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Modernizing Distribution Planning: Drivers and Future Vision

White Paper — *Distribution Operations and Planning*

The distribution landscape is rapidly changing—introducing new opportunities along with increasing system complexity and uncertainty. This changing landscape is driven by the obligation to accommodate and aim to integrate distributed energy resources (DER), changing load patterns, increased stakeholder engagement in the development and application of planning processes, and increased monitoring, automation and control of the distribution system.

Distribution planning is critical to realizing this modern distribution system. However, traditional planning tools, methodologies, and processes only address a narrow piece of these emerging planning demands. For example, existing processes and tools are more geared towards addressing peak demand only and focused on traditional grid upgrade options (transformers, conductor, etc.) rather than considering new solutions like non-wires alternatives (e.g., DER).

Additionally, today's planning processes do not address time and locational values needed to appropriately consider new technologies and customer resources. Planning methodologies and processes are also not equipped to perform strategic and system-wide analyses to support today's integrated resource planning objectives. Applying traditional planning solutions to address these gaps will be manually intensive given new complexities associated with advanced planning needs.

In order to design the distribution system to meet future needs, planning processes and tools must evolve. New processes and tools with built-in automation capabilities are necessary to meet the challenges of planning tomorrow's distribution system. Future tools must provide a comprehensive, efficient, flexible, and integrated approach.

To meet this need, EPRI initiated a research project to develop, test, and demonstrate new methods and tools to efficiently and effectively perform distribution planning assessments and support holistic decision-making [1]. The first step was to work with utilities from across the globe to understand evolving and future needs and challenges with planning a modern distribution system. This paper summarizes those requirements and gaps and provides a vision for addressing them. This is the first in a series of white papers that will provide a roadmap for advancing distribution planning processes and tool capabilities for the modern grid. Specific drivers, objectives, and capabilities will inherently vary from utility to utility. These white papers are intended to be complimentary and inform modernization efforts and distribution planning roadmaps.

DRIVERs and Capabilities to Modernize Distribution Planning

Established tools and methods for the conventional distribution system enabled the effective and efficient design of robust electric distribution systems across the globe which have served both industry and society well. However, the rapid evolution and adoption of emerging technologies and resources are altering how distribution systems are designed, operate, and are expected to perform under future conditions. These changes introduce new dynamics, complexities, and assessment requirements that traditional planning tools were not intended to address.

This section reviews key characteristics of the modern distribution system and how they are driving the need for new planning tools and capabilities. Understanding these needs is an important first step to ensure the developed methods and tools appropriately address and support planning analyses for the modern distribution grid.

DER Accommodation and Integration

In many aspects, the interconnection and integration of DER represents the most significant change associated with the modern distribution system. In this paper, DER encapsulates the various forms of distributed renewable and non-renewable generation sources, demand-side management, and energy storage devices. DER influence on planning can be viewed from two overarching perspectives, depending on their characteristics and the driver(s) for their grid connection:

1. As resources that may require mitigation associated with accommodating at the distribution level
2. As resources that can be integrated into the distribution system as alternative solutions to traditional distribution upgrade

Not all DER fall cleanly into one category or the other, however. From a distribution planning standpoint there is a spectrum between fully accommodating and fully integrating DER, as shown in Figure 1. The influence of the utility on site guidance, control, and visibility of a particular resource determines where on the spectrum that resource will lie. Organic growth of customer-driven PV, for example, where the utility has no visibility or control of, would lie on the accommodating end of the spectrum shown by the red arrow. A utility-owned, installed, and controlled solution would lie on the integrating end of the spectrum, as shown by the blue arrow. A distribution connected storage system whose primary service is to provide frequency response for the transmission system, but that the distribution utility has visibility of, would need to be accommodated at the distribution level. But the distribution utility having visibility means that the resource would lie slightly towards the integration end of the spectrum, where the yellow arrow is located.

Depending whether DERs are being accommodated or integrated, they are accounted for at different points in the overall distribution planning process. The integration of DER, as a non-wires alternative, is examined further in the next section. The general need to accommodate DER drives several new capabilities, including:

- Near and long-term forecasts capturing potential DER adoption rates and locations, which may occur organically or through utility or third-party incentives.
- Assessments of future load and generation temporal interactions and scenarios needed to inform robust system designs.
- Analytical studies, such as hosting capacity, to assess the system's ability to accommodate additional DER and where system constraints might occur.

Non-Wire Alternative (NWA) Design and Evaluation

DER may also be evaluated as potential NWA. NWA are utility-driven solutions to an identified distribution constraint that defers or eliminates the need for a traditional distribution upgrade [2]. When considered as a potential solution to meet near-term expansion planning needs, NWA are introduced in the planning process once system constraints requiring mitigation have been identified. NWA solutions may also need to be captured in the forecast depending upon the nature of the implementation and controls. This will be examined further when discussing the influences of advanced controls.

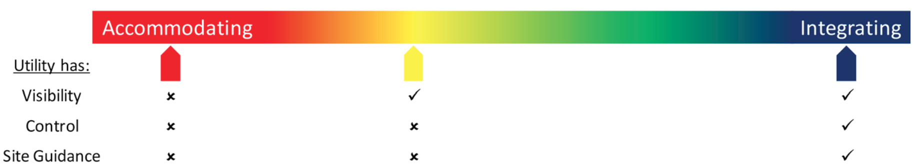

Figure 1 – Spectrum between integrating and accommodating DER

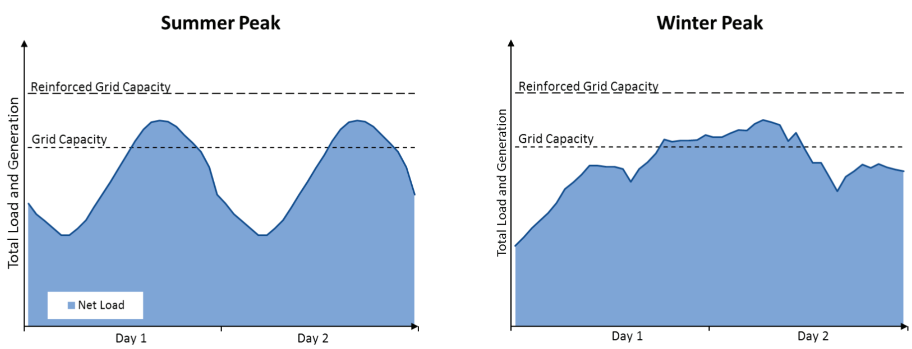

Figure 2 – Illustration of how tradition reinforcements address constraints by increasing system capacity

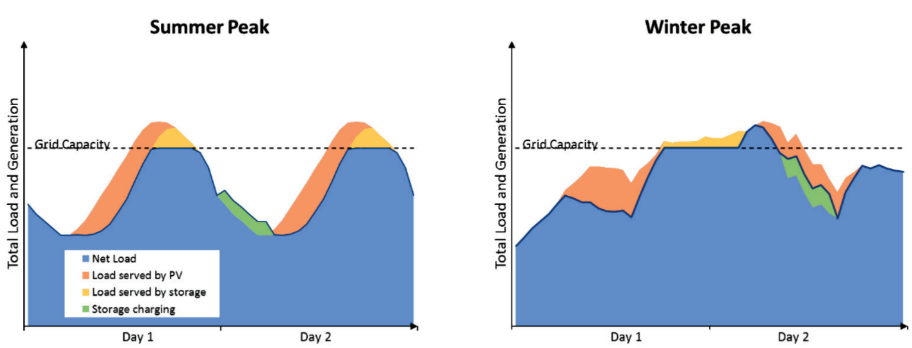

Figure 3 Illustration of how of non-wires alternatives to address system capacity constraints

Traditional planning alternatives are generally passive in nature. That is, their deployment strengthens or increases grid capacity, and that additional capacity does not change over time, see Figure 2. In contrast, NWA are active and more complex solutions designed and managed to reduce or limit net system demands below existing capacity constraints, as illustrated in Figure 3, to adjust or defer major infrastructure investments. As a result, NWA introduce additional assessment and design requirements within the planning process beyond those needed for traditional mitigation solutions. In particular, NWA solutions cannot be designed and evaluated considering peak demand alone. They must be designed and evaluated considering daily and seasonal variations in demand, as well as other system needs. Note that the example solution presented in Figure 3 does not successfully mitigate the winter capacity constraint. Additional uncertainties regarding the availability and variability of different DER types and dispatch schemes is another important consideration. Furthermore, any additional operations of the NWA solution to provide benefits to other parts of electrical system must also be accounted for.

In many cases, identification of potential NWA solutions requires performing quasi-static time-series (QSTS) simulations, which simulate the response of the solution across a series of sequential points in time [3].

These simulations require examinations of specific time-series profiles for the variation of load and existing generation for relevant study periods. Additionally, system models must be updated to reflect the operation of regulators, switched capacitor banks, and other existing system controls that influence the grid behavior over time. Furthermore, as DER technologies continue to evolve at a rapid pace, the availability of accurate and validated DER models for incorporation within planning studies is a constant evolving challenge.

NWAs potentially offer planners increased options and flexibility in their design and operation as a planning criteria violation solution. While this flexibility is a positive aspect of NWA, it also represents a significant effort on the planner's part to design and validate solutions comprised of various DER types and combinations, potential locations in the distribution system, as well as various ways of controlling or dispatching these resources. Each variation and combination of these factors represents a different alternative that must be appropriately designed and evaluated. Manual evaluation of potential NWA options would translate to a significant burden on distribution planning resources. As such, new methods and processes are needed to ensure the design and validation of NWA is both efficient and effective.

NWAs also introduce new dynamics to planning horizon timeframes, impacting both the design and evaluation of these potential alternatives to traditional solutions. One primary application of NWA is to defer the need for traditional system upgrades. Here the planner must evaluate the value of the deferment and cost of the NWA against the cost of the traditional upgrade. Other considerations such as future land availability and project lead-times also need to be considered. These evaluations are further complicated by the modularity of most NWA solutions that permit them to be upgraded or enhanced over time. This raises the issue of comparing different NWA deployment options considering aspects such as installation costs or possible revenues from providing benefits to other parts of the system.

Comparison of NWA and traditional solutions on an equivalent economic basis must also account for vast differences in useful lifetimes. While conventional assets may be expected to be in operation 30 years or more, power-electronics, batteries, and other components have much shorter lifetimes. Further complexity is added when considering that the cost of various hardware solutions may escalate over time at vastly different rates. The cost of battery storage and solar photovoltaics are expected to continue declining significantly in price, while the cost of conventional distribution equipment is much more stable in real terms. Methods for economic analysis can deal with these differences, but a variety of cost-escalation paths can render counterintuitive results.

In order to fully incorporate NWA within planning, specific capabilities are needed:

- Models and simulations to assess system performance and characterize the power and energy constraints during system peaks and longer periods.
- Automated tools that can quickly identify potential NWA designs and verify each solutions viability under multiple system conditions.
- Economic evaluations that holistically compare all alternative costs and benefits, accounting for differences in asset lifetimes, additional value streams, and other new considerations.

Leveraging New Data Streams

Another key characteristic of the modern distribution system, with a significant influence on system planning, is the higher degree of controllability and visibility, compared to what has been historically available. Expanding system visibility, through increased deployment of smart meters and monitoring, can benefit distribution planning in the form of more accurate system models and improved understanding of how system behaviors and needs are changing. But, realizing these benefits can be challenging and requires planning use cases be factored into the decision making on the types and accuracy of the new data collected. Once collected, having the processes, tools, and analytics in place is critical to be able to leverage these data streams in planning.

The need for improved visibility in planning is becoming even more essential when integrating DER. In some cases, smart meters offer the potential to refine existing feeder models to better represent the system assets that connect individual customers, namely secondary transformers and lines at low voltage levels in near real time. Representing this portion of the system was not a concern when planning the traditional grid, as this was effectively captured through the fit-and-forget approach—given the relatively low costs of these assets and static nature of individual customer peak demands. Thus, for many utilities these assets are not included in system models today. With DER, this is changing and requires a closer look.

However, this visibility is not available everywhere presenting challenges in representing emerging technologies where limited historical data is available. Net metering also presents challenges, hindering the ability to confidently separate DER output and load, masking load and thus complicating the planner's ability to generate planning scenarios that properly account for the temporal variations of each.

In order to realize the benefits of these new data streams in planning, there are specific capabilities needed:

- Guidance on what data is required to inform planning decisions.
- Data management practices that ensure effective maintenance and population of GIS information needed to support planners in quickly updating or generating accurate planning models.
- Data storage and processing capabilities that can handle massive amounts of measurements and locational information, which planners can readily leverage to inform planning models and scenarios.
- Robust analytical methods and tools that can remove measurement errors and reconcile deviations from "system normal", such as those due to operator switching or automated system reconfiguration.
- Derivation of appropriate time-series profiles that appropriately capture hourly and seasonal variations in load and DER output and can serve as the basis for QSTS planning studies.

Advanced System and Resource Controls

Advanced system operational controls, such as advanced distribution management systems (ADMS) and distributed energy resources management systems (DERMS), provide numerous functional capabilities and advanced applications that can greatly improve the operation and reliability of the system. However, these advanced control systems do not reduce or eliminate the need for planning. In fact, planning and operations groups will need to work even more closely to ensure the future system upgrades and expansion efforts consider these controls, optimize their benefits, and even expand their deployment in response to changing system needs and demands.

One key aspect, needed to support this future includes the derivation of forecasts and accurate models for relevant control functions and applications, which may influence planning decisions on future system designs and needs. This includes data management to store, update, and disseminate control setting information currently being used in the field, and the ability of planners to evaluate and propose new settings for certain controls that may mitigate issues or strengthen the system. In many cases, existing DMS and other system controls are not explicitly modeled. When performing traditional peak planning studies, the system controls were often represented by manual intervention from planners, setting the state or status of individual system assets to emulate the system control operation for a particular scenario. However, when emulating complex control schemes, this practice can be cumbersome leading to errors and is impractical to perform if QSTS simulations are required.

Deployment of new system controls can also be evaluated as potential NWA. For instance, an electric vehicle charging system's capital and operational costs can be compared against those deferred or offset in the traditional system expansions needed to serve the electric vehicle charging demands. Depending upon how the control operates, planning studies may need to capture these operations in terms of different planning scenarios or through direct modeling of dispatched control signals and logic.

A highly reconfigurable system during contingency events, and even normal operating conditions, is an important attribute of the modern distribution system. Given the potential for two-way flows of power due to injections from various points along the distribution feeder, changes to the system configuration may result in unexpected system impacts that traditional planning approaches may not sufficiently capture. As a result, the number of planning cases needing to be simulated and evaluated can dramatically increase as a function of DER interconnections and system reconfigurability.

In order to account for and incorporate these new controls into planning, specific capabilities needed include:

- Verified models for control schemes that can impact planning simulation results or benefit from planning studies designed to inform control system rollout or determination of control settings.
- Analytics that can quickly assess system-wide benefits of different control implementations to inform strategic planning effort or as potential non-wires alternatives.

Evolving Planning Criteria and Objectives

The desired performance of the distribution system is evolving as well. However, it is unclear how planning criteria will need to evolve to account for changing system characteristics and industry and regulatory objectives. Furthermore, it's difficult to determine the extent to which changes in planning criteria or objectives would impact system expansion plans and capital expenditures.

Identified planning needs and capabilities that will support modernization of the distribution system include:

- Clear, appropriate, and quantifiable metrics for evolving system objectives such as system flexibility and resiliency.
- Ability to effectively and efficiently evaluate the influence that new or altered metrics would have on system performance and capital expenditures in order to ensure they are beneficial to all parties.
- Methods for incorporating stacked benefits and resource implementation objectives, such as greenhouse gas reduction targets, within technical and economic studies.
- Robust risk assessment and predictive reliability assessment tools that can capture changing system objectives and other planning uncertainties.

Distribution planning tools will not only need to support the objectives and criteria at the distribution level, but also support coordination and information exchange between generation, transmission, distribution, and customers. While the objectives of integrated planning will vary depending on utility structure, existing practices, and regulatory aspects, the distribution planning process is most impacted due to the degree of change. In order to inform generation and transmission planning, distribution planning studies are required on a much larger scale, requiring analysis of hundreds or thousands of distribution feeders, across multiple years and planning horizons not typically performed today. Supporting integrated planning, using the traditional methods and approaches, would be highly resource intensive.

Increased Customer and Stakeholder Engagement

In many states, regulatory and stakeholder processes are underway to influence the development of new distribution planning processes that better consider DER integration. These processes include new requirements for distribution planners to communicate the distribution planning process, analytics, and decisions to a broad set of stakeholders. Planning will also need tools to support stakeholder understanding and visibility in distribution planning decisions. With these requirements, future planning processes and tools will not only need to enable efficient technical assessments and economic evaluations but also provide results that are easily digestible and comparable across a range of factors. Planning tool capabilities that support this objective include:

- Simulation and analytics to produce standard as well evolving metrics regarding the technical performance and economic cost-befits of different system reinforcement alternative.
- Ability to quickly introduce new emerging technologies and third-party solutions into the technical assessments and evaluations.
- Tables and visualizations that allow planners to readily document and easily communicate planning study results to both internal and external stakeholders, considering a wide range of alternatives and complex issues.

These capabilities not only support efficient use of available planning department resources, but more importantly, support effective stakeholder engagements through increased transparency and understanding of planning decisions.

The Distribution System Planning Process of the Future (Vision)

Each of these drivers point to specific capabilities that are required within the planning process representing increases in complexity and time to perform planning studies in the future. While currently planning tools may have the ability to be used for certain components of these analytics, new capabilities must be developed to comprehensively plan and design a system, factoring in all these complexities, in an efficient manner.

Review of the drivers and gaps by utility members indicated the following vision for the key features and capabilities for modern a distribution system planning process:

- Holistic evaluation of traditional and non-wires alternatives.
- Flexibility to incorporate changing planning objectives and criteria.
- Engineering analysis that supports effective and efficient system planning.
- Seamless integration of existing and emerging data sources.
- Supports integrated system planning needs between generation, transmission, distribution, and customers.

This process depicted in Figure 4 describes steps of the planning process that will be required in the future. Some of these steps exist today but may be smaller in scale, while others are new steps required for considerations of new resources. New analytics must be developed to characterize various alternatives, optimize their use, and compare them to traditional alternatives effectively.

A major requirement to realizing this vision is the development of tools and analytics that automate various steps of the planning process. As noted previously, the complexities introduced by a more modern distribution system are not easily addressed using traditional planning methods and tools. However, this does not equate to the automation of the entire planning process. On the contrary, many aspects of the planning process cannot be reasonably automated. Furthermore, automation can neither replace the planning engineer's experience and knowledge of the system nor introduce extraneous factors not captured by simulations or analytics. Instead, the planner should have the ability to engineer the appropriate automated analytics and simulations, to more effectively and efficiently answer planning study needs and objectives.

Gaps to Get There

By identifying the drivers, capabilities, and future vision, this white paper is a first in a series of white papers outlining the roadmap forward on future tools and methods to support planners in designing the modern distribution system. The changes are not trivial and require advancements in all areas of the planning process in order to fill the gaps that exist.

In parallel with the roadmap, EPRI is also developing the automated distribution assessment platform and tools "ADAPT" toolset. The purpose of ADAPT is to support research, development, and testing of new methods for automating the planning process steps diagramed in Figure 4.

Applications of the ADAPT toolset will be highlighted in subsequent white papers, which further outline the roadmap and delve further into key aspects of the capabilities required for the modern distribution planning process—such as:

1. Data and modeling needs.
2. Alternative design and assessment.
3. Economic and cost-benefit assessment.
4. User interface and reporting.

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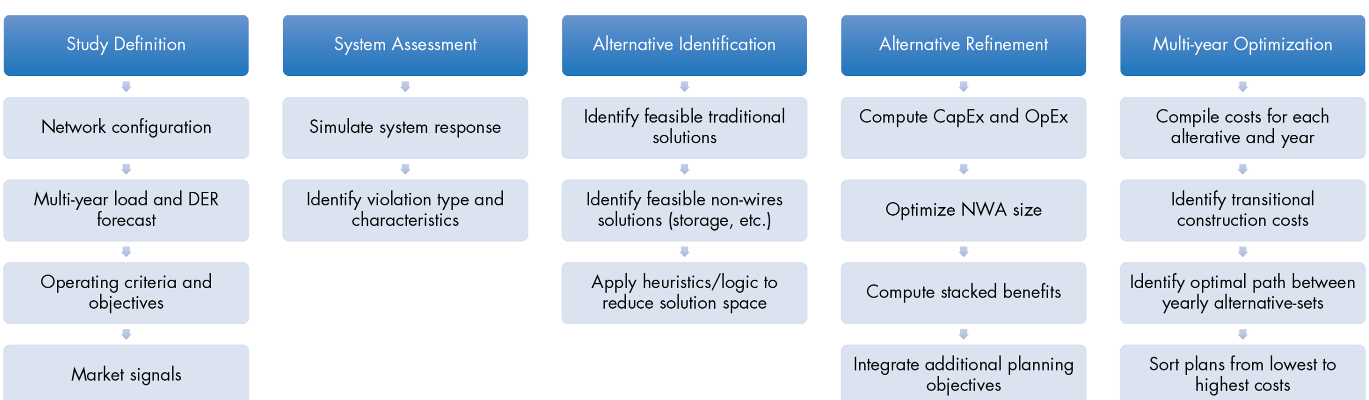

Figure 4 – Steps to the future distribution planning process

3002019874 October 2020

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