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Power, Energy & Grid Of the Future

SCE Distributed Energy Resources

April 8, 2008

High-Megawatt Power Converter Technology Roadmap Workshop

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Power, Energy & Grid Of the Future – Presentation Overview

- SCE DER Activity
- Inverter Interface – What Do I Want
- Beyond DER Activity

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SCE DER Activity

- Prime Mover - MTG Generator Testing
- **Grid Interface** – Interconnection Criteria, Advanced Inverter Development Input 'Utility Perspective'
- Advanced Operating Concepts – Microgrids, DER as System Asset, Smart Grid

SCE DER Activity – Grid Interface

- IEEE Draft Std 1547.4, Intentional DG Islands
  - A KEY SCE PARTICIPATION DRIVER: Concepts Relevant to Accomplishing *Feasible* High Renewable Penetration
  - DoE OE RDSI Proposal 'Catalina Renewable DG': Demonstration of High Renewable Penetration
- 20% BY 2010 California's Renewable Portfolio Standard
  - 20% renewables with significant intermittent content will require more than 'business as usual'
    - 4,000 MW Wind
    - 1,000 MW Solar
  - Energy Storage *with Advanced PCS*, A Solution?

Inverter Interface – What Do I Want

- Starting Point - Do No Harm. Safety first. Mission accomplished…but…
- Moving Toward - System Support from DER. High renewable penetration, grid reliability support, grid-side power quality support
- Inverter Needs - Magnitude, Grid Interactive, Reliable, Cost Competitive, Innovation Incentive Rate

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Beyond DER Activity

- SCE's Circuit of the Future D-FACTS: "What and Why"
- Phasor Measurement Unit (PMU) Application Development: PMU Assisted System Restoration
- Advanced Energy Storage for Wind Integration
- SCE 250 MW PV Project: Interface Specification

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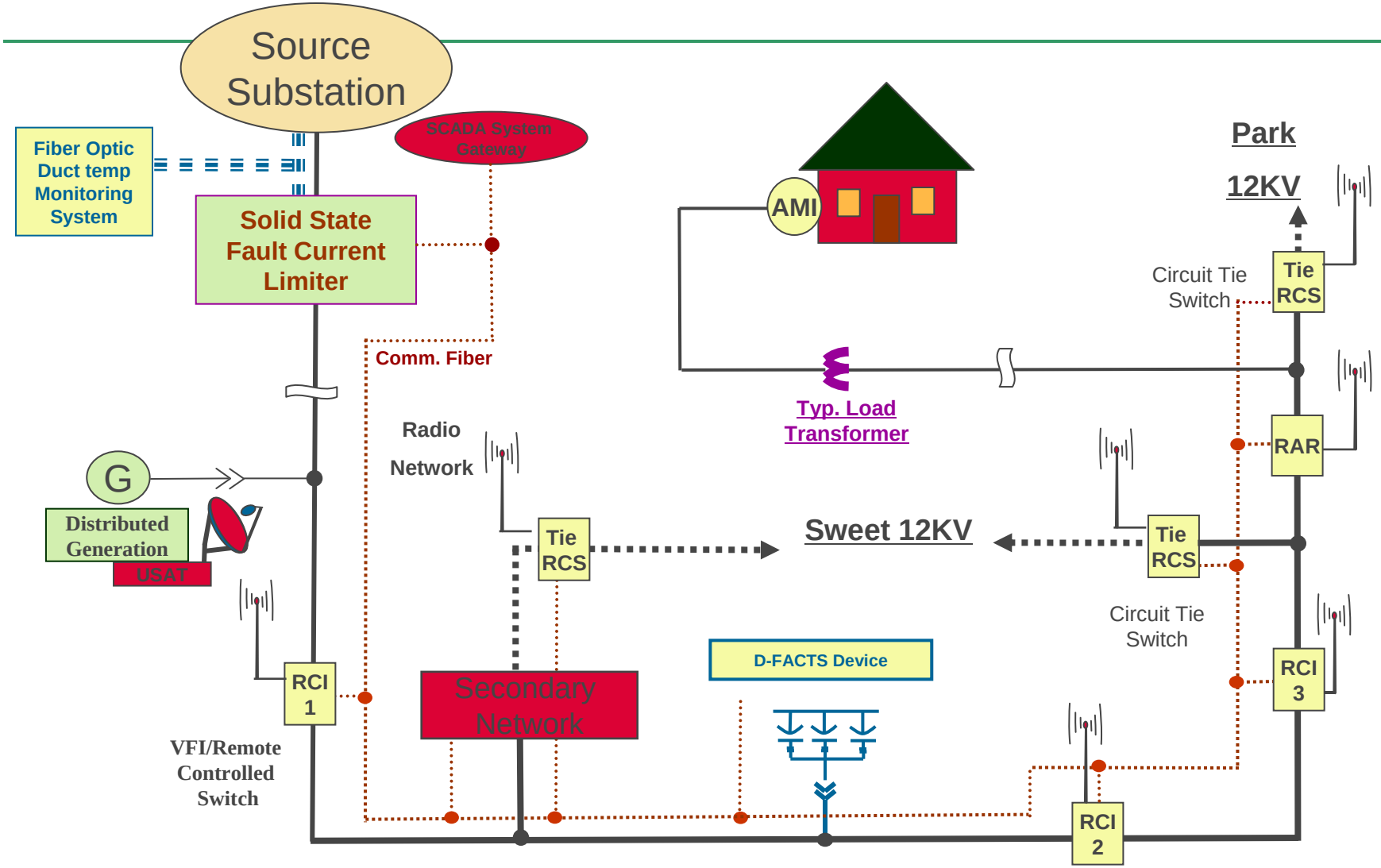
SCE's Circuit of the Future



SCE's Circuit of the Future D-FACTS

D-SVC Performance Specification, Overview

WHAT DO WE WANT?

- Fast response and mitigation of temporary voltage sags
  - Respond and mitigate infrequent temporary deep sags -7 to -12%, (15/year recorded, EPRI DPQ Study)
  - Don't try to fix very infrequent serious events: block device if sag exceeds -12% (Rule 21-based limit)

INPUT FOR DEVELOPMENT OF SPECIFICATION:

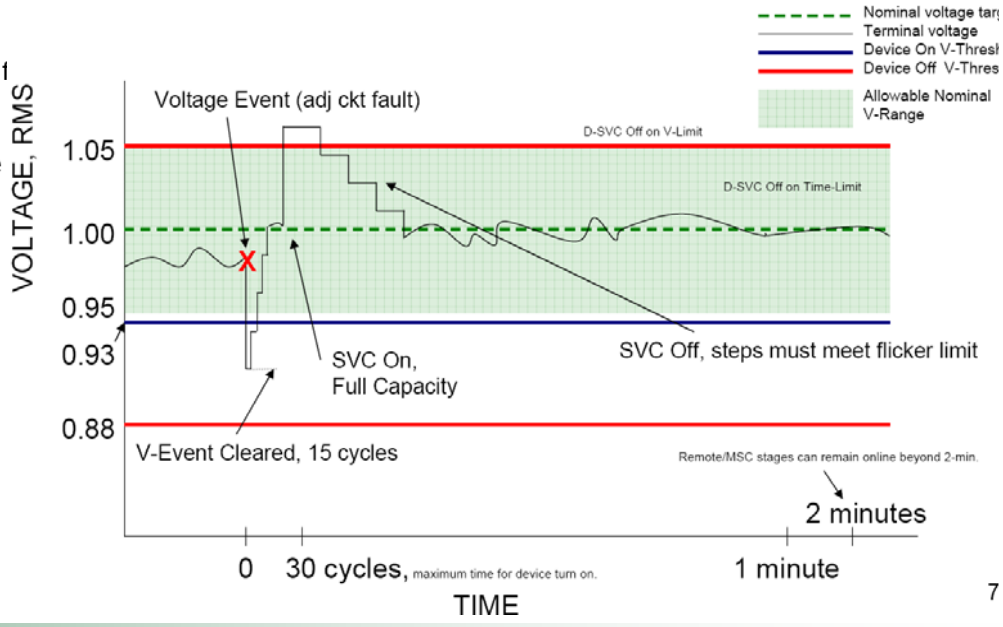
- Emulate organization/headings from relevant sections of I
  - "Existing Power System Characteristics" (3.8)
  - "Electrical Performance Requirements" (3.9)
  - "SVC Operating Characteristics" (3.10)

  But, much less detail needed. And, distribution vs. transmission t IEEE PQ Std vs. WECC T-Planning Criteria.

All stated quantities for proposed D-SVC spec refer to or are relevant to distribution:

- SCE CPUC Tariff Rule 2
- SCE Voltage Fluctuation Limit Criteria
- IEEE 1559 PQ Monitoring Standard
- IEEE 519 Harmonic Limits

D-SVC Operation Illustration, Cleared Fault Voltage & Time Thresholds



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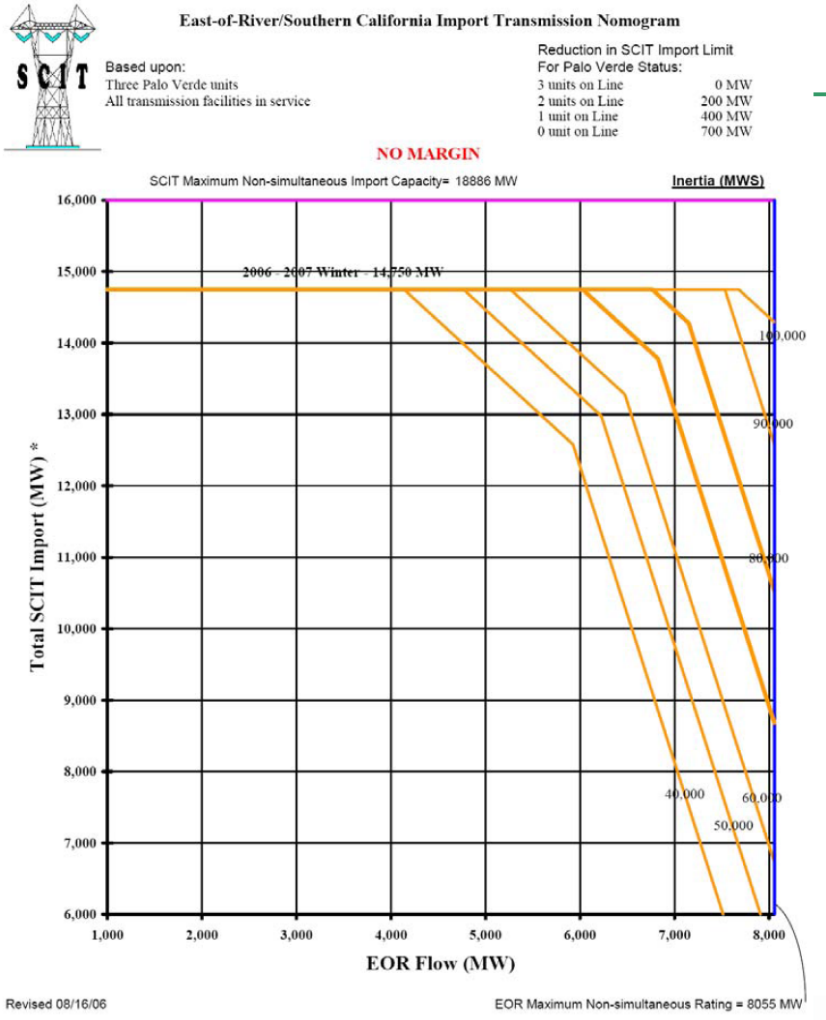
PMU Assisted System Restoration

Energy Storage System Impact

- SCIT NOMOGRAM
  - Dynamic Stability and Transient Voltage Constrained
  - Constraint Based on Total MW-S Inertia in So Cal Load Center
  - RELIABILITY, AND COMMERCIAL, IMPLICATIONS



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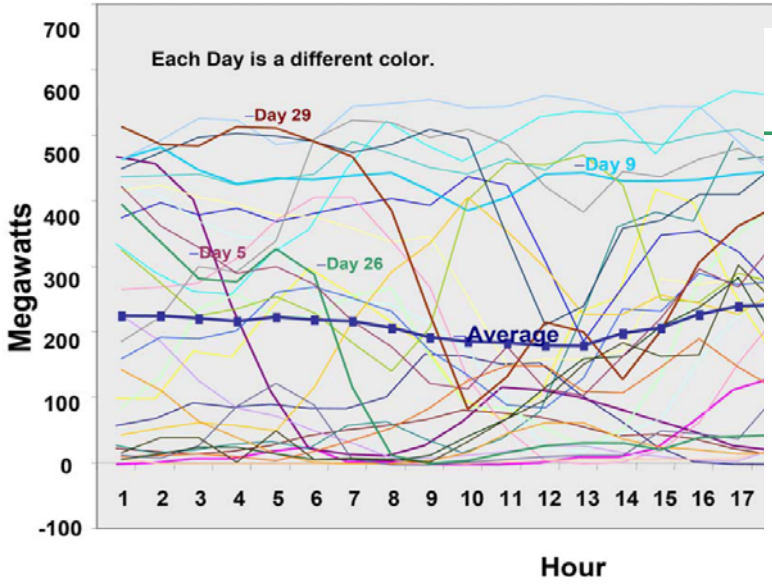
Advanced Energy Storage for Wind Integration

- Operating the CAISO system with 20% Renewables - 6700 MW of wind presents significant challenges

Tehachapi – April 2005



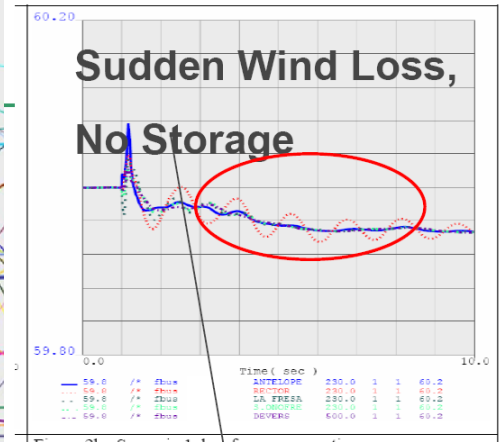


Figure 2b: Scenario 1, bus frequency vs. time

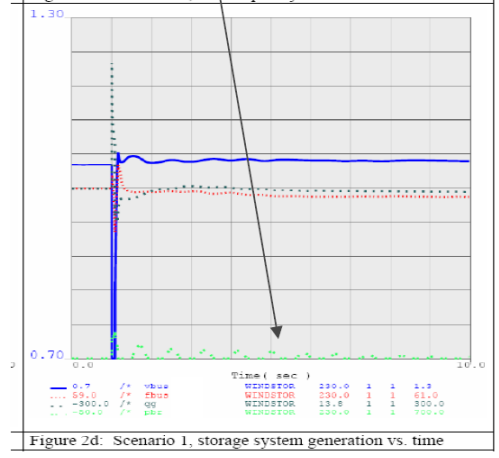


Figure 2d: Scenario 1, storage system generation vs. time

try, March 2008 FINAL DRAFT FOR REVIEW

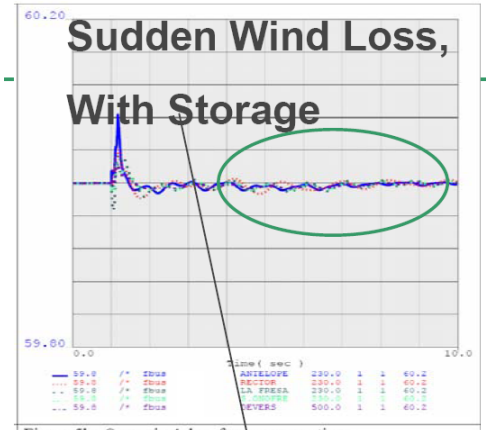


Figure 5b: Scenario 4, bus frequency vs. time

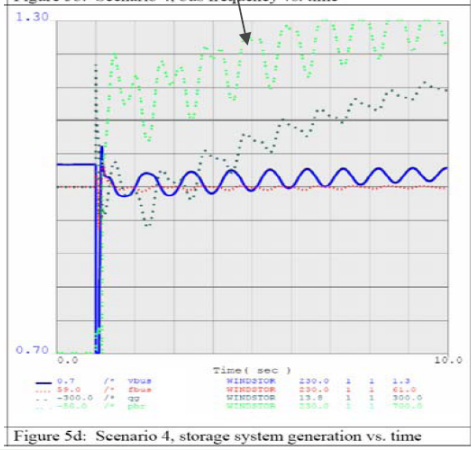


Figure 5d: Scenario 4, storage system generation vs. time

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Inverter Interface – Early Feature List for SCE's 250 MW PV Project

4/1/08 UPDATED INVERTER FEATURE LIST (GRID-INTERFACE FOCUS)
FUNDAMENTAL AND RELEVANT NOW
1) UL 1741/IEEE 1547/Rule 21 Compliant
2) Better than 96% inverter efficiency
3) Control/Optimize PV Array Maximum Power Point

FEATURES TO ENABLE 15+% PENETRATION, GOING 'BEYOND UL/IEEE/Rule 21'
4) Active participation in voltage regulation

FEATURES TO IMPROVE POWER QUALITY, SERVICE RELIABILITY, 'ADDED VALUE' ANCILLARY-TYPE SERVICES FROM THE RESOURCE
5) Respond to voltage transients to actively mitigate voltage sag's via dynamic VAR injection/modulation (STATCOM)
6) Respond to stability transients to damp system-side power oscillations thru dynamic Q and P modulation (Storage & UPFC)
7) High voltage inverter switches/configuration for direct connect to 480 V
8) User specified, location-specific, fault duty multiplier (1 to 'X' times full load current)
9) Participate in wide-area VAR/voltage control schemes
10) Literate in multiple communication protocols (DNP3, Modbus, IEC 68150)

COMMERCIAL
11) Inverter cost below 100$/KVA
12) 'Commoditize' and 'modularize' commercial hi-power hi-functionality inverters

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SCE's 250 MW PV Project

- Filed w/ CPUC, Ratebase 250 MW PV, $875 Million
- 50 MW/year, 5 Years
- 2 MW Pilot Project, In Service August 2008
- 1-2 MW Increments
- 3.5 $/Watt
- Connect on grid-side at 12 kV
- Non-utility roof space, equipment suppliers, installers, O&M services
- Support CA Solar Initiative targets. Of 805 MW available in SCE's service territory only about 50 MW deployed. Average CSI installed cost for residential over $8/Watt