3.0 Task 4.0: Improving Dynamic Load and Generator Response Performance Tools

3.1. Introduction

Secure operation of the electric grid relies on planning studies, conducted off-line, typically months in advance, that consider whether the grid is capable of withstanding credible contingencies (such as the unplanned loss of major generating plants or transmission inter-ties). These anticipatory (or what if) studies are used to establish operating limits for secure operation following criteria established by North American Electric Reliability Council and Western Electricity Coordinating Council . The dynamic load models currently relied on to prepare these studies are known to be inadequate. They were first developed over 20 years ago and have rarely been updated to capture the dramatic changes that have taken place in the underlying composition of load (for example, increased saturation of power electronic devices, induction motors, etc). Similarly, dynamic models for governor frequency response control, until recently, have not kept pace with industry changes. Blackout risks, exacerbated by inaccurate models, were clearly illustrated in the August 10, 1996, blackout, when simulations, using these models, were unable to replicate blackout events. Recent disturbances in Southern California displaying delayed voltage recovery, and lightly damped oscillations on the California-Oregon Intertie are not captured by simulations using current models. This project prepared a scoping study to identify the research required to improve dynamic load and generator response models. The study was based on literature reviews of current state-of-the-art load modeling, active participation in the Western Electricity Coordinating Council Load Modeling Task Force, and discussions with leading researchers and practitioners. The project has already led to formal sponsorship by Western Electricity Coordinating Council of a follow-up, cost-shared PIER project to conduct research on the highest priorities identified in the scoping study.

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This project is the first phase of an ongoing RD&D activity coordinated by the Lawrence Berkeley National Laboratory Consortium for Electric Reliability Technology Solutions. The purpose of this initial phase is to prepare a scoping study that identifies needed research to improve these dynamic models. The research identified in this scoping study is being conducted through a separate University of California Work Authorization Contract 500−02−004: MR−049, Western Electricity Coordinating Council Load Modeling Research Project.

3.2. Background and Overview

To study transient events, such as the sudden, unplanned loss of a major transmission line or generator, dynamic computer simulation models are used to predict the response of the grid in the first few cycles and seconds following an event. California ISO and others have reported that these simulations are inaccurate and, sometimes, do not adequately predict the actual, observed response of the system to events, especially when the grid is under stressed conditions. A comparison of observed voltage and frequency transients to simulated responses suggests that there are inaccuracies both in load models and in generation plant control models used in these simulations.

The load models in use today were first developed over 20 years ago and have rarely been updated to capture the dramatic changes that have taken place in the underlying composition of load (for example, increased saturation of power electronic devices, induction motors, and so forth). Moreover, the forms of the load models that are used are unrealistic because they are based on the estimated composition of loads during the summer peak period, while they are also used for studies of other periods (such as other seasons and other times of day).

Similarly, until recently, the models for governor frequency response control have not kept pace with changes in the industry. California ISO staff have noted decreased frequency response after large outages, and North American Energy Reliability Council has documented a persistent decline in frequency response in both the Eastern and Western Interconnections. As a result of restructuring, the actual settings on generator controls are not as well-known as they used to be by the transmission system operators because different firms now operate the generators. Previously, the same firm operated both the transmission system and the majority of generators, so information sharing on settings was easier. Newer generation technologies, especially, have plant controls that are believed to override the automatic governor controls on the generators. Yet, transmission operators have traditionally assumed that these controls are operating in order to ensure system reliability. Better information is required on the actual settings for these controls, as well as on the plant control systems than may override them. Recent WECC modeling work has resulted in new plant control models that should improve the simulations of plant response.

3.3. Task Objectives

The overall technical objective is to conduct research that will improve the accuracy of the dynamic models used in Western Electricity Coordinating Council to set reliability limits, retrospectively evaluate significant disturbances, and conduct additional planning studies.

Incorporation of research results into the models used by Western Electricity Coordinating Council to conduct these studies is the principal measure of success for this program of research.

The specific technical objective of Task 4.0 is to prepare a scoping study that identifies and prioritizes the research activities needed to improve the performance of computer-simulation models.

Follow-on work, which has been awarded through a separate University of California Work Authorization Contract 500–02–004: MR–049, Western Electricity Coordinating Council Load Modeling Research Project, to conduct the research identified in this scoping study, is the principal measure of success for this project.

3.4. Task Approach

The task approach involved gathering information through literature reviews of current state-of-the-art load modeling, phone and electronic consultations with experts, and active participation in meetings of the Western Electricity Coordinating Council Load Modeling Task Force.

The draft report of research findings and recommendations was submitted for review to a panel of seasoned and knowledgeable industry experts, including: Bob Cummings (North American Energy Reliability Council), Dimitry Kosterev (BPA), Irina Green (California ISO), Anatoliy Meklin (PG&E), Gary Chinn (Southern California Edison), Abraham Ellis (Public Service Company of New Mexico), Henry Huang (Pacific Northwestern National Laboratory), Donald Davies (Western Electricity Coordinating Council), David Hawkins (California ISO); and Baj Agrawal (APS). In addition, presentations were made to the Western Electricity Coordinating Council Load Modeling Task Force, California ISO, and Transmission Research Program.

A final report, Improving Dynamic Load and Generator Response Performance Tools, that responds to these reviewers was prepared and is attached. (Appendix G. Scoping Study Report on Improving Load and Generator Response Models.)

3.5. Task Outcomes

- The literature reviews and interviews with staff in the West, documented the need for improved load generator governor modeling. Consortium for Electric Reliability Technology Solutions paid special attention to Western Electricity Coordinating Council modeling activities, including the work of both the Model Validation Working Group and the Load Modeling Task Force. As a result, the project team learned that Western Electricity Coordinating Council research had neared completion of a project to improve models for generator governor controls, but that more work is required in the area of dynamic load modeling. Accordingly, the project team focused its efforts on RD&D needs to improve dynamic load models.

The project team developed 16 recommendations to improve dynamic load models. See Table 1. The recommendations are grouped into three general areas (Policy, Load Modeling, Measurement and Validation, and so forth), by level of effort, including time required, the need for/role of PIER support, and our assessment of the overall significance of each recommendation with respect to the others.

As part of the review process for the scoping study, the project team vetted its recommendations with the aforementioned Western Electricity Coordinating Council Working Group and Task Force. They were well-received. While the scoping study was in its final stages of development, the Western Electricity Coordinating Council Load Modeling Task Force sponsored a research project to implement the highest priority recommendations from the scoping study. Industry participants and PIER are sharing the study's cost.

Table 1: Summary of Research Recommendations

Recommendation	Level of Effort	Time Required	PIER Support	Significance
Load Model Development and Policies				
Develop seasonal models.	Low	1-year	Low	Moderate
Validate with state estimator models.	Low	1-year	Low	Moderate
Review reliability criteria.	Low	Multi-year	Low	High
Load Modeling				
Study motor mechanical load characteristics and impact.	Moderate	1-year	Moderate	High
Study impact of single-phase and three-phase motors.	Moderate	1-year	High	High
Model motor load shedding and Low-voltage conditions.	Moderate	1-year	Moderate	Low
Improve Low-voltage protection.	Low	1-year	Low	High
Measurement and Validation				
$10K load monitor	Low	1-year	Low	High
Scoping study: research needs for automatic validation and dynamic state estimation.	Moderate	1-year	Moderate	Moderate
Load Monitoring				
Estimate load composition from measurements.	High	Multi-year	High	High
Characterize model uncertainties using measurements.	Moderate	Multi-year	High	High
Use harmonic information in measurements to enhance load composition estimates.	Moderate	Multi-year	High	unknown
Measurement-Only (Black Box) Models				
Follow research activities in this area.	Low	Multi-year	Low	Low
Uncertainty Analysis				
Develop methods to assess the impact of load model uncertainties on system studies.	High	Multi-year	High	High
Generator Governor Models				
Support WECC activities to implement best model and maintain data for generator	Low	Multi-year	Low	High

characteristics.				
Develop tools to monitor individual generator frequency response.	High	Multi-year	High	Moderate

Source: Consortium for Electric Reliability Technology Solution

3.6. Conclusions and Recommendations

3.6.1. Conclusions

Consortium for Electric Reliability Technology Solutions corroborated industry sentiment that dynamic load models are the least accurate of all of the components in current dynamic system models. Consortium for Electric Reliability Technology Solutions also developed support for the contention that air conditioner models, as a prominent class of dynamic load models, represent the most important area for improvements.

Alarmingly, evidence suggests that generator response to disturbances has been steadily decreasing. Studies conducted using traditional dynamic models do not reproduce these findings. A recent Western Electricity Coordinating Council project, however, has already produced an improved model that better represents actual generator governor behavior. Hence, additional, fundamental research is not required, as these efforts are already well-underway. Nevertheless, maintenance of the databases of generator characteristics remains important. In the future, there may be a need for tools to monitor generator frequency response, which is not a modeling issue, per se.

3.6.2. Recommendations

As noted in Table 1, above, the project team makes 16 recommendations to improve dynamic load models (Appendix G. pages 16–41). The recommendations are by general area (Policy, Load Modeling, Measurement and Validation, and so forth), level of effort, time required, need for PIER support, and significance. Consortium for Electric Reliability Technology Solutions recommend pursuit of research on these topics in a follow-on project.

Consortium for Electric Reliability Technology Solutions also strongly recommend that this program of research be conducted in close collaboration with and, ideally, with support from the Western Electricity Coordinating Council Load Modeling Task Force. Western Electricity Coordinating Council already has a standing committee structure whose sole purpose is to review these models and seek to improve them as needed. Working directly with Western Electricity Coordinating Council is essential for ensuring that the results of this research can be implemented readily.

3.6.3. Benefits to California

California will benefit from improved dynamic models in several ways. First, improved models and a better understanding of the likely impacts of remaining uncertainties in these models will increase the reliability of grid operations by allowing operators to more accurately study system voltage problems and the dynamic stability response of the system to disturbances.

Second, improved models will increase operator confidence in operational limits and operator controls. Secure operation of the grid is maintained through planning for credible contingencies, including the specification of path ratings and the deployment of remedial action schemes. Improved models may identify the need to curb optimistic ratings or may allow increases for overly conservative ratings. In either case, confidence in grid security will increase. Confidence for operator actions will also increase with the ability to accurately predict system responses to events and actions.

Third, in the longer-term, improved models will benefit the decision process for capital investments, which must account for how operational limits value the benefit of a proposed resource. For example, load modeling studies will lead to better informed investments in components for remedial action schemes. Similarly since the models are used to set operational path ratings, they will impact decisions for transmission and generation investment.

4.0 References

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5.0 Glossary

APS	Arizona Public Service
BPA	Bonneville Power Administration
CA ISO	California Independent System Operator
CERTS	Consortium for Electric Reliability Technology Solutions
CIEE	California Institute for Energy and Environment
DOE	Department of Energy
EIPP	Eastern Interconnection Phasor Project
EMS	Energy Management System
EPG	Electric Power Group
EPRI	Electric Power Research Institute
LBNL	Lawrence Berkeley National Laboratory
LMP	Locational Marginal Pricing
LMTF	Load Modeling Task Force
MRTU	Market Redesign and Technology Update
NERC	North American Electric Reliability Council
PDC	Phasor Data Concentrator
PG&E	Pacific Gas and Electric
PIER	Public Interest Energy Research
PMUs	Phasor Measurement Units
PNM	Public Service Company of New Mexico
PNNL	Pacific Northwest National Laboratory
PSE	Puget Sound Energy
PSERC	Power Systems Engineering Research Center
PSLF	Positive Sequence Load Flow
RD&D	Research Development & Demonstration
RTDMS	Real-Time Dynamics Monitoring System
RTSO	Real-Time System Operations

SCADA/EMS	Supervisory Control and Data Acquisition/Energy Management System
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
TAC	Technical Advisory Committee
TRP	Transmission Research Program
VAR	Volt-Ampere Reactive
VSA	Voltage Security Assessment
WAN	Wide Area Network
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council