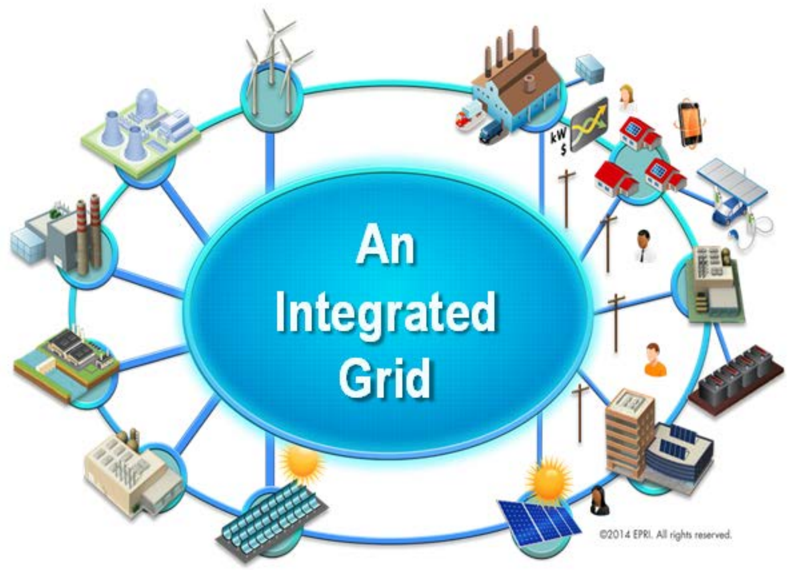
Executive Summary

Distribution Modeling Guidelines: Executive Summary

Recommendations for System and Asset Modeling for Distributed Energy Resource Assessments



Why is Distribution Modeling So Important?

The vast majority of *change* on the grid is occurring at the distribution level and most of that *change* is occurring due to the introduction of distributed energy resources (DER). Planning approaches, data, and models have been used throughout the years that are now proving to be insufficient to fully realize the concept where DER is efficiently and reliably interconnected, integrated, and utilized in the electric grid.

The utility industry is devoting a great deal of effort integrating new customer technologies into the distribution system. However, the industry is still in need of addressing the modeling challenges associated with this evolution. Effective distribution models are necessary in order integrate this new technology and fully realize the concept we refer to as an Integrated Grid.

Traditional Techniques: With growing penetration of DER, rules of thumb simply aren't sufficient anymore. Traditional rules of thumb originally designed to help utilities reliably serve customers via 1-way power flow have proven quite effective through the years. The introduction of technologies such as DER by which the "dynamics" of the distribution system change, however, find utility planners faced with the fact that traditional, non-model based techniques are no longer sufficient.

Screening of DER: Screening based upon rules-of-thumb aren't sufficient anymore either. With the high-penetration levels the industry is experiencing now and ever more so in the near future, modeling is increasingly becoming necessary to reliably assess DER impacts prior to interconnection to the grid.

Planning with DER: The new requirements imposed on distribution utilities to incorporate DER into the planning process necessitate the need for improved distribution system modeling. This has most recently come to light with the recent California distribution resource plans (DRP) and NY Reforming the Energy Vision (REV) where utilities are required to develop and post distribution-wide maps where DER can more/less easily interconnect to the grid as well as provide certain services. System-wide planning for DER requires system-wide data and models.

Integration of DER: Effective integration of distribution technologies such as DER requires utility's to better locate and/or control these devices in order to more efficiently, reliably, and cost-effectively serve all customers. Distribution modeling of the grid and the new technologies is a necessary step towards this integration.

Future Planning of the Distribution System: The future "state" of the distribution system is much different than that which we see today. In many cases, the distribution system looks a lot like the transmission system where generation is dispatched and controlled, distribution systems are networked and reconfigured, and customers are served through local and remote services. In some cases, the distribution system is considered no longer a means for serving energy to local customers, but rather providing services to the bulk transmission system. Can such services be delivered "through" the distribution system? Distribution models are going to become a necessity in order to answer such questions.

While the utility industry has spent a great deal of effort interconnecting these new DER technologies, little effort has focused on how to better model the distribution system in order to efficiently, effectively, and reliably integrate DER and other new technologies into the grid.

The report provides guidance in terms of distribution system modeling elements that are critical to the future of distribution planning with DER. Each component is discussed separately, providing insight into scope, gap/issues, value, challenges, approach, and requirements. In addition, each element is prioritized based upon relative importance and urgency.

Benefits Realized Through Distribution System Modeling

Through effective modeling of the distribution system a broad range of benefits can be realized from improved confidence in decision making to increased efficiency of DER impact assessments, visibility into the distribution system, and better utilization of existing assets.

Rather than relying on rules-of-thumb that estimate distribution impacts, models enable utilities to more accurately assess DER impacts on the distribution system. Models also allow utilities to better evaluate solutions to accommodating DER. Doing so gives engineers the ability to better articulate potential issues and solutions to both upper management and the public a like.

- DER Screening
- Evaluating the true value and cost of DER
- Distribution resource plans
- Targeted grid modernization projects
- Evaluating effectiveness of new technologies
- Efficiency assessments
- Evaluating/designing DMS/DA schemes
- Contingency analysis
- Capacity planning
- ....

Figure 1. Benefits of Modeling

When models are readily available, utility engineers can also save considerable time assessing the impacts of DER. Variations in grid and DER conditions can be readily evaluated allowing distribution engineers to consider a wide range of possible conditions by which DER can interact with the grid.

Much of the new technology is interconnecting to the grid where utilities have less visibility regarding grid health. Most often, DER connects at the low-voltage level or at the "ends" of distribution feeders where limited measurement data is available. Models allow utilities to "see" into those areas where measurement equipment is expensive to deploy, maintain, and utilize.

In order to reliably serve all customers utilities often plan to worst-case conditions. When models of specific assets are not available, utilities typically find it necessary to be conservative in these estimates. This can lead to under-utilizing existing assets due to the uncertainty regarding potential risk of "pushing" assets to hard. Models allow utilities to better understand asset margins and better quantify when infrastructure changes and/or upgrades are necessary.

Adversely, potential risks of not modeling exist as well. Some of these potential risks include 1) overestimation of impacts leading to ultra-conservative limits and increased costly upgrades or 2) underestimation of DER grid impacts leading to decreased reliability and power quality. Other potential adverse side effects include stranded system investments and system ineffencies.

Challenges Associated with Distribution Modeling: The Breadth and Depth of the Distribution System

Breadth

An entire distribution service territory often consists of multiple large planning areas in which substations and feeders have widely varying design and control parameters. Due to unique design and operating criteria developed over the years, two adjoining planning areas may have unique planning and operational requirements. Within each planning area, utilities may have tens or even hundreds of substations that connect and deliver energy from the transmission system to serve hundreds or thousands of different distribution feeders. Each of these feeders is outfitted with equipment for providing both voltage control and system protection; this equipment is operated using custom settings to enable the utility to serve all customers in an efficient and reliable manner.

Since distribution feeders have been shown to have a unique response to DER[1,2], models of each distribution feeder is needed. Any two feeders are never alike. They may have similar characteristics yet their ability to accommodate DER is different. The difference in ability to accommodate DER is dependent on the interaction of all feeder components and controls. The dynamic interaction of thousands of elements on a single feeder will always be unique.

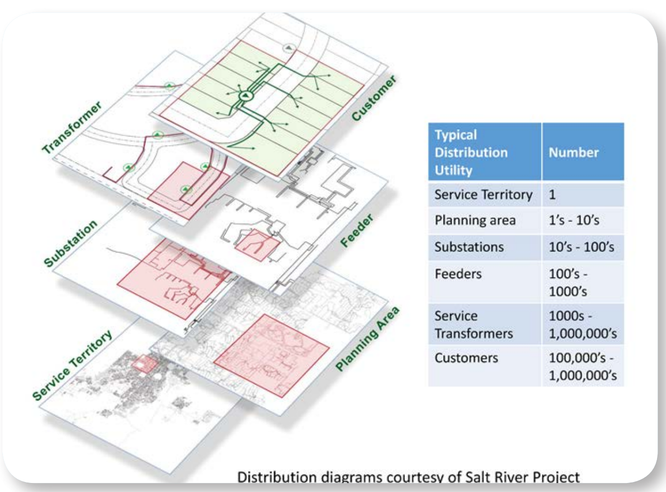


Figure 2. Characteristics of a Typical Distribution Service Territory.

Depth

Within each feeder there are tens to hundreds of service transformers that convert power from the medium voltage down to a more usable, low-voltage service level. These transformers distribute this service through multiple secondary systems that connect each service transformer with individual residences, commercial buildings, and industrial complexes. Therefore, customers located at the very "edge" of the grid where DER is often connecting—and distribution utilities often have hundreds of thousands or even millions of customers—are served by a vast and diverse network of feeders, substations, planning areas, and, ultimately, an entire distribution service territory.

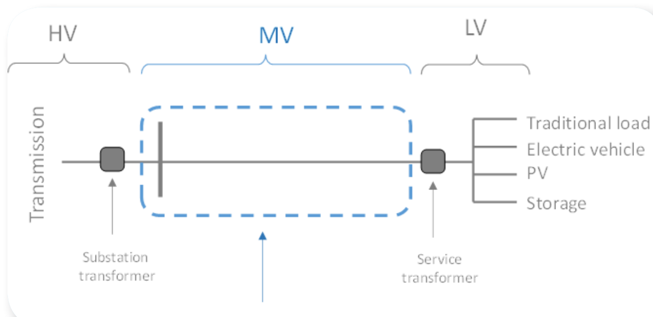


Figure 3. Distribution planning models typically contain only MV assets.

The depth of distribution models typically don't quantify this level of impact effectively. As it relates to modeling, the closer we get to the "edge" of the grid the more unclear we are of the distribution system and performance. The deeper we envisage into the distribution system, the more "fuzzy" things become, just as shown in the image in Figure 4.

Developing and maintaining distribution models that cover the breadth (large number of feeders) and depth (clarity and fidelity through each feeder) allows utilities to better reflect grid assets and performance across the entire distribution system and at the "edge" of the grid. This does come at a price, however.

The "Cost" of Modeling

Time: Depending upon where a utility resides on the spectrum of distribution system modeling (breadth and depth), the time it can take can be rather significant (man-months to years) to develop distribution system models of every single distribution

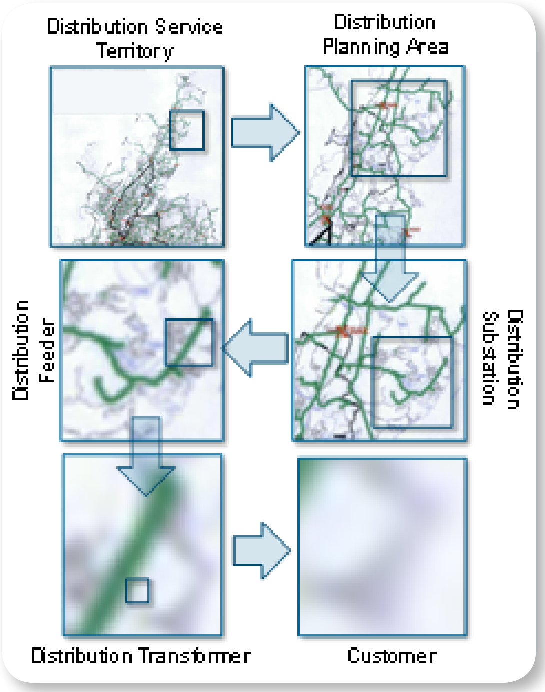


Figure 4. Illustration of the "Visibility" of a Typical Distribution System

feeder. Many factors impact how long it would take for a utility to develop such models, including use of and status of GIS database, status of existing procedures for developing present distribution models, availability of SCADA and customer databases and linkage to distribution assets to name just a few. Due to the time necessary to perform such a task, it is essential to begin systematically moving towards developing effective models. As seen throughout the US and elsewhere over the past few years, DER can grow exponentially over the course of a very short amount of time. Proper preparation for the onset of such conditions is the key to success.

Expense: Developing and maintaining distribution feeder models that account for the depth (fidelity) and breadth (sheer number of feeders) is a non-trivial task at best. Dedicating time and resources for developing and maintaining models are necessary. Often multiple data repositories have to be utilized and rigorous and regularly scheduled updating and verification of models is necessary as well.

With all of that being said, the overall net benefits should outweigh the costs of developing and maintaining effective models of the distribution system.

So What is Needed?

Broadly speaking, improvement in existing models (depth) and coverage for the entire distribution system (breadth) need to be addressed. This report outlines the components necessary to enable utilities to better screen, plan, interconnect, integrate, and utilize DER effectively in the distribution system.

The State of the Industry

Perception is Often Not Reality

Working with various non-utility industries throughout the world, it has become apparent that many have an unrealistic expectation of what are current "standard" modeling practices or what is practical regarding modeling of distribution systems.

Much of this is spurred from externally-funded demonstration projects on select areas of the distribution system. In many of these scenarios, highly detailed models were developed specifically for the demonstration project, wherein every distribution component is modeled explicitly, from the local transmission system all the way down to individual load types (residential AC, TVs, heat pumps, etc). Often times these are the very "public" facing efforts that are given the spotlight, and thus the public layperson assumes the utility has equal levels of fidelity in both measurements and models on the rest of the 100-1000's of feeders and assets on the distribution grid. Reality is much different.

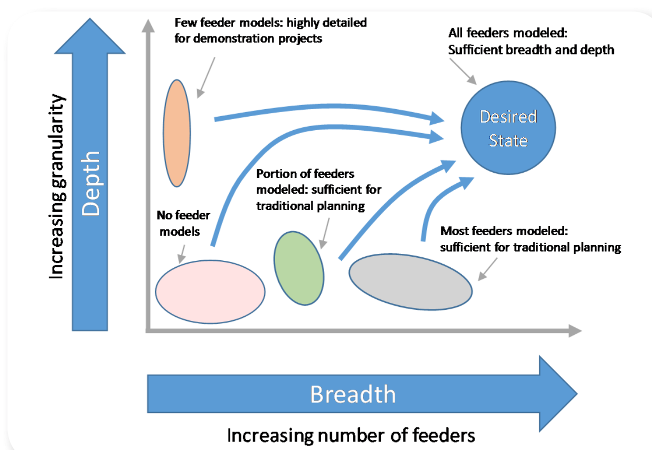


Figure 5. Illustration of where utilities reside on the "spectrum" of distribution system modeling.

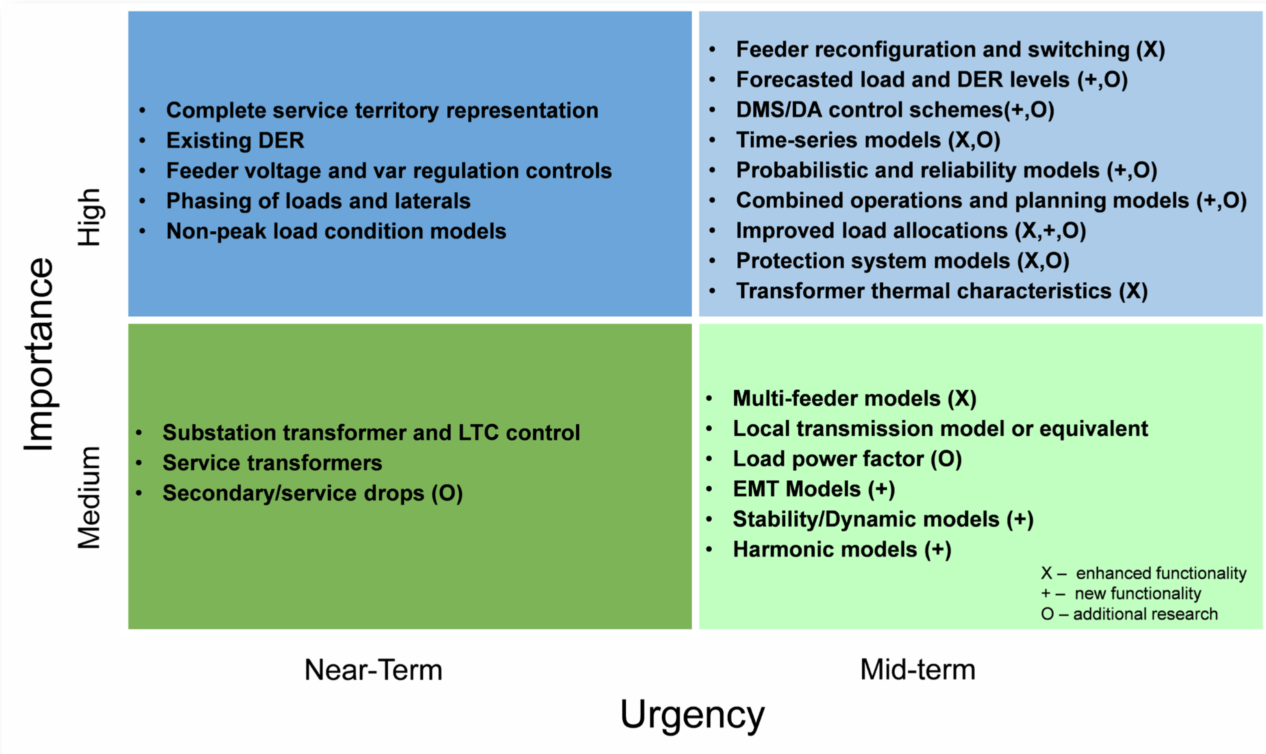


Figure 6. Prioritization Matrix for Distribution Modeling Elements

Reality: Utility Philosophies Vary

The reality of the situation is much different. Utilities may or may not have models. The utility may have limited to no local SCADA measurements either. These issues become more prevalent when we begin looking across the entire distribution system.

The landscape varies across the US and abroad. Some utilities have full models of every distribution feeder. Other utilities, however, may have NO models of their distribution system at all and use rules-of-thumb for planning. Most utilities reside somewhere in between—models are available, but have been created in certain areas only or on an as-need basis.

The lack of distribution-wide modeling EPRI has seen throughout the utility industry is not limited to the type (IOU, municipality, co-op, etc.) or size (100's or 1000's of feeders), location (east coast, west coast, or southeast), or country. Realizing this, we have intentionally refrained from performing a survey of *where* utilities stand on the spectrum of distribution system modeling. This report is intended to provide guidance to ALL utilities, whether that be related to those improving their models or developing models starting from scratch.

Prioritization of Distribution Modeling Elements

To better provide utilities with guidance regarding the many elements associated with distribution system modeling, a prioritization matrix has been created by which each of the distribution modeling elements are mapped.

This prioritization matrix is provided in Figure 6 where each modeling element is assigned an importance (medium or high) and urgency (near-term or mid-term) factor. In addition, whether the element requires tools with enhanced functionality, new functionality, or additional research is identified as well. *All elements require additional data beyond that typically used in today's models.*

Throughout the report[3] each of the elements are described in detail addressing the values associated with modeling the specific element as well as the challenges and data requirements. In addition, based upon EPRI's experience working with a wide range and number of utilities, we have provided a summary of our sense of where the utility industry stands on the "spectrum" of distribution system modeling.

Summary

Just as distribution systems are built out to reliability serve all customers in a cost-efficient manner, distribution models have been built and maintained through the years when needed to assist in this process. Historically, this may or may not have required the use of distribution system modeling.

The introduction of DER increases the need for modeling due to the growing complexity of the system. Effectively modeling the "depth" and "breadth" of the distribution system has become a necessity. Regardless of where a utility resides on the spectrum of distribution modeling, this report is intended to provide guidance such that utilities can identify gaps within their own system models and identify action plans for filling those gaps. In some cases, utilities may not have models of their system and are needing justification to management for doing so. The full report gives a detailed assessment of the elements of the system that should be modeled and to what extent.

References

1. *Distributed Photovoltaic Feeder Analysis: Preliminary Findings from Hosting Capacity Analysis of 18 Distribution Feeders*. EPRI, Palo Alto, CA: 2013. 3002001245.

2. *Determining the Effectiveness of Feeder Clustering Techniques for Identifying Hosting Capacity for DER*. EPRI, Palo Alto, CA: 2015. 3002005795.

3. *Distribution Modeling Guidelines: Recommendations for System and Asset Modeling for Distributed Energy Resource Assessments*. EPRI, Palo Alto, CA: 2015. 3002006115.

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