Load Modeling and Control

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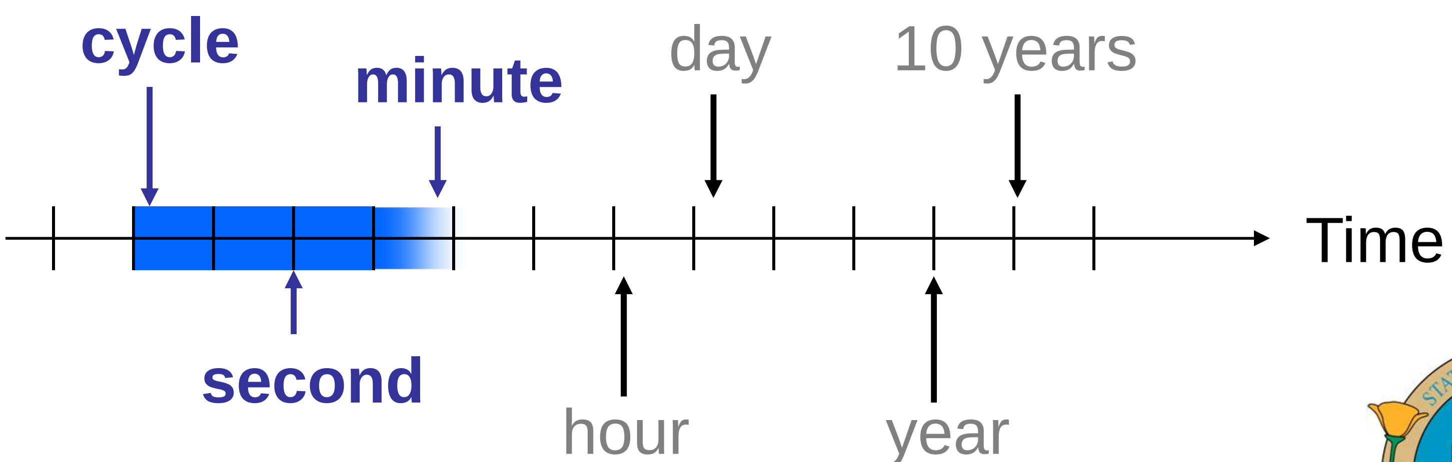
Load Modeling and Control
Timescale of Interest

Our primary interest is the *dynamic behavior* of loads in cycle to minute time frame, not projections of future demand.



Fundamental Changes in Load Characteristics

Electronic Ballast Discharge Lighting

Air-Conditioning and Heat Pumps

Power Electronics (Computers, Data Centers, VFDs)

Plug-in Hybrid Electric Vehicles

Photo-Voltaic Panels

Incandescent Lighting

Resistive Space and Water Heating

Aluminum smelters

Fundamental Changes in Load Characteristics

- Resistive loads are energy inefficient but "grid-friendly"

- New loads are more energy efficient (VFDs, heat pumps, CFLs), but create greater challenge for grid dynamic stability

- Grid impacts of distributed generation (PV) need to be assessed, appropriate standards developed

Fundamental Changes in Load Characteristics

- Loads play much more influential role in power system stability
  - Load-Induced voltage stability
    - Multiple events of delayed voltage recovery in Southern California, Texas and the Southeast
  - Damping of inter-area power oscillations

- Need for models to understand load behavior and to develop a portfolio of solutions

Load Models

System Studies

Portfolio of Solutions
(System & End-Use)

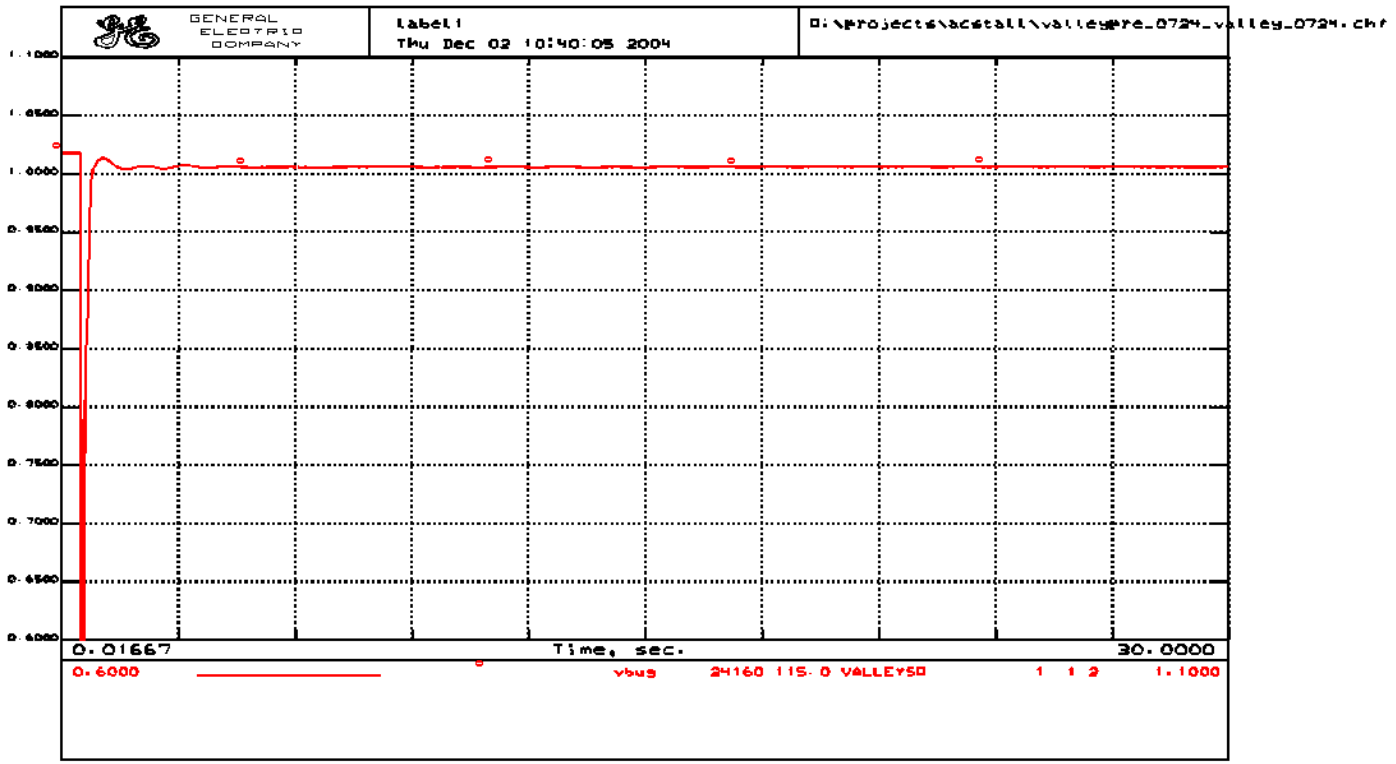
System Performance Monitoring

STATE OF CALIFORNIA
ENERGY COMMISSION

Load Modeling

Motivation for Better Load Modeling

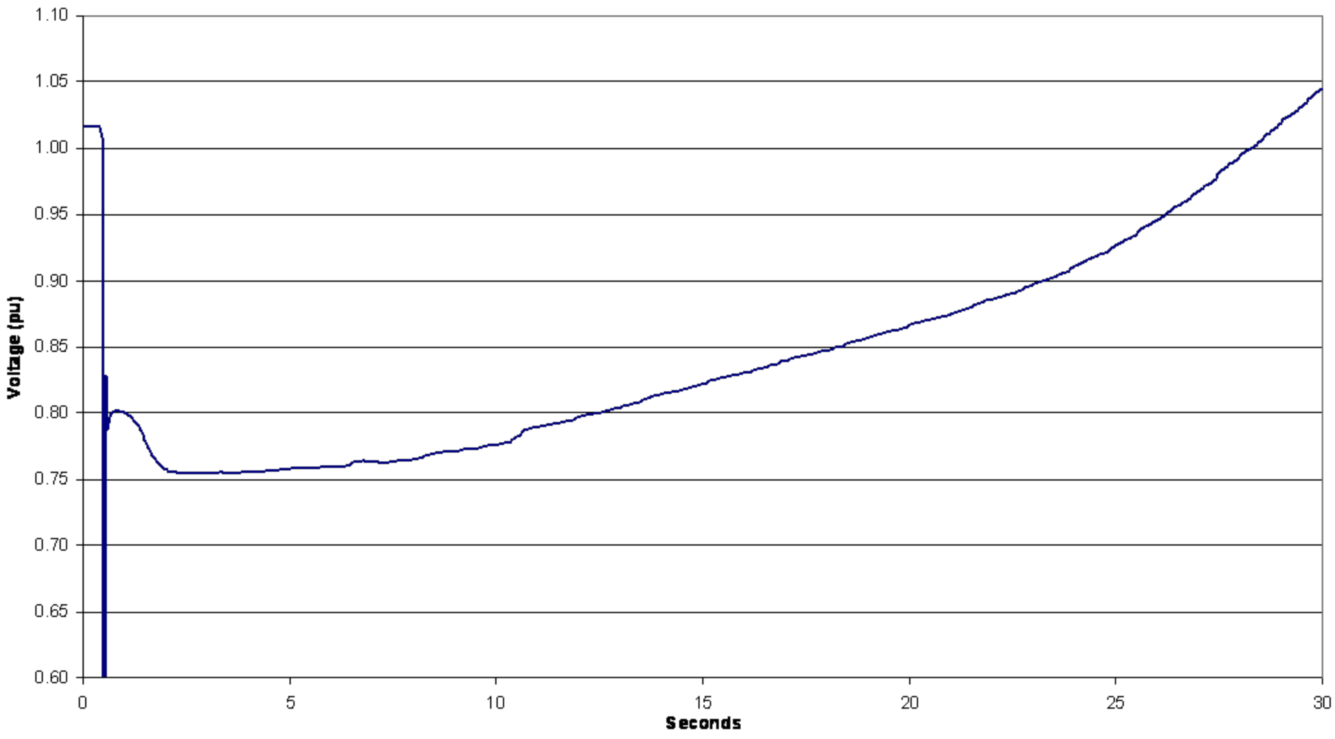
This is what we thought would happen (in 2004) …



Simulations
– instantaneous voltage recovery

Motivation for Better Load Modeling

… and this is what **actually** happened



Reality
– 30-second voltage recovery, 12 seconds below 80%

WECC Load Modeling

- WECC is in final stages of development and implementation of a composite load model
- CEC made important contributions to the project:
  - o Development of models of single-phase air-conditioning units
  - o Load composition analysis
  - o Benefit from other CEC-funded projects:
    - ▪ 2006 Commercial End-Use Survey
    - ▪ LBNL load composition studies

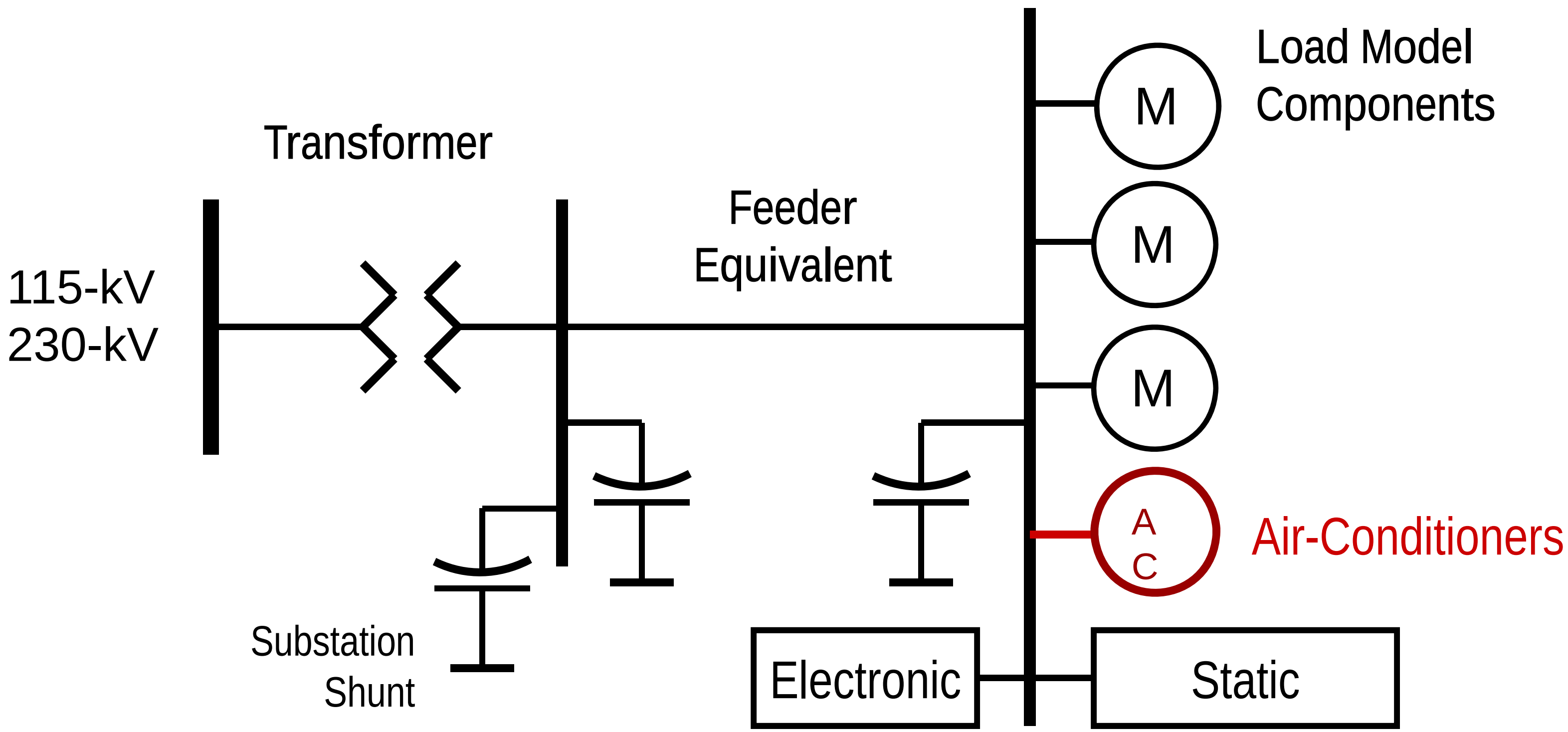
Single-Phase AC Motors

- Residential AC compressor motors are single-phase capacitor-run
- Compressors have high nominal power factor 0.95 to 0.98
- Compressor power increases with temperature
- Compressors stall at high voltages (if voltage dips to 55-60% for 3 cycles or longer at 100F ambient). Stall voltage increases with temperature
- Once compressor motor stalls, it is likely to remain stalled even if the voltage is recovered (Newer scroll units have shown ability to re-start)
- Stalled motor consumes 5 to 7 times of its nominal current
- Thermal relay trips motor in 3 to 20 seconds, has an inverse time over-current characteristic

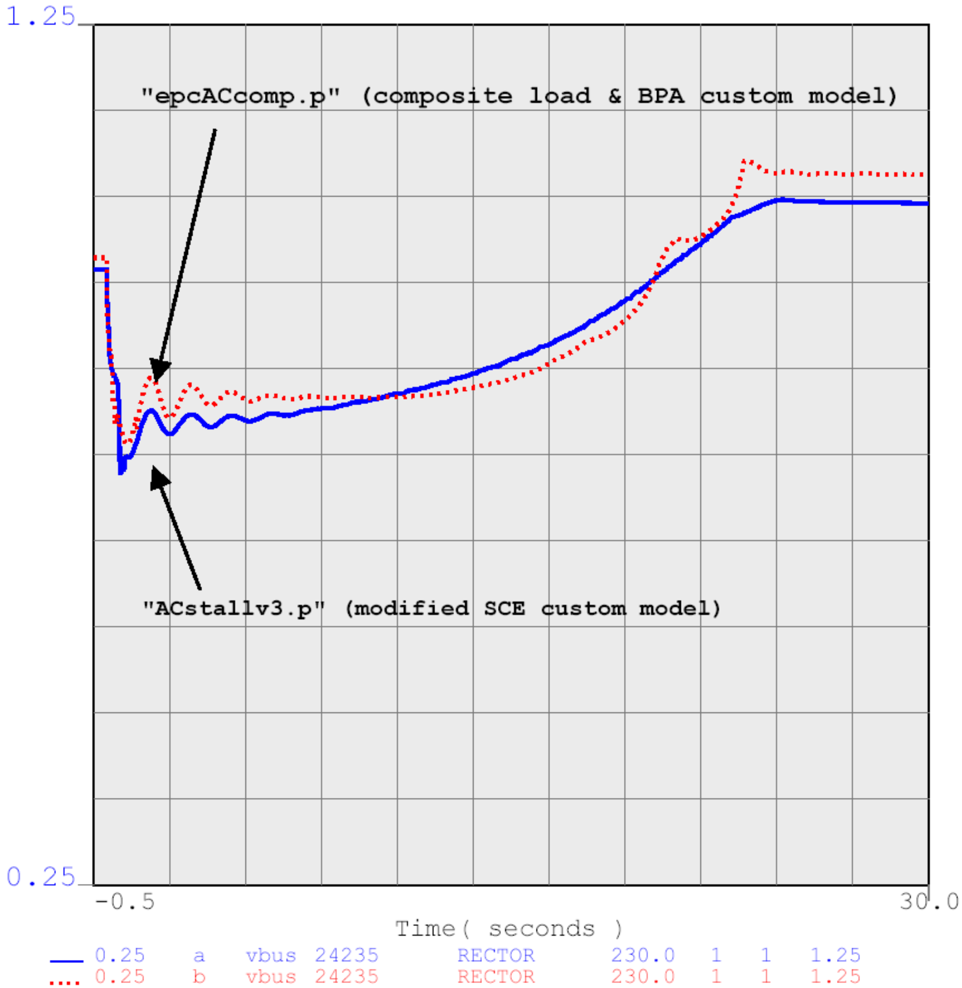
1-phase Compressor Motor Models

- A White Paper with modeling requirements is developed first
- Several Modeling Approaches are considered, prototyped and tested:
  - Phasor Models
  - Performance-Type Models
    - Polynomial-type models
  - Hybrid model
    - Initially developed by SCE, enhanced by EPRI

New Load Model



Load Model Validation

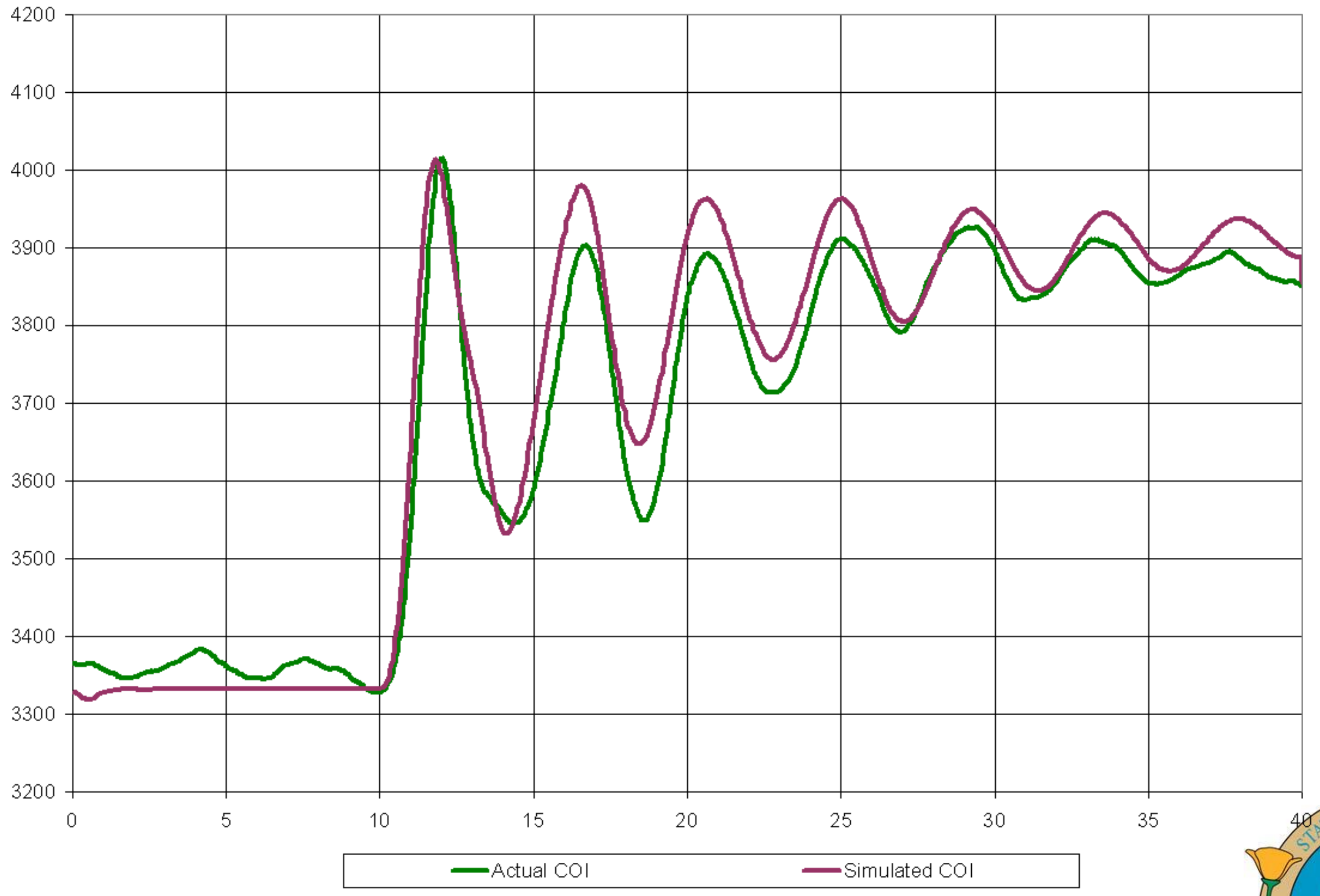


Capable of reproducing the phenomenon of delayed voltage recovery

Explicit representation

1phase A/C models

Load Model Validation



Inter-area Power oscillations

WECC Load Modeling

- WECC needs better information in the following areas:
  - Load composition data
  - Motor protection data

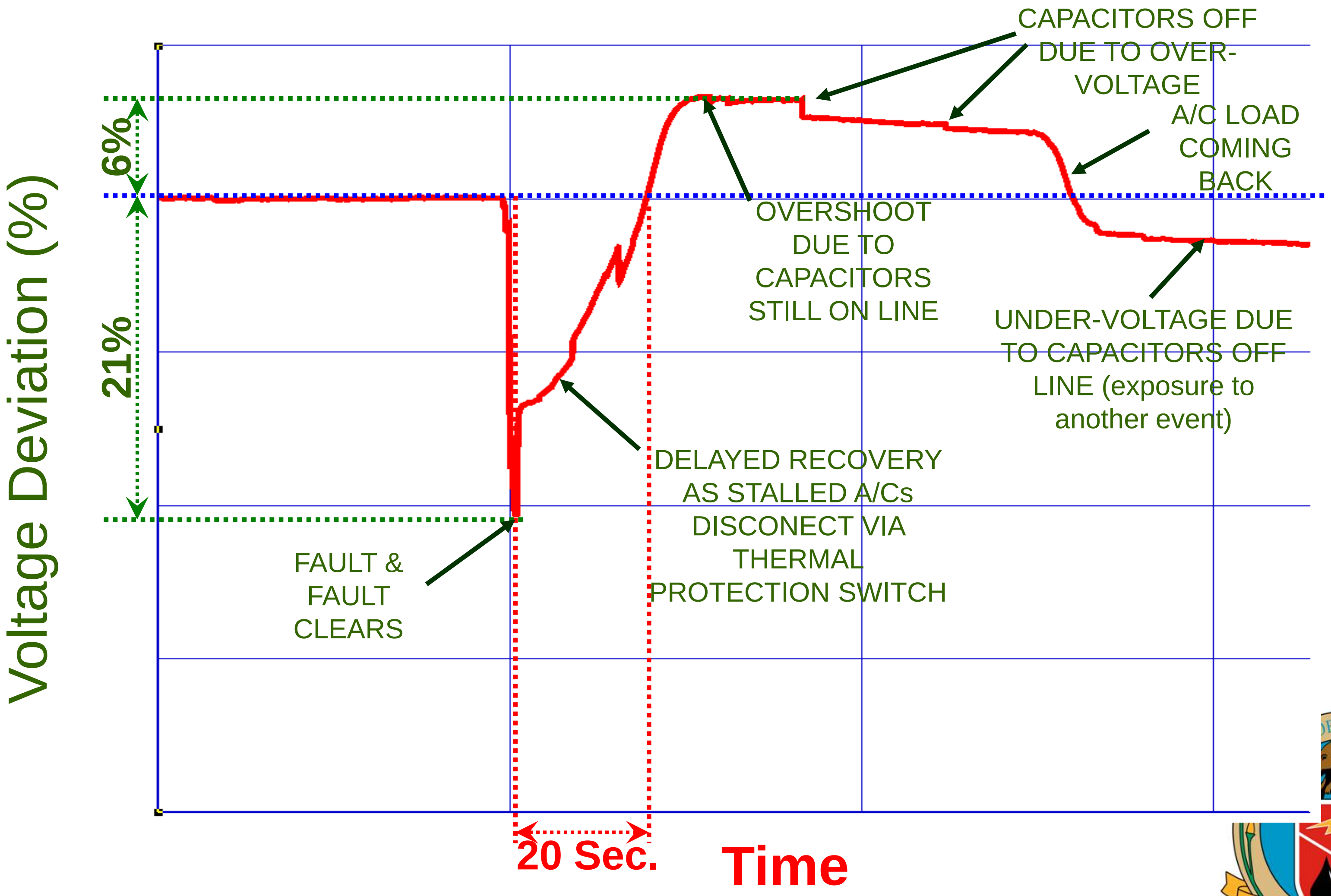
- WECC is shifting from model development to model validation and system impact studies

System Studies

- Inter-regional stability:
  - Voltage stability of major WECC paths (COI, EOR, P15 and P26)
  - Damping of inter-area oscillations
- Fault-Induced Voltage Recovery in Large metro areas:
  - Increasing amount of air-conditioning load
  - Limited dynamic voltage support – generators are remote and VARS do not travel well
  - Prone to dynamic voltage stability problems

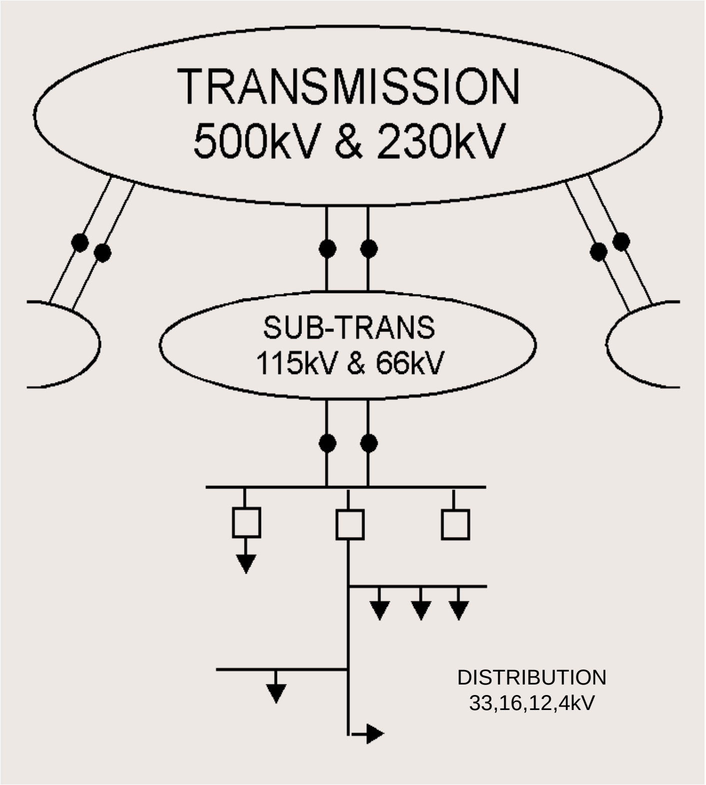
Solutions to Fault-Induced Delayed Voltage Recovery

What is FIDVR ?

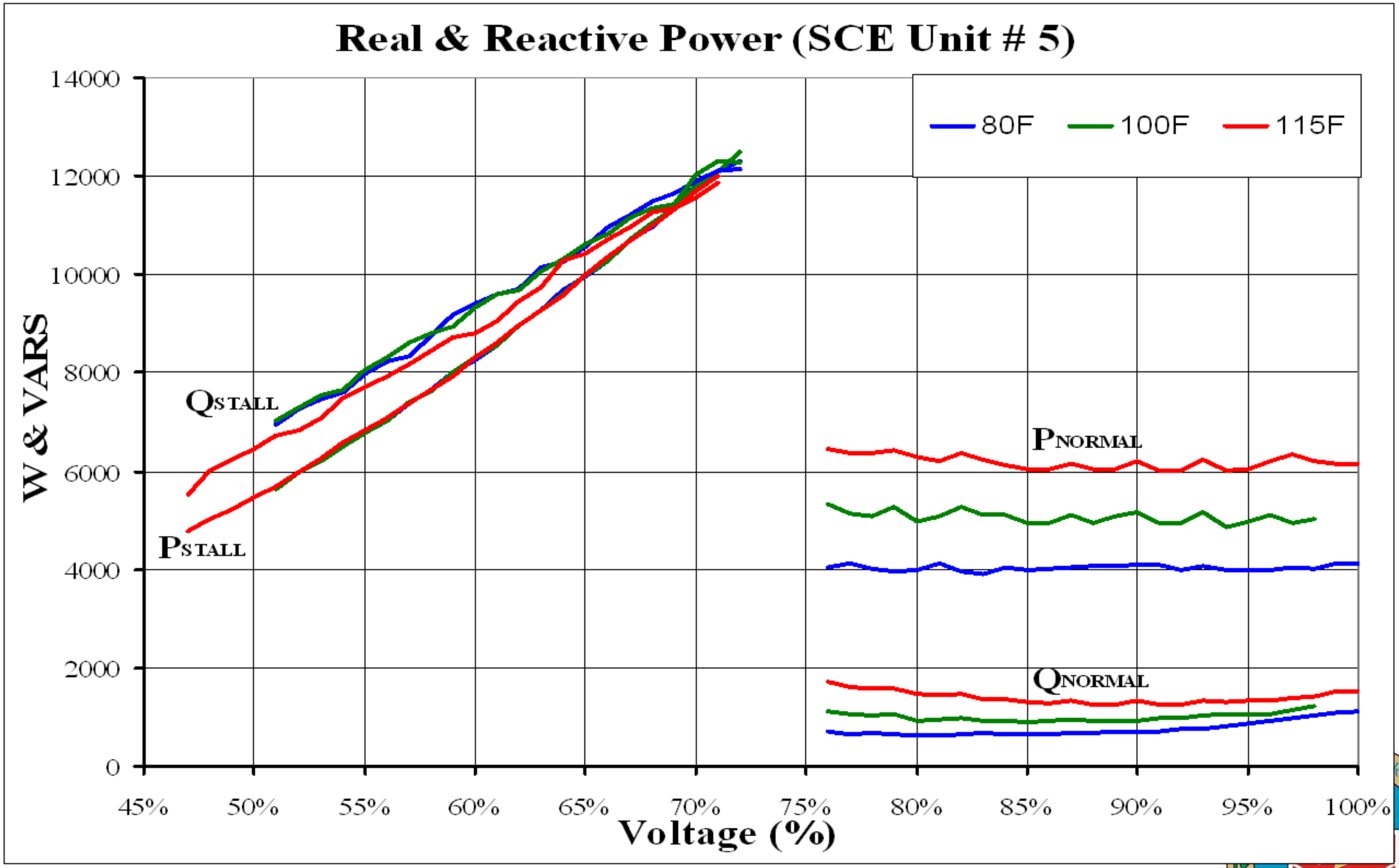


Why Are We Concerned?

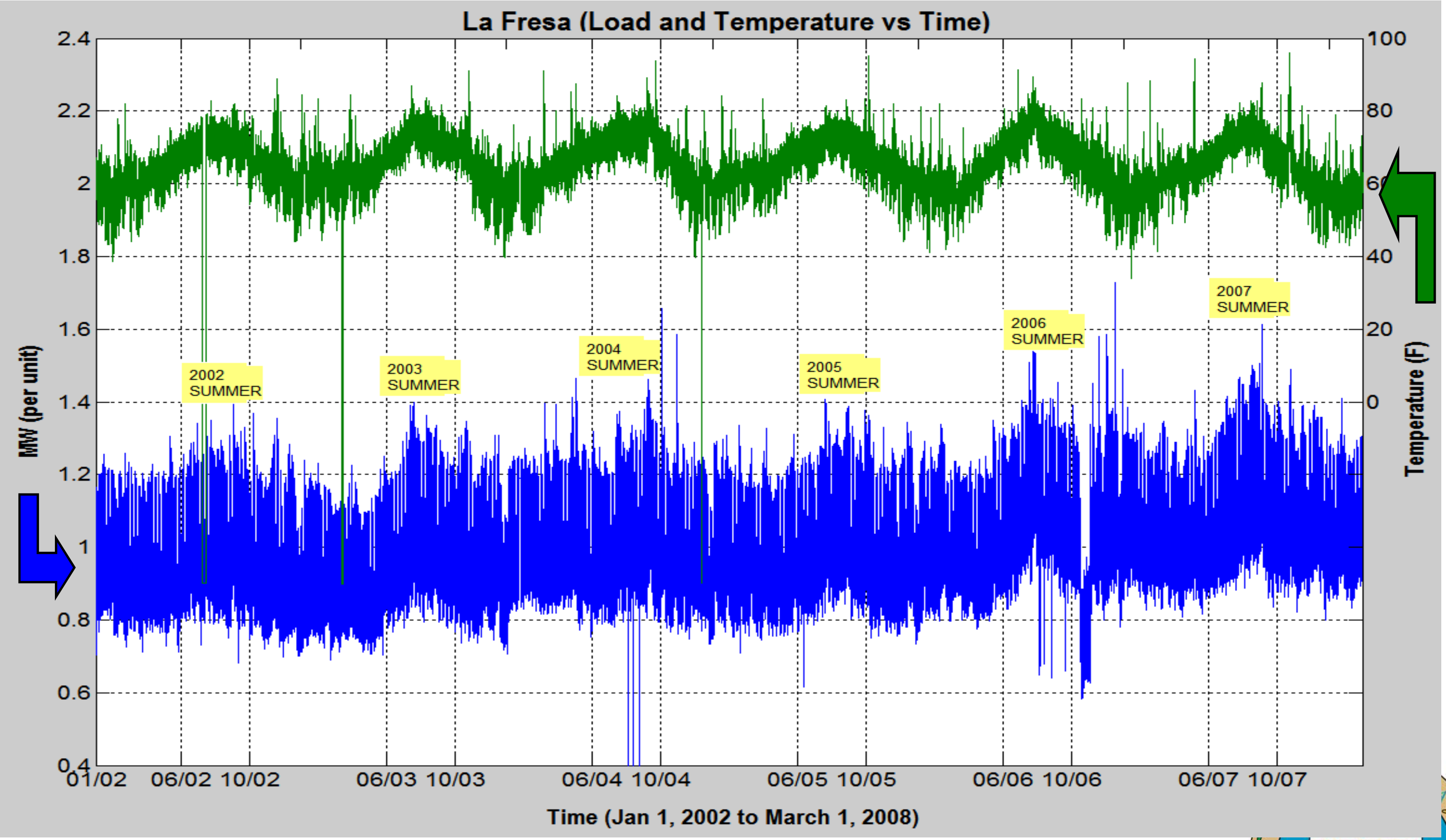
- Undervoltage event could lead to total system voltage collapse
- Presents voltage sag to all customers in the area (PQ issue)
- Getting worse as more homes with air conditioners are built in warm inland areas



A/C Stall Behavior



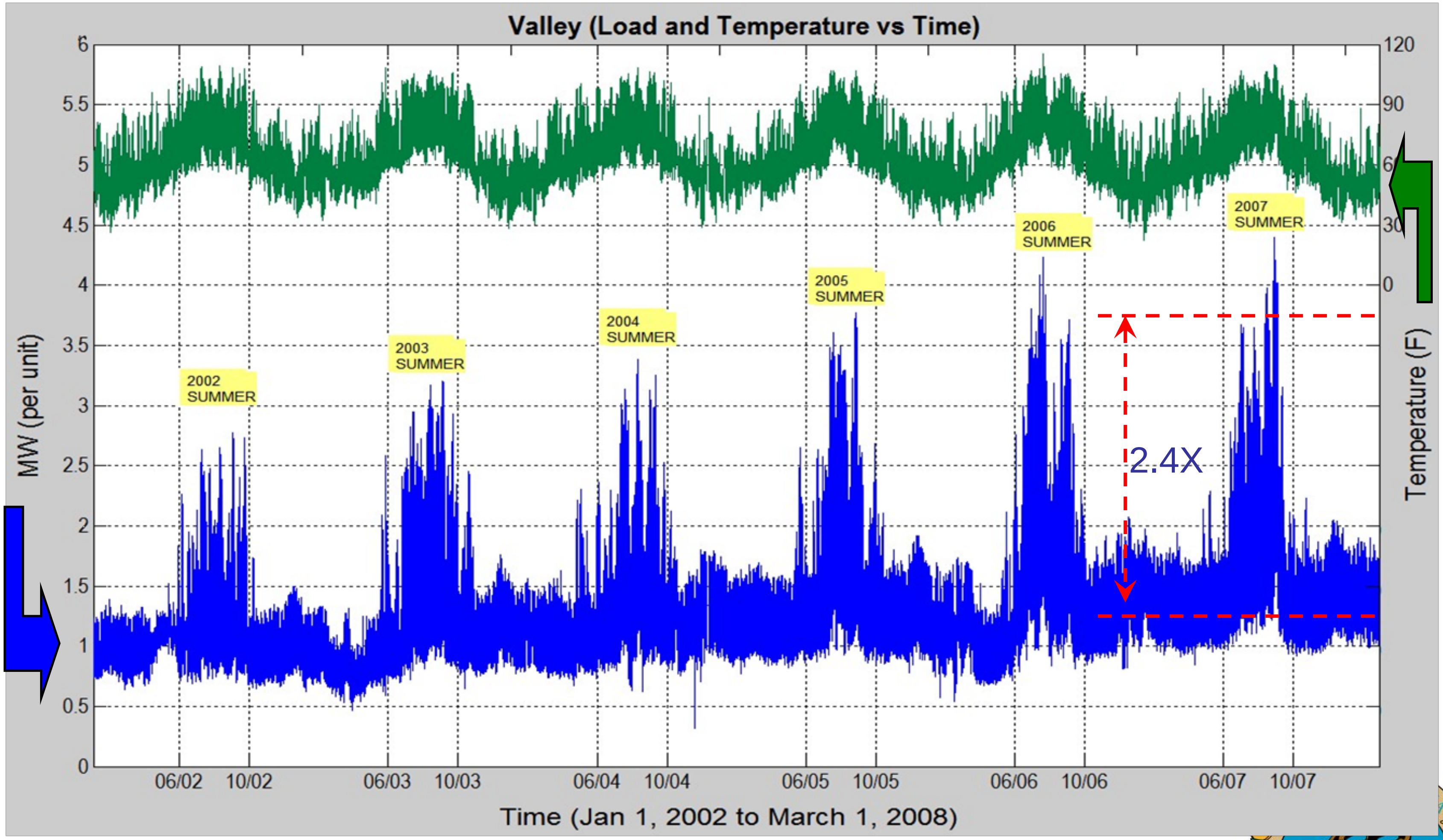
Coastal Load



Peak Load ~ 600 MW

25% of Peak Load is A/C

Inland Load



Peak Load ~ 1,500 MW

60% of Peak Load is A/C

What's Being Done

- Completed A/C tests to obtain better A/C performance data
  - SCE, BPA, and APS/EPRI
- WECC developing new A/C load models to more accurately model A/C stalling effects
- System modeling underway to determine vulnerability
- Evaluating mitigation measures
  - Electric System level
  - A/C Unit level
- Engaging NERC, A/C Industry, Utilities, DOE, and regulatory bodies to develop comprehensive national solutions

Assessment of Electric System Level Measures

- Cannot prevent faults from occurring nor A/C units from stalling
- System level solutions (e.g. SVC, Statcom) :
  - Reduce the size of the area affected
  - Reduce the duration of stall events
- Could be very costly
  - Would need a number of devices throughout the SCE system
  - A large SVC costs $20M to $50M each
- Southern Company and Center Point Energy are deploying SVCs for FIDVR mitigation in Atlanta and Houston metro areas respectively

Assessment of A/C Unit Level Measures

- Fix problem at its source
- Disconnect A/C compressor motors when they stall
  - Reliable detection of a/c stall is required
- New air conditioner standard is needed; e.g.:

  "Any air conditioner shall include features which prevent the compressor from remaining connected to the electrical supply system in a stalled condition for more than {one-tenth?} of a second."
- An A/C standard would keep the future situation from getting worse
- Large number of existing A/C units means retrofit might be necessary

Portfolio of Solutions

- The final product is likely to be a portfolio of solutions including transmission and unit-level solutions. Portfolio is likely to evolve in time.
- Portfolio to address the following risks:
  - Risk of voltage collapse developing in a metro area
  - Risk of voltage collapse cascading outside metro area
  - Risk of extreme over-voltages following AC tripping
- Is FIDVR an indication of a more serious systemic problem ?
- Need a comprehensive review and vetting of the solutions by the industry
  - Electric Power Industry
    - NERC Transmission Issues Subcommittee is issuing a White Paper
    - WECC Planning and Coordinating Committee
    - BPA has a panel of top industry experts
  - Professional Organizations - IEEE
  - Equipment Manufacturer's – NEMA, ASHRE

Project Continuation

Roadmap of Solutions

- System Level Solutions
  - Addition or relocation of reactive resources closer to load – generators, SVCs, Statcoms, DVARs
  - Under-Voltage Load Shedding
  - Limiting affected load by sectionalizing
  - Special Protection Schemes to contain disturbance spread

- Unit-Level Solutions
  - Relays that disconnect a compressor motor when it stalls
  - Devices that make a compressor motor ride through typical faults

- Distributed Generation
  - e.g. PV converters with Voltage Controls

Smart Grid

- The fundamental change in load composition is likely to have negative impact on the transmission reliability if nothing is done
- At the same time, power electronics (VFDs, Distributed PV Generation, PHEV) offer grid control capabilities that did not exist before
- It is time to make the load a part of solution, not a problem

BPA Technology Innovation Office

- Responsible for all BPA R&D, guided by roadmaps, growing budget and FTE commitment
- BPA Technology Innovation is currently funding research in the area of load-induced voltage stability
- BPA hired a panel of industry experts to advise on voltage stability issues, including load-induced voltage stability
- Since Power Electronic loads have shown to have negative impact on voltage stability and damping of inter-area power oscillations, BPA initiated a project to study feasibility of making electronic loads grid-friendly
- BPA continues support of WECC load modeling activities

Industry

- April 2008 - DOE Workshop on Role of Residential Air-Conditioners in Delayed Voltage Recovery
- July 2008 - IEEE General Meeting - Panel Session on Load Modeling – 3 papers
- December 2008 - NERC is planning to release a White Paper on Fault-Induced Delayed Voltage Recovery
- April 2009 - WECC Modeling Workshop is planned, hosted by PG&E

Proposed to CEC

Phase II research to include:

1. Continue studying solutions to Fault-Induced Delayed Voltage Recovery
2. Load model sensitivities
3. Feasibility of single-phase load simulations
4. Load Composition Analysis

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