

2024 White Paper

# Grid Modeling in Distribution Planning and Operations

Importance of Good Grid Models in the Modern Grid Era

## INTRODUCTION

Utilities have always had the need for grid modeling to anticipate grid behavior for grid planning and operations. In the last decade, driven by the increasing complexity of the grid with the proliferation of new technologies such as DER, advanced communications, controls and new actors such as prosumers, DER aggregators, and DER service providers, utilities have either identified the need for (or been required to perform) more complex and detailed model-based analyses. At the same time, tools are being rapidly developed to perform such analyses. While those new modeling and simulation capabilities can provide a better representation of the grid behavior and unlock the full potential of the modern grid, they require an increased amount of correct and granular grid model data. With this comes a change in perception where grid model data plays a central role in both operations and planning departments due to its growing importance for informed and confident decisions. Given the necessity of this information, grid model data is now seen as a critical utility asset.

The growing dependency on model-based studies and the criticality of the underlying grid model data is well understood by planners and operators who have to handle a myriad of model issues and conduct studies on a daily basis. Although the ‘garbage in, garbage out’ philosophy is universally accepted, the relative importance of model data may be less understood more broadly, which may hinder the development of and resource allocation to efforts aiming to modernize grid model data management practices.

Previous EPRI research<sup>1</sup> has identified the benefits of a centralized grid model data management approach in improving grid model assembly and maintenance for multiple end-uses within a utility from a qualitative perspective. With the goal of bringing awareness to the importance of grid model data to multiple teams across a utility, this document

provides practical examples of how common model errors associated with poor model data quality can impact the utility business by identifying many of the associated risks.

## IMPORTANCE OF GRID MODELS

Before the utilization of detailed model-based planning analyses, such as those based on power flow solutions, many of the planning activities were based on approximations, assumptions and rules of thumb – e.g., the use of  $K$  factors for voltage drop/rise computations, approximate loss factors for system losses computations and assumptions regarding load distribution such as uniformly distributed loads, etc. The error introduced by these approximations and assumptions have traditionally been accounted for with the use of engineering margins and/or conservative approaches.

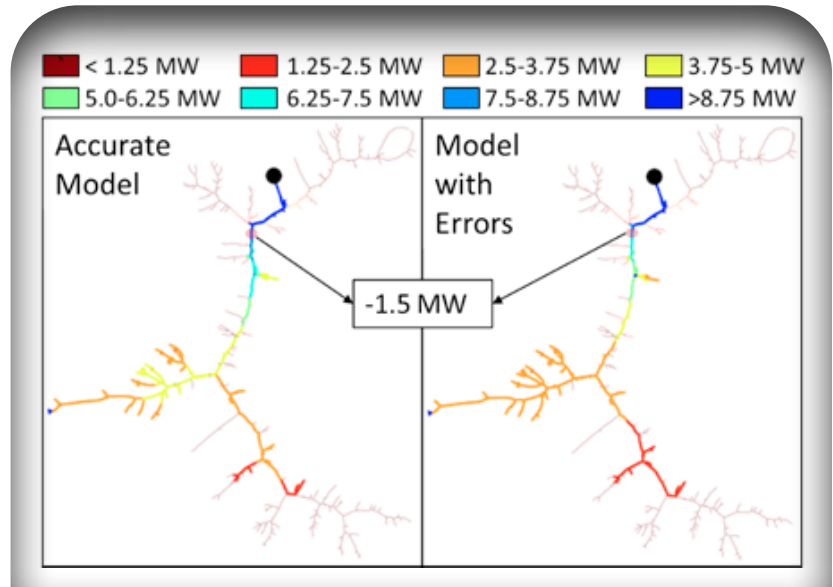
In the context of power engineering, a grid model corresponds to a mathematical representation of an electrical power system built upon the mathematical representation of a collection of model components that comprise the grid. Grid model data corresponds to the parameters that are used to populate that representation. It is common to generally use *grid model* to refer to one or another, or both the mathematical representation and the underlying model data. Since the mathematical representations for typical power flow solutions are well consolidated, the focus herein is given to the grid model data.

The introduction of computer-based modeling and simulation tools considerably increased the potential improvement to planning studies at the expense of detailed model data to support those simulations. When the existence of model data issues is known to planners and cannot be resolved either due to the lack of model verification and validation processes or due to missing data, planners resort, again, to wider engineering margins and conservative assumptions, which can lead to reduced asset utilization and investment recovery, potentially undermining the purpose of performing simulation-based analysis.

1 *Enhanced Grid Modeling: A Collaborative Framework for Model Verification, Validation, and Quality Tracking*. EPRI, Palo Alto, CA: 2021. [3002021521](#).

In the operations space, any advanced operational application such as FLISR, VVO and CVR that leverages poor grid models can directly lead to poor operational decisions impacting both service and power quality. Poor OMS grid models, which typically don't require a grid model as granular and detailed as DMS, can also cause operational inefficiencies and added costs.

A most undesirable case occurs when those grid model issues are not well understood nor substantial enough to be perceived by utility engineers, which can lead to unnoticed poor planning decisions or operational inefficiencies that might only be identified afterwards – if ever identified.



**Figure 1.** Interconnection capacity heatmap indicating maximum generation resource size that the feeder can accommodate.

“Large margins and safety factors are added due to the uncertainty of modeling. While safety factors are important, sometimes they are larger than what would be needed if the model were more accurate. This can lead to equipment being incorrectly sized, or the installation of equipment that is not actually needed (regulators for example).”

– EPRI Member Utility

Given the central role of grid models in modern distribution utilities, the importance of grid models and implications of poor-quality models spans multiple areas of the utility enterprise. From damaged public perception to internal employee satisfaction, all implications ultimately incur added expenses to the utility. The following examples provide several instances of risk incurred from poor grid models as well as highlighting the benefits from alleviating those risks.

### Ineffective Planning

Power flow grid models are critical for performing planning studies. A common issue encountered involves lateral, service transformer and/or customer phasing, the latter two being the most common. In this example, single-phase laterals and service transformer phasing issues are present in a grid model. They consist of wrong phasing of six single-phase service transformers and eight single-phase laterals.

These modeling issues effectively reduce the feeder’s simulated ability to accommodate a future resource at a location near the primary substation by 1.5 MW as shown in Figure 1. Such a difference could induce a planner to not expedite an interconnection request, triggering the need for detailed interconnection studies and allocating unnecessary time and resources, increasing utility and customer costs, delaying interconnection and reducing operational efficiency.<sup>2</sup> Ultimately, if the phasing issues are not spotted during the detailed interconnection study phase, feeder upgrades may

be identified and executed, or the total installed resource size may be limited – therefore not leveraging the full potential of the existing assets.

An EPRI member utility estimates that interconnection requests at locations with enough capacity can shorten the approval time by an estimated 10 hours per customer while also avoiding customer costs who would pay for the study hours, which are estimated at one to ten hours depending on the type of customer request and required study. It also avoids planning study time estimated to be between one to two hours per application request.

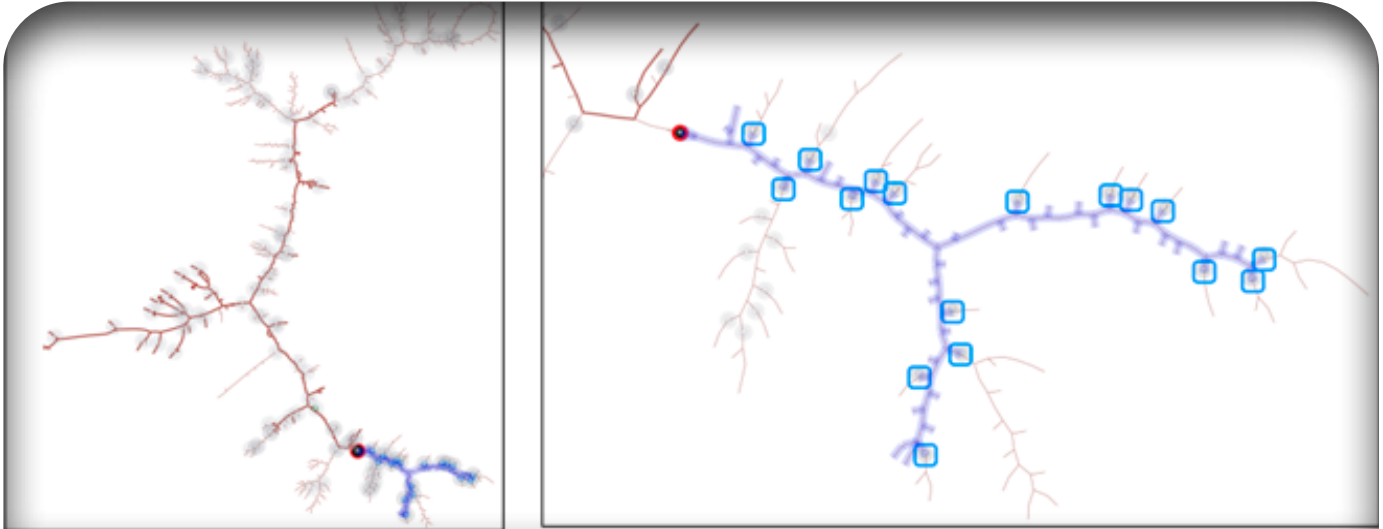
<sup>2</sup> [Final Advanced Metering Infrastructure Benefits Progress Report](#), Puget Sound Energy, February 2024

## Increased Service Interruption

Short circuit grid models are critical for protection engineers at the time of performing protection coordination studies. In distribution, the existence of ground sources can highly increase the fault current levels for single-line-to-ground (SLG) faults. The grid model used in this case study contains five ground source transformer banks located along the feeder main trunk, that have incorrect connec-

tions that effectively remove the ground source. This model issue substantially reduces the fault current at each node, especially at nodes far away from the source.

Precise fault currents are important to set up relays to pick up and trip on fault current within a safety margin. An automated protection performance study performed on the incorrect grid model shows a problematic recloser as shown in Figure 2.



**Figure 2.** Single-Line Diagram showing protection devices (grayed icons), with problematic recloser highlighted in red and downstream fuses in blue.

To address this issue, a protection engineer might reduce both the recloser pickup setting and the downstream fuse ratings to maintain fuse-saving coordination. However, considering the reduced recloser and fuse ratings leads to miscoordination in the field as actual fault currents are much higher because of the ground sources. A miscoordination like this defeats the purpose of the fuse saving scheme as fuses may melt for temporary faults or accumulate damage over time. This in turn results in reduced service quality to customers protected by those fuses as well as additional utility costs with crew dispatches that could be avoided with the original higher coil and fuse ratings had the service transformers been well modeled.

Not properly modeling ground sources can lead engineers to overlook potential issues like desensitization of relays upstream, or reduced selectivity for faults in adjacent

feeders, among others<sup>3</sup> – all potentially leading to service interruptions. This is only a simple example among many other protection issues that can be caused by this type of modeling error on distribution short circuit models including increased life-threatening risks associated with reduced incident energy computed on arc flash studies, and improper relay sensitive modes parametrization aiming for wildfire mitigation.

## Delayed Investment Recovery

For many utilities, modernizing the distribution planning and operation processes entails large investments in purchase and acquisition of advanced commercial vendor technologies to equip planning and operation engineers with the tools to meet the required performance of the modern grid.

<sup>3</sup> *Effective Grounding for Inverter-Connected DER: Final Report.* EPRI, Palo Alto, CA: 2021. [3002020130](#).

This is especially the case for advanced distribution management systems (ADMS) tools, which are a relatively new technology that many utilities have been deploying in the last decade. At the core of many of the advanced applications implemented in ADMS systems – FLISR, VVO, DSSE, etc. – lies a grid model. A common issue encountered by many early ADMS adopters was the unanticipated significant amount of time and resources required to sufficiently clean the underlying grid model data from corporate data repositories – mainly GIS – so that the advanced applications would satisfactorily run in the ADMS environment. Many early adopters suggested setting up different projects for complete grid model data capture and cleaning.<sup>4</sup> In fact, EPRI has also heard from several utility members about the demanding efforts associated with getting grid models analysis-ready, i.e., producing results that are deemed sufficient to allow models to confidently be promoted to the production environment and be leveraged in the control room by operators.

### Reduced Customer Satisfaction

Grid model data issues can impact customer and external stakeholders’ satisfaction in many ways. Consider the case of customer to transformer association, which is a relatively common issue in many utilities that don’t have low-voltage service models available. This issue can impact several areas of the utility.<sup>5</sup>

A utility member has indicated that the consideration of large error margins due to model inaccuracies can lead planners to cancel planned work or to not approve load transfers during planned work, directly impacting customer satisfaction due to avoidable outages.

On the planning side, wrong customer to transformer association can significantly impact load allocation, which propagates to any planning study that requires a power

flow solution. For utilities publishing public facing hosting capacity maps, this can directly impact customer and DER developers leading to frustration and lack of trust.<sup>6</sup> On the operations side, in particular, this issue can lead to field crews being dispatched to wrong locations in response to customer outage calls, increasing outage response times. Likewise, in public facing power outage maps, impacted customers may be identified as in normal service or with incorrect time estimated for service restoration, leading to customer frustration and reduced satisfaction, specially under stress situations such as during Public Safety Power Shutoffs (PSPS).

### Inefficient Use of Engineering Resources

A survey<sup>7</sup> conducted by EPRI with 32 utility members of varying footprints revealed that 62.5% of the utilities perform grid model data validation manually, as shown in Figure 3. Another 16% don’t have the time/resources to correct bad data. While 22% with automated processes in place to automate correction of bad data, this question does not capture the details of the automated processes, some of which may still rely on a considerable amount of manual work.



Figure 3. Results of Survey Conducted by EPRI with 32 Utility Respondents

4 Berdahl, *Voices of Experience: Insights into Advanced Distribution Management Systems*, 2015.  
 5 Presenter, Rosenstiel R. (2024, February 28). Grid Network Data Quality is More Than a Data Issue [Conference panel]. DISTRIBUTECH International 2024, Orlando, FL. <https://www.distributech.com/conference-sessions-shown>.

6 Nagarajan, Adarsh and Yochi Zakai. 2022. *Data Validation for Hosting Capacity Analyses*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A40-81811. <https://www.nrel.gov/docs/fy22osti/81811.pdf>.  
 7 *Enhanced Grid Modeling Data for Planning and Operations*. EPRI, Palo Alto, CA: 2020. 3002018992.

Significant time spent troubleshooting and cleaning grid models is a very common concern raised by utility members. A survey conducted with 25 engineers from a utility member has shown that, on average, 20% of their time is allocated to model cleaning activities. One planning engineer indicated that more than 75% of his time is dedicated to such activities.

While model issue identification and remediation are vital, manual identification and remediation of grid model data errors can be time-consuming and repetitive, especially for specialized engineering position. Although this is more related to how poor grid model data quality is identified and remediated rather than the existence of erroneous data itself, it is important to mention this aspect as it can impact job satisfaction and potentially contribute to turnover.

## OPPORTUNITY TO IMPLEMENT NEW PROCESSES AND TOOLS

Advanced model-based studies and applications are needed to plan and operate modern distribution systems more than ever. This growing dependency causes the associated grid model data to be a critical utility asset.

Good quality grid model data starts with a clear understanding of the model data requirements for each end-use study and application. Utilities must take a proactive approach in obtaining and maintaining the data throughout its

life cycle. The maintenance of the data involves establishing processes to connect the silos that different departments across the utility have traditionally been working in. All internal stakeholders that either source or consume grid model data must work collaboratively to maintain a single grid model data repository that can be trusted by all grid model data consumers.

Finally, grid model data quality control processes must be in place to quickly and preventatively detect and remediate model data issues, therefore minimizing the many risks to the safety and reliability of the distribution system – as well as the overall utility business – that poor models create. EPRI has been actively working with utility members in these areas in the following projects.

- *Applied Grid Model Data Management (GMDM) for Distribution*. EPRI, Palo Alto, CA: 2024. 3002014739.
- *Intelligent Grid Modeling to Expedite Studies*. EPRI, Palo Alto, CA: 2024. [3002031056](#).

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### EPRI CONTACTS

**MATTHEW RYLANDER**, *Team Lead, Sr Principal*  
972.556.6504, [mrylander@epri.com](mailto:mrylander@epri.com)

**CELSO ROCHA**, *Grid Model Verification and Validation*  
[crocha@epri.com](mailto:crocha@epri.com)

For more information, contact:

**EPRI Customer Assistance Center**  
800.313.3774 • [askepri@epri.com](mailto:askepri@epri.com)



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3420 Hillview Avenue, Palo Alto, California 94304-1338 USA • 650.855.2121 • [www.epri.com](http://www.epri.com)

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