Voltage Stability Management: Voltage Instability Predictor Methodology

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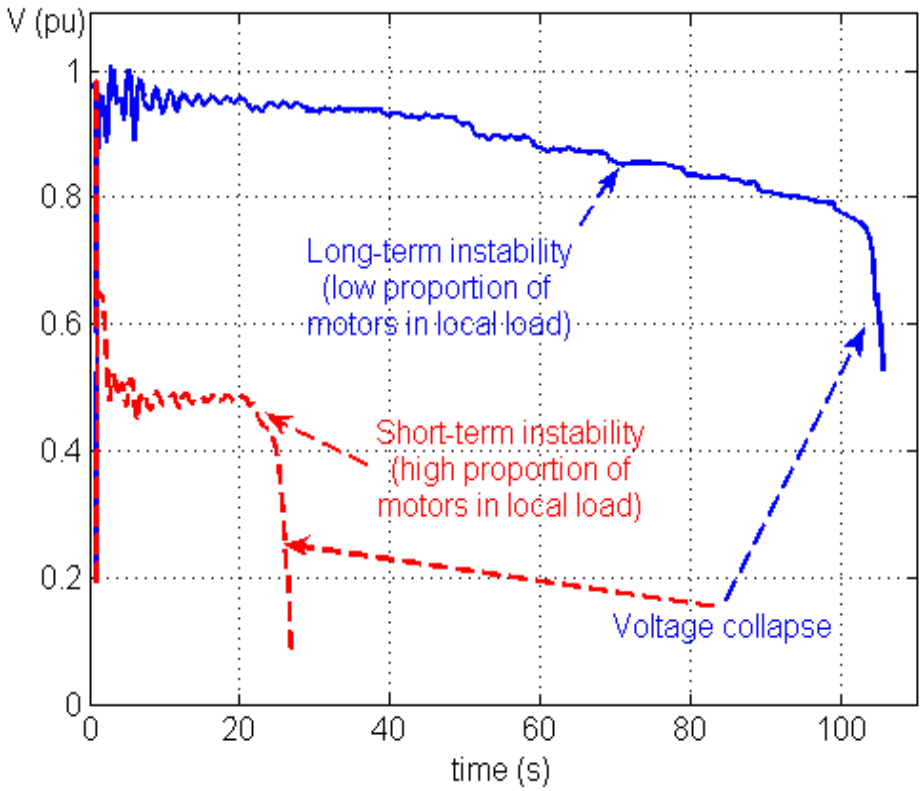
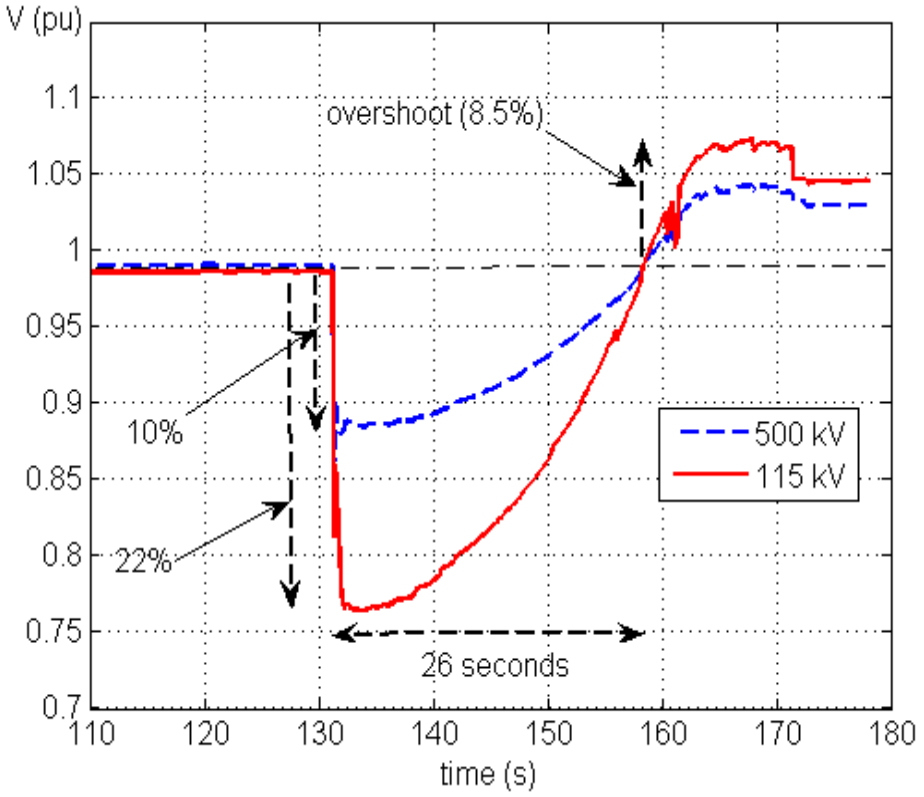
Voltage Related Issues

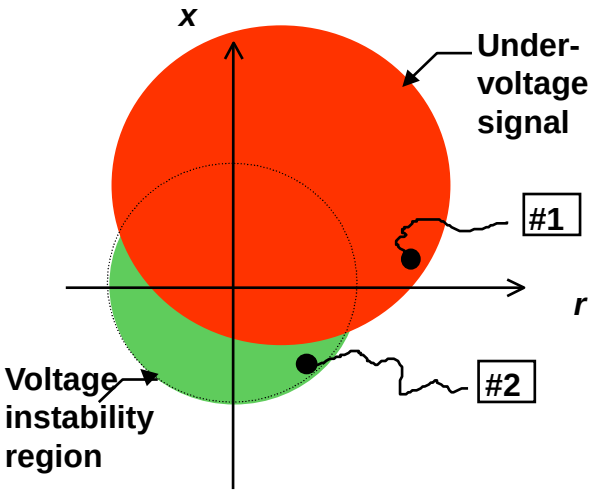


Voltage Instability: Short- and Long- Term

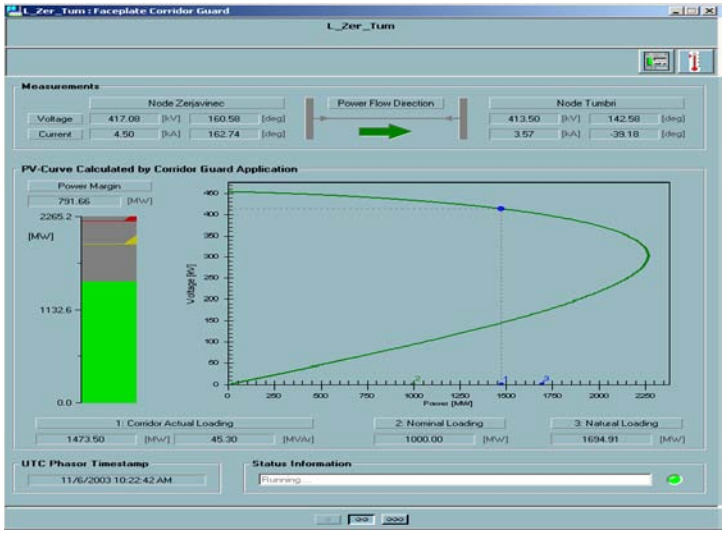


Fault Induced Delayed Voltage Recovery (FIDVR)

Voltage Stability Monitoring & Assessment



#1: inaccurate under-voltage detection
#2: under-voltage fails to detect



- Dynamic, time-domain simulation tools
  - Voltage Stability Assessment (VSA) based on State Estimation contingency analysis
  - Validate model correctness
- Simple voltage-only measurements may not be a good indicator of proximity to voltage collapse
- Tracking the relative distance from voltage instability continually in real-time:
  - Distance to the nose of the PV curve or SE–based stability boundary (model based)
  - Observing the distance of reactive power level from its' 100% value when operating the Secondary and Tertiary Voltage Regulations
  - Distance of the load's apparent impedance to the Thevenin impedance (similar to a relay with an adaptive setting)

Source: ABB

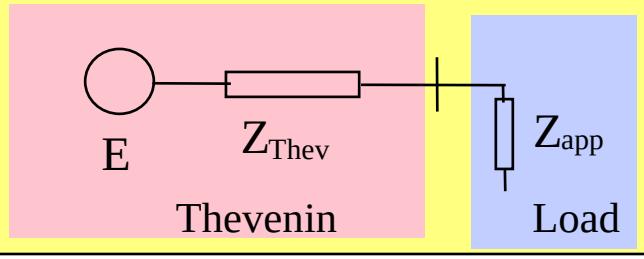
Voltage Instability Detection

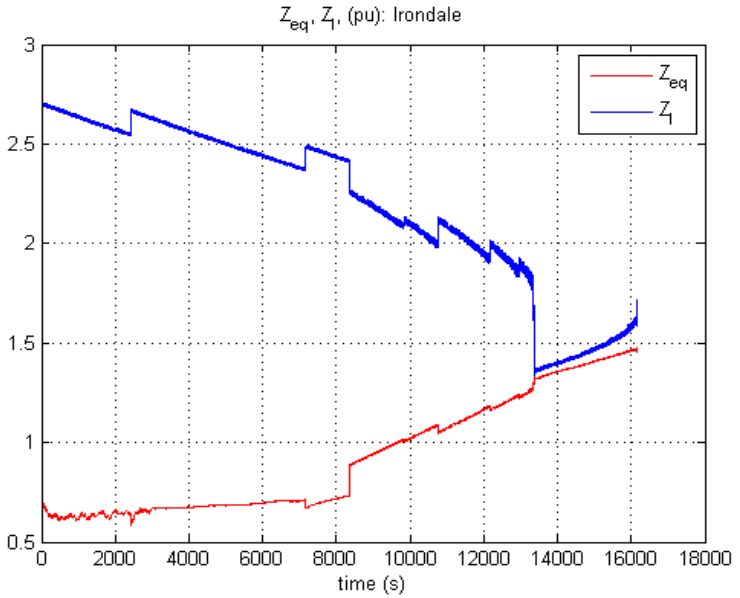
- Simple, real time, voltage instability margin detection, e.g. VIP*
- Better than voltage-only methods, but simpler than any other method
  - Much faster than EMS/SE contingency analysis and not model dependent
- Enabling tracking both slow changes and system dynamics using PMUs (10-120 frames/s)
- *New Reactive Power Margin Method*: Major improvements in accuracy, numerical stability, implementation variants, and ease of use

Maximum power transfer

$\Leftrightarrow |Z_{app}| = |Z_{Thev}|$

Point of collapse

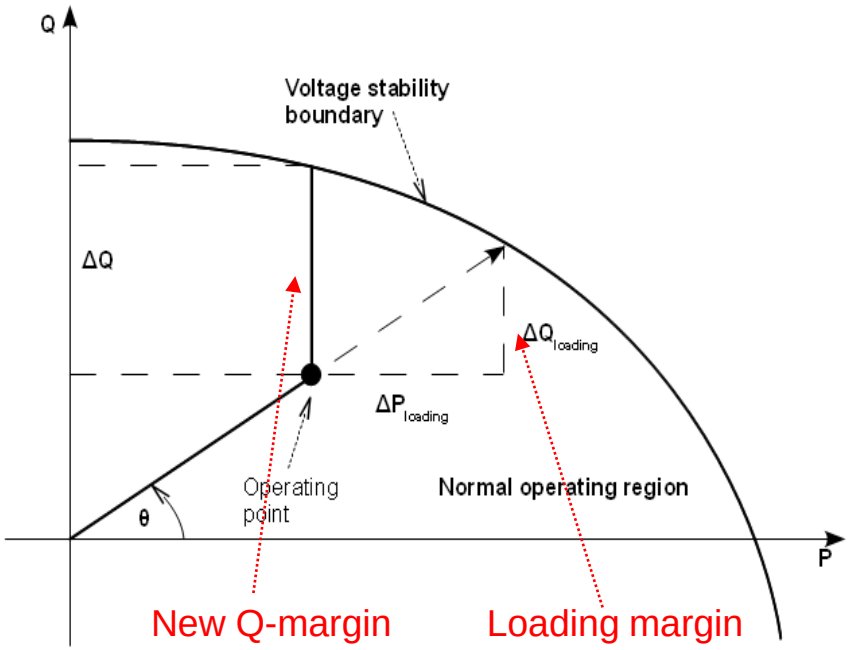




* K. Vu and D. Novosel, "Voltage Instability Predictor (VIP) - Method and System for Performing Adaptive Control to Improve Voltage Stability in Power Systems," US Patent No. 6,219,591, April 2001.

New RPM Advantages 1 (2)

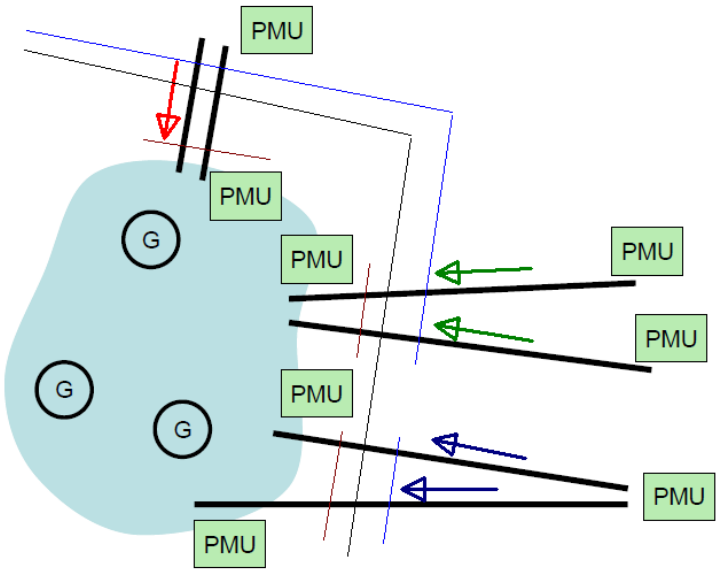
- Model-free, fast real-time voltage instability detection method*, independent of state estimation
- Implementation in several variants: bus, load center, transmission line, transmission corridor
  - Calculates Q-margin & other indices for proximity to voltage collapse
  - Stability boundary calculated with real-time PMU data refresh rate
- Easily combined as complementary to other methods and indices
  - Reactive power monitoring
  - Could initiate model-based contingency analysis, e.g. by alarming the operator



* M. Glavic, M. Lelic, D. Novosel, "Real-time Monitoring of Electric Power System Voltage Stability Margins", patent application.

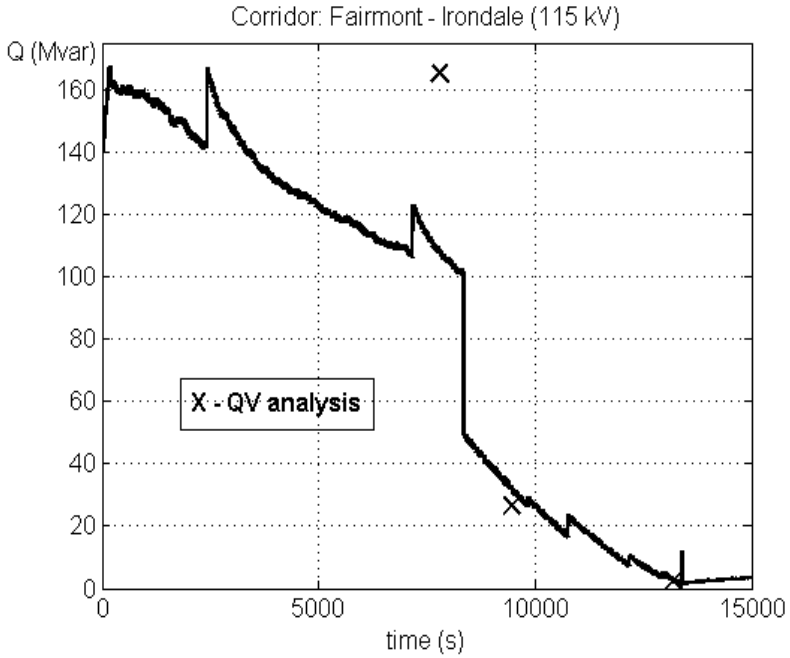
New RPM Advantages 2 (2)

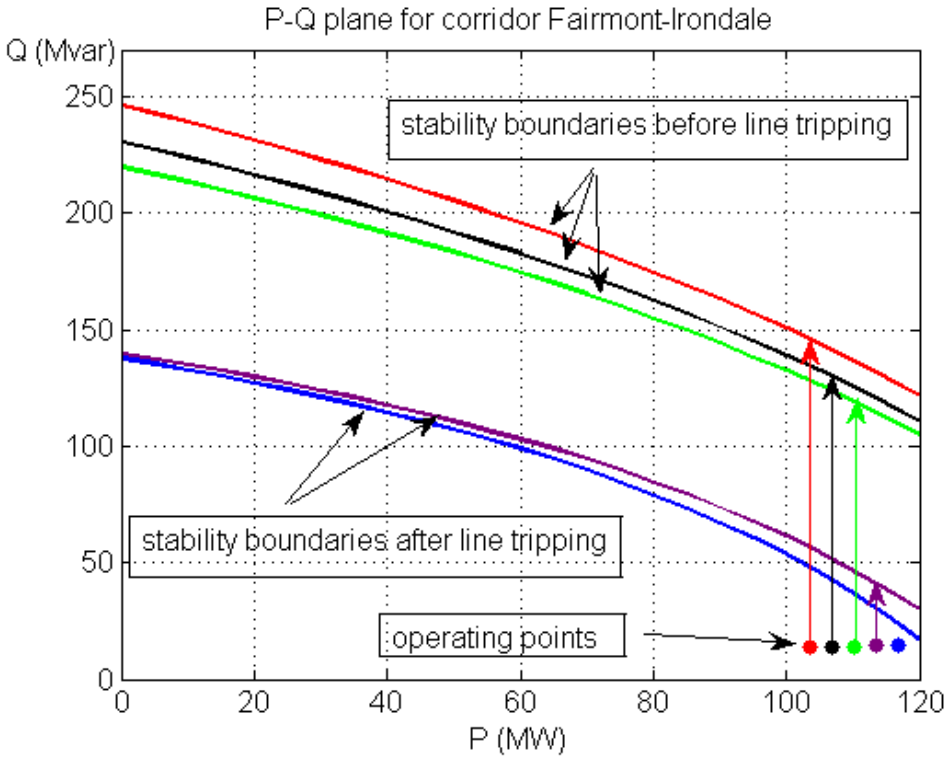
- Ability to process data from different sources (PMUs, SCADA, simulation outputs (static and dynamic)
  - Takes immediate advantage of available PMUs
  - Scales up well with increased number of PMUs
- Excellent results from actual system tests on slowly changing system operating conditions (load ramp) and in tracking system dynamics after large disturbances
- Able to distinguish FIDVR from voltage instability even if voltage is very low
- Simple implementation in Control Center tools local and/or IEDs for:
  - Operator tools to increase situational awareness
  - Local automated actions
  - Addition to SIPS



Load center (Source: BPA)

Real-Life System Test Results





Alarm when measuring real-time Q margins

Realistic PQ-curve slope before and after the disturbance

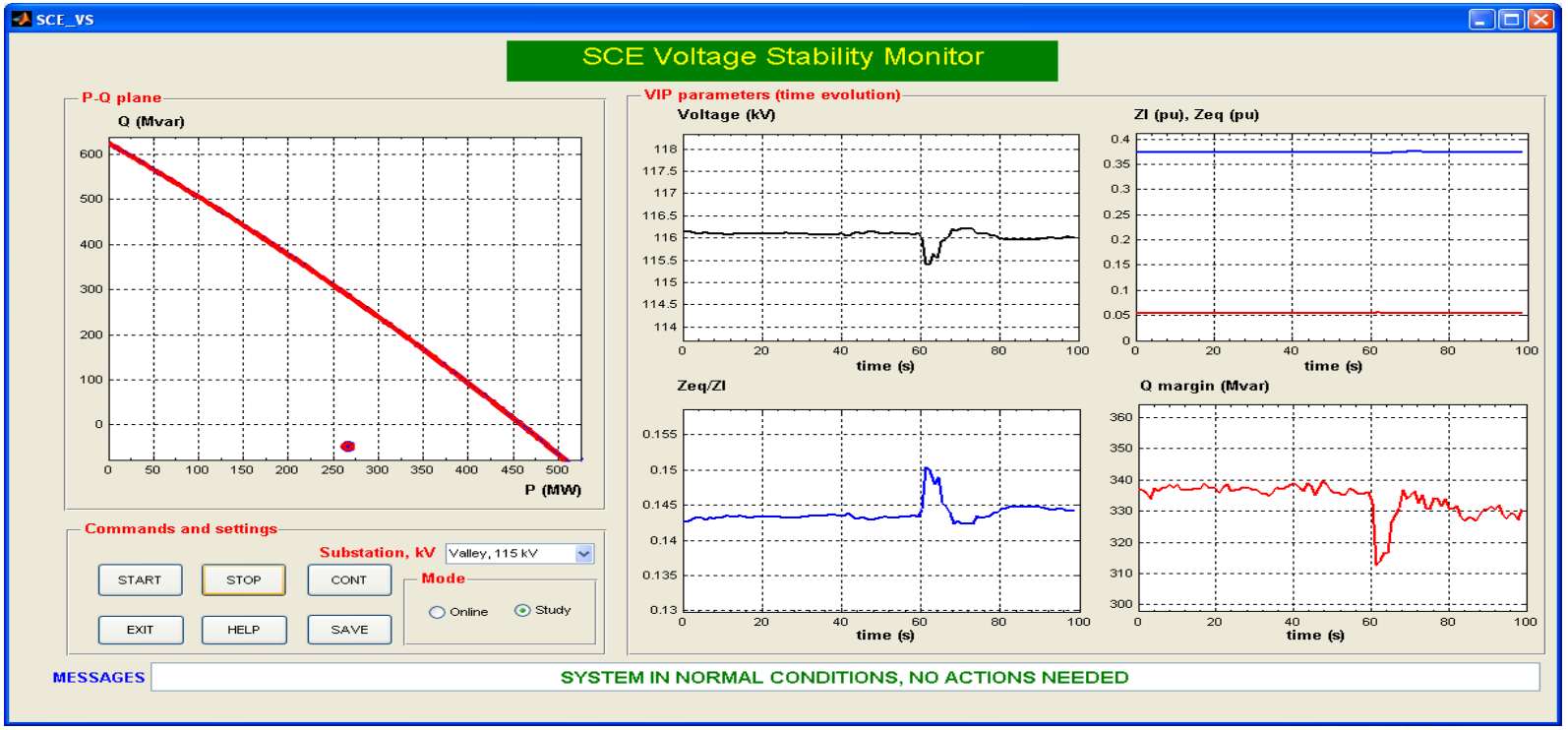
Test Results – BPA, SCE, PG&E

*Comprehensive tests using **real-life** PMU and SCADA **measurements** and off-line **time-sequence** simulation **tools***

- Ability to detect instability even if voltage close to nominal
  - Accurate results for load centers, transmission lines, and corridors
  - Detection at highly-meshed high voltage systems (e.g. 500 kV) is more difficult
- Results comparable to detailed, model-based off-line QV analysis; very accurate closer to instability boundary
- Discriminates between FIDVR and fast voltage instability
  - FIDVR cases (no voltage collapse) are accurately detected despite the fact the voltage is low for some time
- No false alarms

Present and Future Activities

- Deploying real-time application software based on RPM
- Developing visualization tools to display the Corridor & Load Center results in a control room, including FIDVR detection
- Design monitoring and control strategies based on RPM



Source: SCE