WECC Experience with Deployment of Composite Load Model

Presentation to
WECC LMTF
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In the beginning…

WECC used static load models through early 2000s for planning and operating studies – constant current for active power and constant impedance for reactive power.

Utilities in California observed events of delayed voltage recovery as early as 1980s. Planners developed custom models for their local areas to study the reliability risk of air-conditioner stalling:

FIDVR Events

August 1997:

A multi-phase 500-kV fault in Southern California

Delayed voltage recovery

~ 3,500 MW of load is disconnected (incl. phase imbalance)
Motivation for Dynamic Load Model in the West

July 2 1996
Motivation for Dynamic Load Model in the West

August 10 1996
Motivation for Dynamic Load Model in the West

August 4 2000
Interim Load Model

Initial need for dynamic load model was driven by the need to model power swings and oscillations, not FIDVR

WECC implemented “interim” model in 2001, where
- 20% of total load was represented with an induction load model
- 80% with static loads (constant current for active power, constant impedance for reactive power),

WECC started initial CMLD development with GE PSLF
The first CMLD version was implemented in 2006 and did not have Motor D
FIDVR
Simulation of P1 Contingency

This is what we **thought** would happen using interim load model...

![Graph showing voltage recovery simulation](image)

30 seconds

Simulations
- instantaneous voltage recovery
PMU Recording of the same Contingency

... and this is what **actually** happened

30-second voltage recovery, 12 seconds below 80%
FIDVR Events

Several WECC utilities started deployment of PMUs in early 2000s.
Transmission Planners observed increased number of FIDVR events in mid-2000s.
Similar FIDVR events were observed in other parts of NERC.


DOE and NERC conducted industry workshops with Transmission Planners, Regulators, Air-Conditioner Manufacturers, Researchers:

NERC Transmission Issues Subcommittee prepared a technical reference on Fault-Induced Delayed Voltage Recovery in 2009

https://www.nerc.com/docs/pc/tis/fidvr_tech_ref%20v1-2_pc_approved.pdf
SCE, EPRI, BPA tested a number of residential and a few of commercial air-conditioning units for the purpose of model development

Motor D “performance” model was developed to capture the behavior of single-phase compressor motors

- it is generally recognized that the model captures reasonably well aggregated motor behavior after they stall
- less confidence in model’s ability to predict whether motors stall during a fault
- does not capture motor re-acceleration or motor stalling due to failed re-acceleration

Initial stall thresholds were 60% voltage, 2 cycles
FIDVR Recordings

Most of FIDVR events were recorded in a part of California desert system. The area has very high percentage of air-conditioning load. The area is sectionalized, a fault would cause motor stalling in the area. Good for validating what happens after motors stall, not so good for validating whether motors stall during a faults.

DOE supported a project to get FIDVR recordings in distribution networks in California and Texas. We found many FIDVR events in distribution, but they never propagated upstream to the transmission.

Transmission FIDVR recordings are rare.
Transmission FIDVR Recordings - California

500-kV

620 MW, or 44%, of end-use is disconnected during the event

115-kV

MW

MVAR
Transmission FIDVR Recording - Arizona

3-phase fault with less than 3-cycle clearing in Arizona in July 2003
~2,685 MW of generation tripped
~1,500 MW of load disconnected
CMLD Composition for Arizona

Motor A

Motor D

DSW_RES
- Motor A: 7%
- Motor B: 3%
- Motor C: 16%
- Motor D: 45%
- Total: 10%

DSW_COM
- Motor A: 21%
- Motor B: 14%
- Motor C: 3%
- Motor D: 21%
- PwrElect: 6%
- Resistive: 14%
- Current: 14%
- Total: 21%

DSW_MIX
- Motor A: 16%
- Motor B: 16%
- Motor C: 8%
- Motor D: 16%
- PwrElect: 16%
- Resistive: 12%
- Current: 27%

DSW_RAG
- Motor A: 13%
- Motor B: 15%
- Motor C: 14%
- Motor D: 12%
- PwrElect: 11%
- Resistive: 14%
- Current: 26%
CMLD Verification, $V_{\text{stall}} = 0.6$, $T_{\text{stall}} = 2c$

Model Validation studies:

- 60% stall voltage threshold was very conservative
- Lowering stall voltage to 40 to 45% gave much better matches between studies and simulations
Phased Approach

WECC adopted phased approach for CMLD deployment in 2011

Phase I had Motor D stall disabled

• Simulation results were too conservative according to engineering judgment and Hassayampa event validation (with \( V_{\text{stall}} \) of 0.6)

• Transient voltage dip and recovery criteria needed to be coordinated with the delayed voltage recovery displayed by the model
AC Testing, Revisited

John Undrill implemented a point-on-wave model to simulate behavior of single-phase air-conditioners. He found that a point on wave where a fault is applied plays significant role in whether AC will stall or not.

John Undrill, Bernie Lesieutre, BPA, EPRI performed additional testing of air-conditioners with respect to point on wave where sag was applied as well as the rate of voltage change.

Plots provided by Dr.Bernie Lesieutre at University of Wisconsin.
CMLD Verification, $V_{stall} = 0.45$, $T_{stall} = 2c$
CMLD Verification, $V_{stall} = 0.40$, $T_{stall} = 2c$
CMLD Verification, $V_{\text{stall}} = 0.45$, $T_{\text{stall}} = 3c$

![Diagrams showing voltage, frequency, and end-use disconnected simulations over time.](image-url)
Phased Approach

Additional AC tests and model validation studies supported revision of V_{stall} down to 0.4 to 0.45 voltage and T_{stall} of 2 cycles.

WECC also relaxed its transient voltage dip and recovery criteria.


Motor D stall enabled with V_{stall} = 0.45 and T_{stall} = 2 cycles.
FIDVR Study Experience

AC Stalling and voltage recovery are affected primarily by:
- Percentage of Motor D (could be up to 45% in residential suburban feeders in hot climates)
- Assumptions on Vstall
- Load Density
- System strength
Data Management

WECC uses Load Type to manage dynamic load model data

Load Types include 12 climate zones X 4 economic uses + industrial

Transmission Planners are required to provide Load Type as a part of powerflow base case data as a part of NERC MOD-032 data submittal

WECC staff uses NERC LMDT–type tool to generate PSLF DYD and PSS®E DYR records

WECC uses load-specific records

WECC is planning to move to Load-Type records
Moving Forward

Loads will play a greater role in Bulk Power System stability
  Increasing share of electronic loads
  Distributed Energy Resources
  Energy Storage

Modular CMLD structure is needed so that new model components can added without changing structure of the model
  new electrical end-uses and distributed generation
  continual improvement of end-use models
    3-phase motor models
  Motor D – phasor model with protection and control
  Power electronic loads
Thank You