

Fault-Induced Delayed Voltage Recovery (FIDVR) & Dynamic Load Modeling Workshop

Takeaways & Lessons Learned

September 30, 2015 – October 1, 2015
Alexandria, VA

Workshop Objectives

The 2015 NERC-DOE Workshop on Fault-Induced Delayed Voltage Recovery (FIDVR) & Dynamic Load Modeling was held in Alexandria, VA on September 30-October 1, 2015. The workshop brought together power system and end-use manufacturing industries to accomplish the following:

- Review the current state of dynamic load modeling
- Review DOE-sponsored R&D efforts to better understand and model end-use loads
- Discuss findings related to motor stalling and its aggregate effect on system performance
- Discuss current and future trends in end-use equipment manufacturing, and facilitate an open dialogue between the manufacturing and electric utility industries
- Provide insight into load model data derivation and discuss data management practices
- Explore the value of field measurements in understanding dynamic load behavior
- Share Transmission Planning experiences in using composite load models
- Relate the efforts of dynamic load modeling and FIDVR to bulk system reliability aspects

Key Takeaways

The following takeaways were identified as high priority, and should be the focus of efforts moving forward:

1. **Composite Load Model:** The CmplDW¹/CMLD is considered the state-of-the-art in dynamic load modeling; although not a required model, its use is considered a “best practice”. Phased implementation similar to the one adopted by WECC is recommended, as it allows utilities to proceed at a measured pace, and gain experience and confidence in the model. Systematic sensitivity studies help to identify model inputs that deserve focused attention. Software tools need to be benchmarked to ensure uniformity in load model implementation.
2. **Transient Voltage Response Criteria:** The transient voltage response criteria required in TPL-001-4 Requirement R5 provides a baseline for transient voltage response; however, it does not directly relate to bulk power system reliability and should be re-evaluated.

¹ [https://www.wecc.biz/Reliability/WECC Composite Load Model Specifications 01-27-2015.docx](https://www.wecc.biz/Reliability/WECC%20Composite%20Load%20Model%20Specifications%2001-27-2015.docx)

- 3. Dialogue with End-Use Manufacturing Community:** End-use loads technology is rapidly evolving and likely will no longer be directly coupled to the grid; instead loads will be coupled through power electronic interfaces. The end-use (load, storage, generation) manufacturing community is receptive to unified electric utility participation. Understanding the reliability needs of the grid will enable development of loads and resources that remain “grid-friendly”.
- 4. Risk-Based Framework:** A risk-informed criteria should be considered that differentiates required system performance between high probability, low consequence events where continuity of service is key and low probability, high consequence events where continuity of the bulk power system is critical.

Workshop Summary

The workshop agenda was broken down into distinct focus areas, providing a comprehensive overview of dynamic load modeling and FIDVR. Each section had unique takeaways, which are listed below.

Current State of Load Modeling

- Explicit representation of the dynamic behavior of end-use loads is now essential for reliability studies of the performance of the bulk power system
- The Composite Load Model (CMPLDW/CMLD) represents the current state-of-the-art in dynamic load modeling; the model is evolving and its use is considered a “best practice”, although not a required practice.
- CMPLDW is extensively used by GE PSLF users in the Western Interconnection, with tens of thousands of simulations completed up to date.
- Revisions to air-conditioner models are planned as a result of recent testing and analysis work, and will be available in Phase 2 composite load model implementation.

Fundamentals, Testing & Modeling of Air Conditioners

- The physics of stalled residential air conditioner (AC) units is now well understood and can be modeled. There is a continuing need for information on the character of compressor load in stopped, low speed, and restarting conditions.
- Current focus relates to understanding the propensity of populations of central AC units to stall (or not stall); the understanding and capability to model this is close at hand.

Manufacturing Perspective, Future Trends & Technologies

- End-use load technology is rapidly evolving towards loads with advanced controls and operations
- Future loads will increasingly no longer be directly coupled to the electric grid; instead, these loads will be coupled through power electronics interfaces.
- Unified communication between the manufacturing and electric utility industries will be essential such that each is aware of the others’ needs and requirements. This includes engaging load, storage,

and distributed generation manufacturers. The manufacturing community is eager to hear from utility experts related to the development of advanced controls moving forward.

Load Model Data

- The Composite Load Model was developed to explicitly model a range of dynamic load behavior and account for the effects of the distribution systems that connect loads to the bulk power system.
- Default load composition data sets are available for various climate zones and types of substations.
- WECC has years of experience developing and using the CMPLDW/CMLD model. This has led to rapidly maturing, systematic modeling practices, including reliance on open source software developed by DOE-sponsored research. Tools are available for load data management; WECC planning and seasonal operating cases include Phase I composite load model.
- Significantly more work needs to be done, and is underway, to facilitate the effective use these models in conducting stability studies.

Field Measurements

- The use of field data at the transmission, sub-transmission, and distribution systems has been instrumental in understanding the phenomena of FIDVR in real-world power systems as well as in directing needed improvements in modeling studies aimed at reproducing FIDVR.
- Time synchronization between measurements taken at transmission and distribution levels is required to develop a cohesive view of the FIDVR propagation.
- The experience gained in collecting and analyzing field measurement data has demonstrated that this data is invaluable in improving our understanding of the aggregate behavior of a changing population of end-use loads. This data and analysis will be essential moving forward.

Experience Conducting Studies using Composite Load Models

- Phase adoption of the Composite Load Model has allowed utilities to gain experience and build confidence in using the model. In WECC, Phase 1 implementation has air-conditioner stalling disabled; Phase 2 will include model improvements related to single-phase air-conditioner modeling.
- Utilities in WECC have used the Phase 1 composite load model in their TPL compliance planning studies and seasonal operating studies to set System Operating Limits since 2014. Long-term investment plans are often tested using the expected Phase 2 model.
- Disabling the stalling effect of single-phase air conditioners in the model still provides a detailed (composite) representation of induction motor load, power electronic load, and static load. In addition, it provides capability to model protection system settings that inherently come into play for severe undervoltage conditions during major grid disturbances.
- Systematic sensitivity studies are necessary to identify the specific inputs to the model that deserve focused attention.

- Having the software vendors more engaged in the development of dynamic load models will enable quicker and more efficient development of models that meet the needs of those using the models in reliability studies.
- There is a need for composite load model benchmarking between software vendors to ensure modeling consistency.
- Sharing experiences among industry practitioners is essential to advance implementation of the composite load model in North America.

Reliability Focus

- FIDVR originating from within the distribution system is no longer the most significant load-related issue for the operational security of the bulk power system.
- The transient voltage response criteria serves as a baseline; however, it does not directly relate to the reliability needs of the bulk power system and should be reconsidered to capture actual risks.
- Traditional generation and load technologies, by design, had performance margins or grid-friendly behaviors, respectively, that reduced concerns regarding what could not be studied adequately with conventional simulation tools. These margins and behaviors are disappearing as both fleets (generation and loads) change; hence, our exposure to the limitations of what can be studied with current simulation tools is increased.
- Looking forward, the industry needs to revisit the purposes served and manner by which future planning studies are conducted, starting with the reliability objectives they seek to support.
- The value of modeling is insight rather than numerical output; it is essential for those conducting reliability studies to understand the phenomena in which they are modeling and studying such that they also understand the limitations of the software tools and the results obtained from these tools.
- A risk-based framework needs to be considered such that our understanding of the inherent risks to system reliability can be modeled, studied, and addressed in an effective manner. The trade-off between risks must be considered in developing a planning criteria. High probability, low consequence events (common system faults, generator tripping, etc.) should be evaluated against a criteria in which continuity of serving the load is a priority. Low probability, high consequence events (rare system faults, failed protection systems, natural disasters, etc.) should have a criteria in which continuity of the bulk power system is a priority. The former focuses on criteria such as a load-based voltage response criteria while the latter ensures generation security and mitigation of cascading outages.

FIDVR Workshop Reference Materials

- [http://www.nerc.com/comm/PC/Pages/System-Analysis-and-Modeling-Subcommittee-\(SAMS\)-2013.aspx](http://www.nerc.com/comm/PC/Pages/System-Analysis-and-Modeling-Subcommittee-(SAMS)-2013.aspx)
- <https://certs.lbl.gov/project/fidvr-meetings-and-workshops>