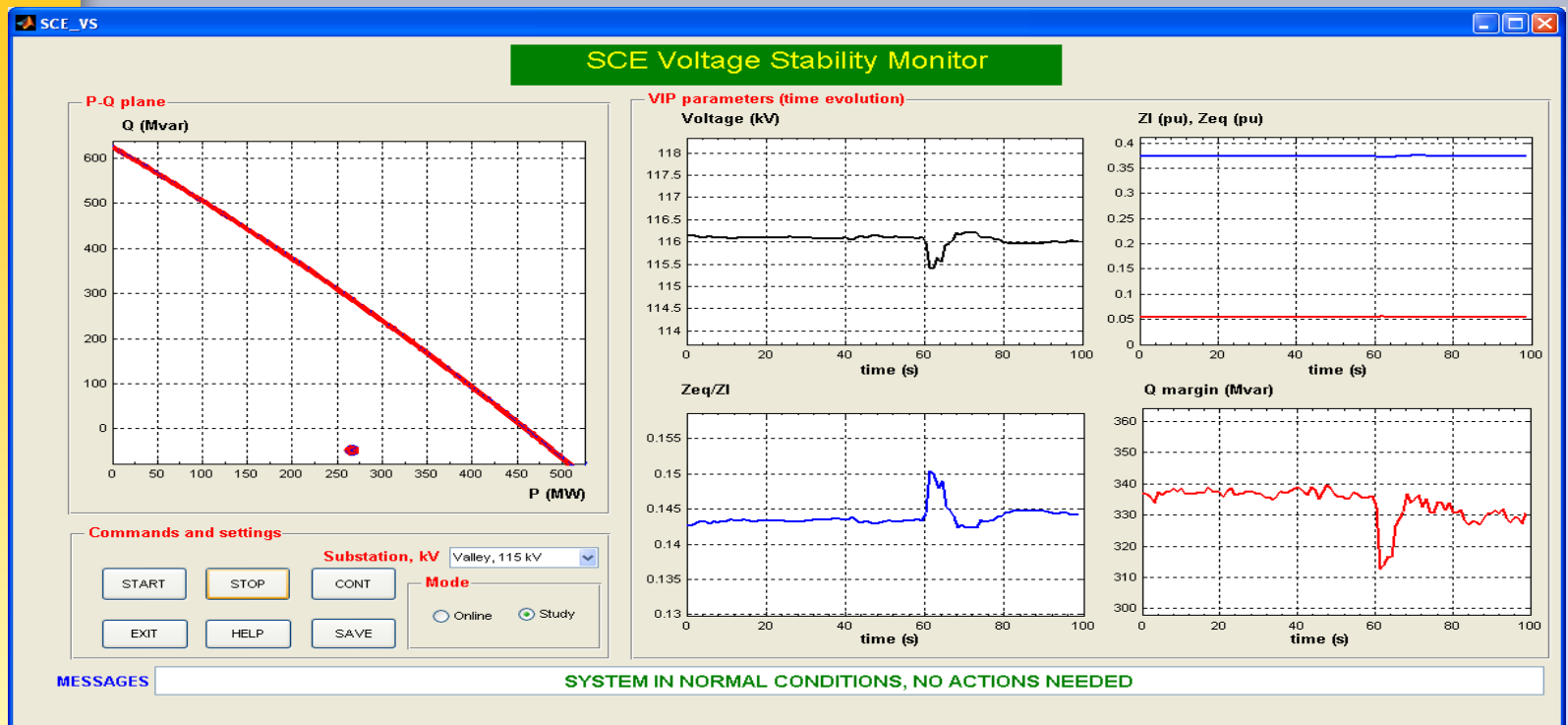
Real-time Monitoring Advantages

- Model-free, fast real-time voltage instability detection method, independent of state estimation using PMU and SCADA data
- Implementation in several variants: bus, load center, transmission line, transmission corridor
 - Calculates Q-margin & other indices for proximity to voltage collapse
 - Stability boundary calculated with real-time PMU data refresh rate
- Able to distinguish FIDVR from voltage instability even if voltage is very low
- Easily combined with other methods and indices
 - Reactive power monitoring
 - Could initiate model-based contingency analysis



Real-Time Monitoring Example: SCE Pilot Installation

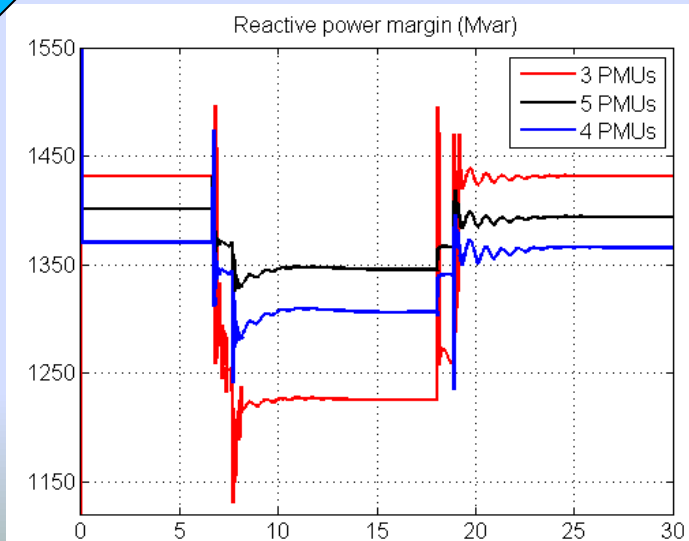
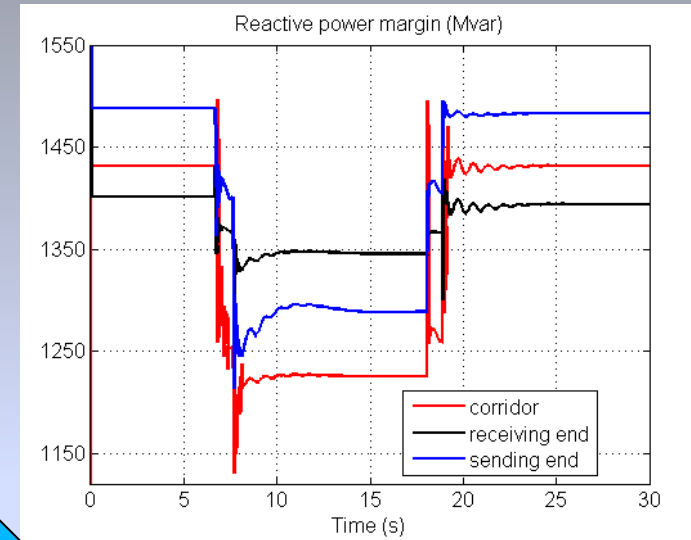
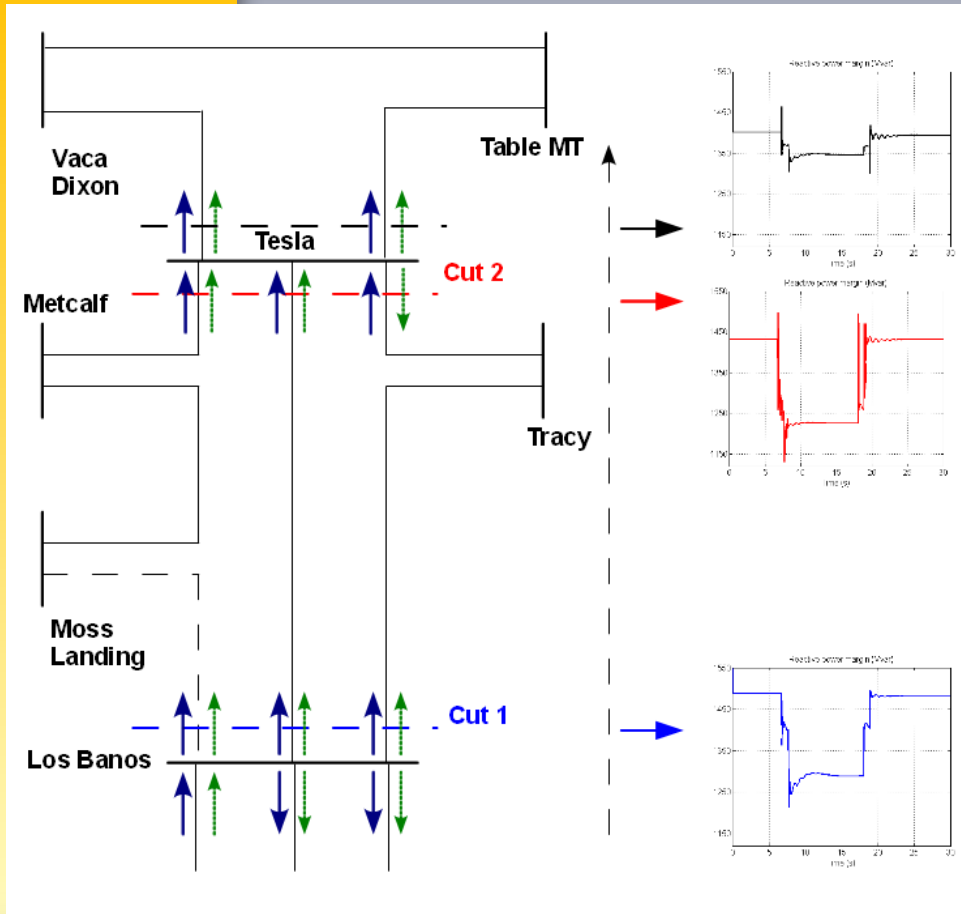
- Customized visualization tool using Improved Voltage Instability Predictor methodology at the Advanced Technologies Center
- Using real-time phasor streaming data





Extracting More Information from RVII

- Increased observability improves accuracy
- Managing loss of PMU data



Source: PG&E

Summary

- Different methods have different advantages and users should select methods optimal for their system
 - None is suitable for all systems and all possible manifestations of instability, measurement configurations, etc.
- Real-time, model-free methods are faster but generally less accurate – Good for trend and status monitoring
- Combination of selected methods provides comprehensive solution for voltage stability issues
 - Real-Time Voltage Instability monitoring technology is needed as a part of the overall solution
- Importance of integration and coordination at the Interconnection level