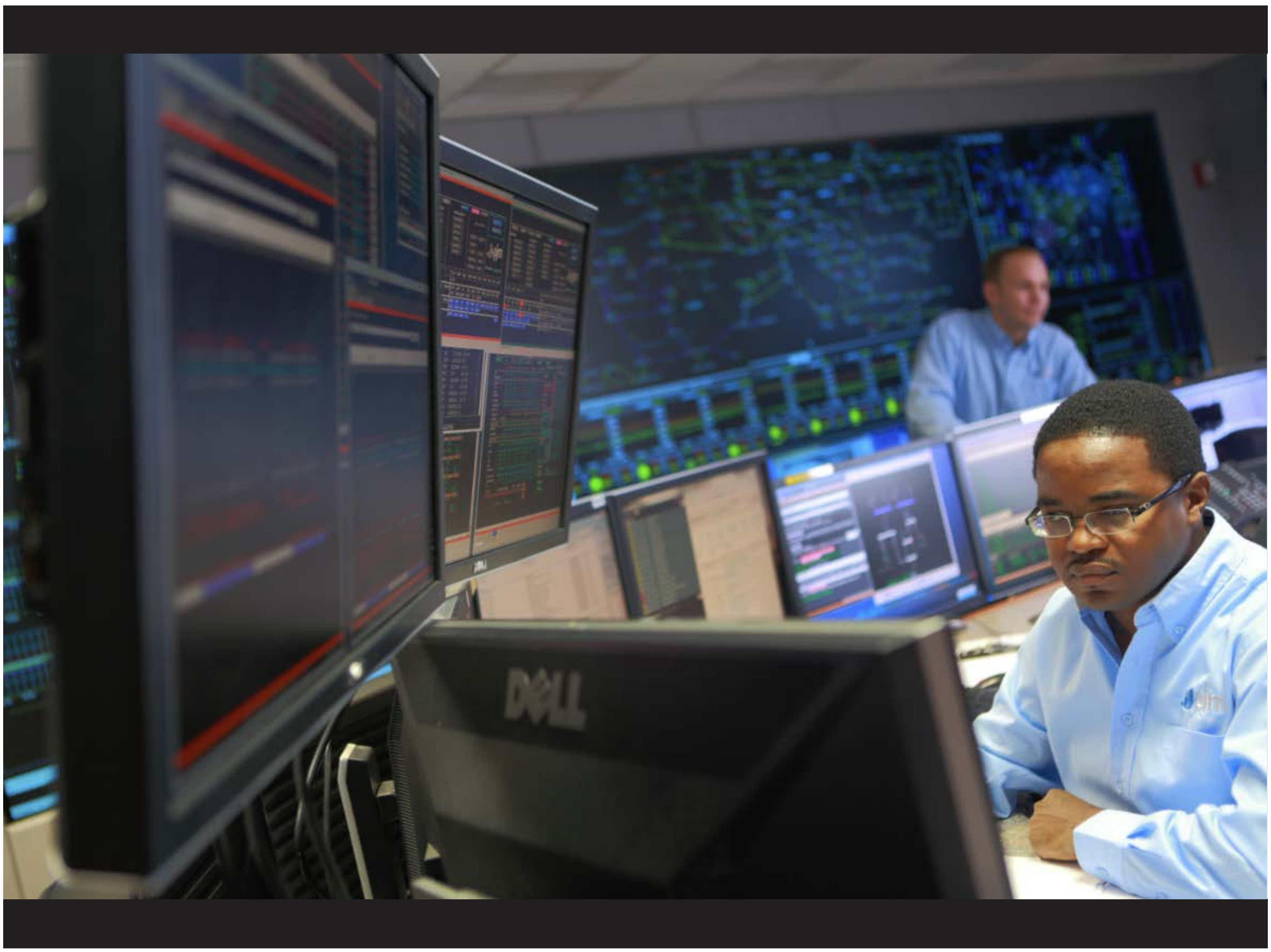
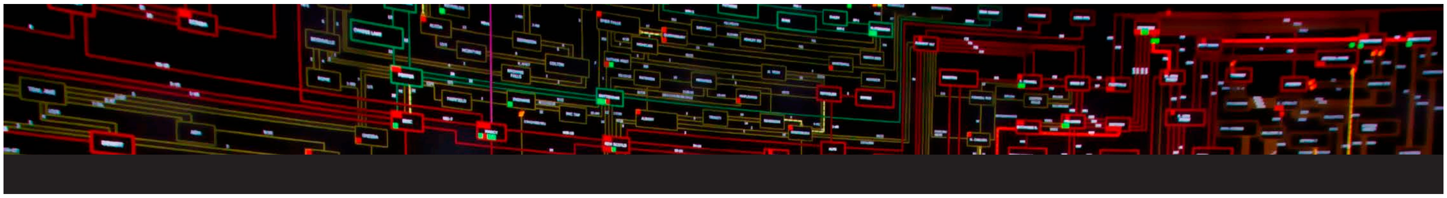
DISTRIBUTION OPERATIONAL PLANNING: EXPANDING THE CAPABILITIES OF A MODERN CONTROL CENTER



December 2022



Introduction

There is no question that the distribution system is being challenged in a way that hasn't been seen for many decades. From modernization efforts that improve reliability to sustainability initiatives that enable more distribution energy resources (DER), the complexity of the distribution system is growing exponentially. As the distribution system transforms into more dynamic, automated, and resilient future state, new roles, capabilities, and analytics will be needed in the control center. Whether its leveraging new data streams, making use of advanced applications in DMS systems or managing dispatchable resources, distribution operators will be at the center of this transformations.

Distribution System Operators (DSOs),[1] who at one time were solely responsible for orchestrating the provision of safe and reliable service to grid customers, are continually inundated with emerging technology, new data streams, and growing responsibilities. The modern distribution control center (DCC) will undoubtedly require additional roles to be filled by staff with diverse skillsets, competent in both operational duties as well as advanced analytical capabilities. One of those roles, is a new role, ***distribution operational planning***.

Like their transmission counterparts, DCCs have begun exploring a new functional role that integrates capabilities of the planning department with the ever-changing responsibilities of the control center. Distribution operational planning is aimed at addressing many of the emerging challenges by providing additional capabilities to the control center. *This paper will focus on several key responsibilities associated with operational planning in support of the DCC by discussing the evolution of operational roles and identifying the skillsets and tools that will be needed within the control center to enable the active management of the electric delivery system of the future.*

Technological Transformation of the Distribution Control Center

Driven by a need for increased productivity, reliability, and safety, today's DSOs are well-informed, efficient, and equipped with powerful tools to distill vast amounts of data into actionable information. However, this has not always been the case. Early distribution operators – who were often, and more aptly, called 'dispatchers' – did not actually operate the system and instead served the role of a communication hub for line crews. The line crews operated the system, obtained their own clearances, and made their own switching plans for repairs and restoration. The operator or dispatcher role was primarily administrative, stationed within line crew headquarters, and consisted of taking customer calls and disseminating the information on paper notes (tickets) to construction or repair crews.[2] Over time, as technology progressed, the capabilities and roles of the operator expanded, eventually paving the way for today's DSO.

In fact, technological advancements, including the development of tools, digitization, and high-speed telecommunications, are largely responsible for the shift towards a centralized distribution control center. Initially the distribution operator was limited by their institutional knowledge of the local system and the number of calls they could manage during a shift. Today, a DSO can orchestrate the operation of complex, highly automated distribution systems that may be hundreds of miles away. As illustrated in Figure 1, the centralization, efficiency, and autonomy of the DSO can be attributed to key technological advancements.

The first shift in distribution operations came when two-way radio systems allowed a single operator to communicate with multiple line crews, eventually leading to a centralized distribution operations center. Supervisory Control and Data Acquisition (SCADA)

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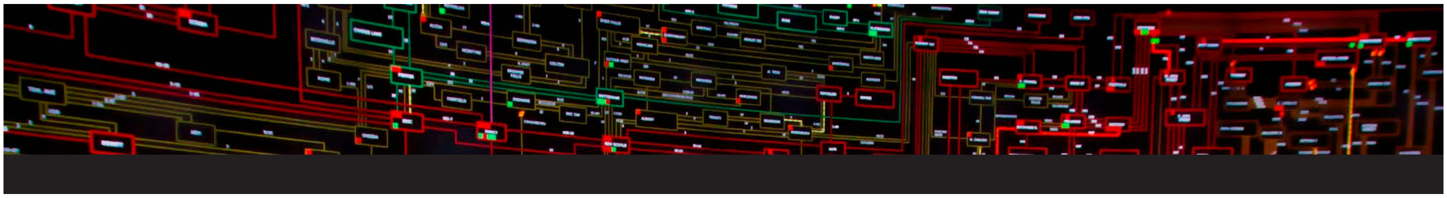
[1] In this paper, DSO refers to the individuals in the control center, the person responsible for real-time operations aka operators, dispatchers, system operators)

[2] *Distribution System Operator of the Future: Defining the Past, Present and Future DSO*. EPRI, Palo Alto, CA: 2019. 3002015267.



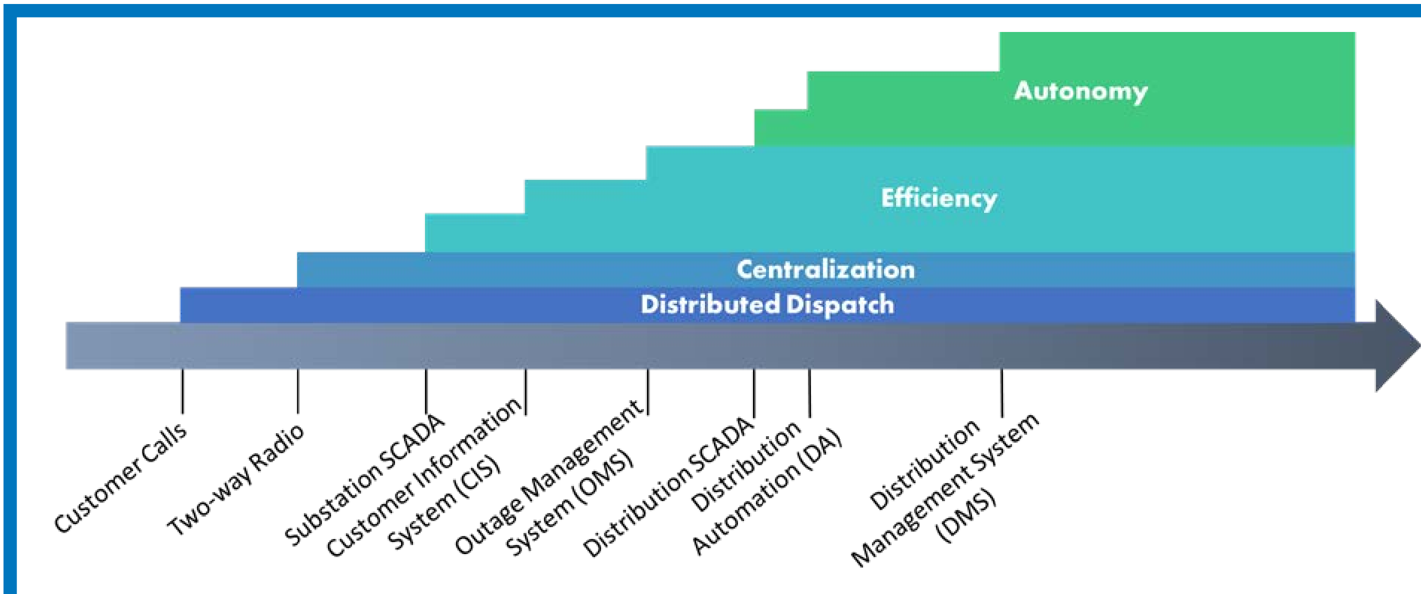


Figure 1. Technologies that have reshaped distribution operations

deployment in substations added efficiency by allowing distribution operators to control substation breakers, representing the first shift of direct control from the line crews to the DSO. Customer information systems (CISs) and outage management systems (OMSs) added to the efficiency gains by separating the customer call center and dispatch roles. As SCADA was deployed further into the distribution system, DSOs gained the autonomy needed to perform major restoration switching faster than could ever be achieved with field crews alone.

However, technology has not always streamlined distribution operations. The deployment of distribution automation (DA) devices, for example, changed the complexity of the distribution system making it difficult for local crews to manage their own clearances safely and effectively. In turn, operators needed to carry the responsibility of both managing these new automated devices and serving as the primary control authority for clearances and hot-line tags. Moreover, each new device and communication stream installed on the distribution system brings with it a deluge of information, some of which is in effect a distraction to the DSO.

In today's complex distribution system, the DSO can quickly become overwhelmed with data, alarms, and cursory notifications. These problems are only exacerbated during high workload or unexpected outages and equipment malfunctions. To alleviate some of these issues and build upon the efficiency gains of an OMS, utilities are in various stages of adopting distribution management systems (DMSs) to manage the system more effectively. These applications were developed to leverage digital system models, and ideally enable the DSO to have greater capabilities to operate the system in ways that were not possible before. With applications such as Volt/VAR Optimization (VVO), Distribution System State Estimation (DSSE), and Fault Location Isolation and Service Restoration (FLISR), the DMS can process the manifold streams of distribution data into actionable operations, some of which are even automated.

Standing in stark contrast to the dispatchers of the past, the modern DSO has developed many advanced capabilities driven by technological advancements. These capabilities have centralized, streamlined, and empowered the DSO, but have also caried growing responsibilities for the DCC. Looking towards the future, there are no signs that this transition is slowing.

On the Brink of a New Era

There is no doubt that technology that has impacted the role of the Distribution System Operator, and technological advancements will continue to unfold into the future. But there are many other drivers, either currently under way or likely to occur soon, that have the potential to reshape the functional roles and responsibilities of the DCC. Like technology, some of these changes will place additional demands on the existing roles of the DCC while others will create a need for new roles and capabilities.

With widespread recognition of climate change, utilities and customers alike recognize the need to transition to a decarbonized and electrified energy future. Much of that change will occur on the distribution system. From a year over year uptick in Electric Vehicle (EV) sales to induction cooktops and gas-free building codes, consumers are in the early stages of relying more heavily on electricity as a primary source of energy for residential, commercial, and transportation applications. With an increasing reliance on electricity the tolerance for service interruptions is rapidly diminishing, putting more pressure on the DCC to maintain and improve reliability.

The proliferation of distributed energy resources (DER) such as solar and energy storage increases the potential for adverse impacts to the distribution system. For years, utilities have screened or studied those resources as a safeguard against violating the power quality, reliability, and safety limits of the distribution system. This strategy ensures that the DSO does not have to manage the DER if the feeder is in its normal configuration. Now, the active management of those resources for distribution[3] and wholesale services[4] presents an opportunity to increase the utilization of assets while reducing the carbon footprint of the electric power sector. Realizing these goals requires a paradigm shift in the operation of the distribution system. In particular, the DCC will need to orchestrate distributed generation similar to the way ISOs manage centralized generators.

As previously mentioned, the control systems and operating environment for distribution control centers continue to evolve toward a fully integrated and fully connected platform.[5] While these tools are extremely powerful, many of their capabilities are not part of the traditional operators experience and skillset. As the distribution system evolves, there may be a need for new roles within the operations organization. On top of that, the traditional pathway to system operations from experienced field crews may not persist. The future DCC will likely be staffed by personnel with diverse and highly specialized backgrounds, much of which may not include distribution system operations.

[3] Distribution grid services can include non-wires alternatives, demand load management, blackstart, and others.
[4] FERC Order 2222 instructs ISOs and RTOs to modify their participation models to enable groups of DER to participate in wholesale electricity markets.
[5] *Distribution Management System: Requirements Reference*. EPRI, Palo Alto, CA: 2017. 3002011003.

Hallmark Capabilities of a Distribution Operational Planner

Historically, the DCC managed functions that could be considered pseudo-planning in nature. These functions include Volt/VAR optimization, outage scheduling, performance of contingency analyses, selection of locations for new protective devices and switches, etc. These functions have historically been assigned to a combination of DSOs (perhaps on back shifts), engineering support teams, or planners. The increasing complexity of the operation of the distribution system is driving the need for new roles and responsibilities that are now commonplace in transmission control centers. Operational planning, which consolidates the existing planning responsibilities within the DCC, is steadily becoming paramount to the distribution control center as utilities continue to deploy new systems to proactively manage resources and grid assets alike.

Serving as the interface between long term planning and the distribution operator, distribution operational planning focuses on evaluating and informing operating decisions over the week-ahead, day-ahead, and just-in-time timeframes. Industry advancements are making many critical resources for operational planning readily available, enabling the rapid integration of advanced technologies and DER into the grid.[6] Eventually, technology adoption will permit distribution operational planners to be fully integrated into the DCC with a variety of responsibilities as depicted in the figure below.

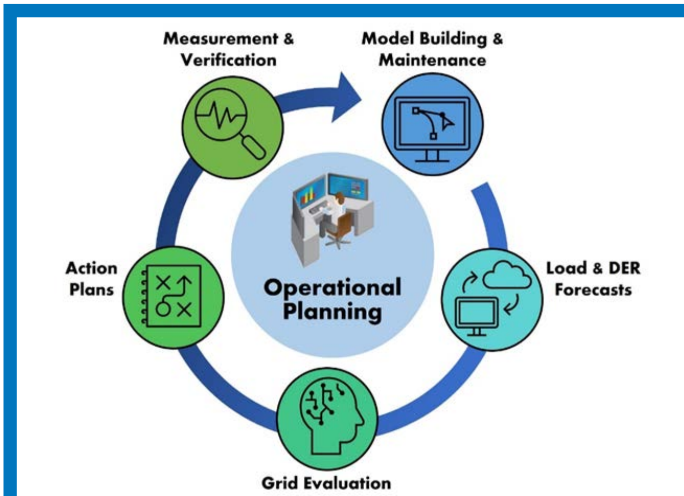
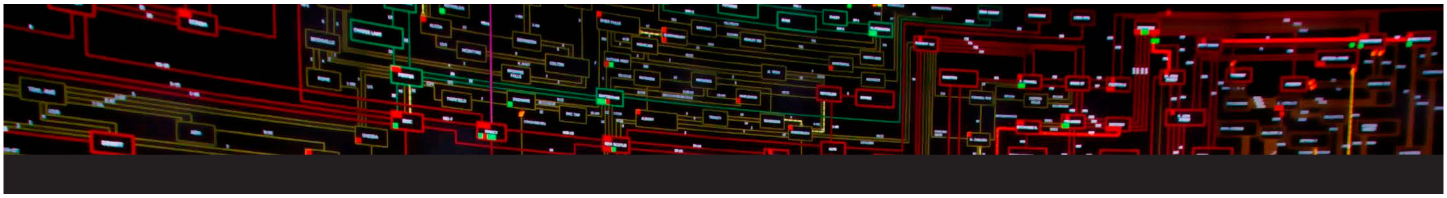


Figure 2. Future responsibilities of a distribution operational planner

[6] *Modernizing Distribution Control Center Operations: Evolving Operator Roles and Responsibilities.* EPRI, Palo Aldo, CA: 2020. 3002019511.



In the beginning these responsibilities may be performed relatively ad hoc as the review of complex switching orders, contingency switching analyses, and evaluation of proposed DA switch locations are required infrequently. As DER penetration grows, market opportunities become pervasive, and reliance on grid services becomes the norm, the tasks may become somewhat cyclical, being performed on a regular and perhaps daily basis. As that evolution unfolds the capabilities described below will become the central focus of a distribution operational planner.

Distribution System Modeling

Previously only required in planning applications, access to grid models is now expanding the capabilities of the modern distribution control center. The relatively passive nature of the distribution system has historically allowed operators to rely on local knowledge most of the time and, on an exception basis, request support from distribution planners for detailed assessment of operational impacts and action plans. The traditional one-line displays common in most control centers offered needed situational awareness but stop short of providing 'what if' type analyses. The changing landscape of the distribution system is driving the need for applications driven by advanced analytics to be integrated into daily operations, and access to high fidelity distribution system models lays the foundation for the processes and tools that will modernize the control center, as indicated in Figure 3.

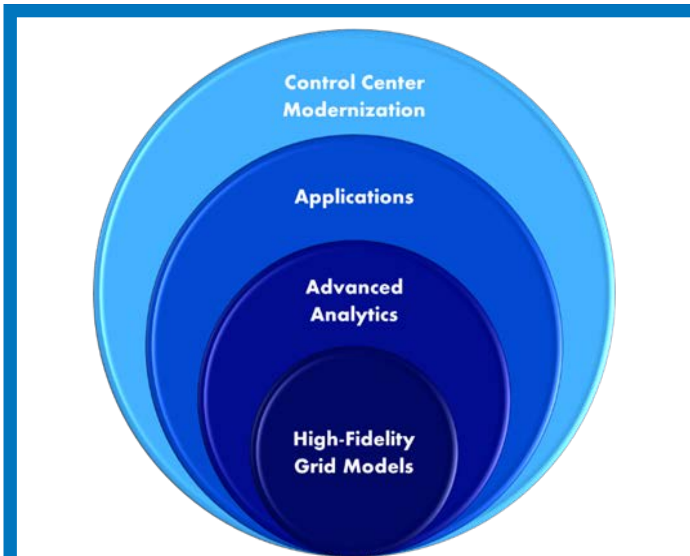


Figure 3. High-Fidelity grid models are at the core of control center modernization

One of the most tangible model-based tools in operations is the Distribution Management System (DMS). Comprised of core functionalities, advanced applications, and integrations with enterprise data sources, the modern DMS has the potential to offer numerous benefits to distribution system operations, but only when built around an accurate grid model. Moreover, the DER Management Systems (DERMS) that will be critical to enabling a flexible DER future will rely on the same high fidelity grid models. Therefore, a critical first step in unlocking the benefits of a DMS and DERMS is prioritizing the creation and ongoing maintenance of distribution system models. To effectively achieve this goal, collaboration is needed between the data producers and managers (GIS professionals), data consumers (operations, planning, asset management engineers), as well as the vendors that supply the platforms and tools connecting those organizations.

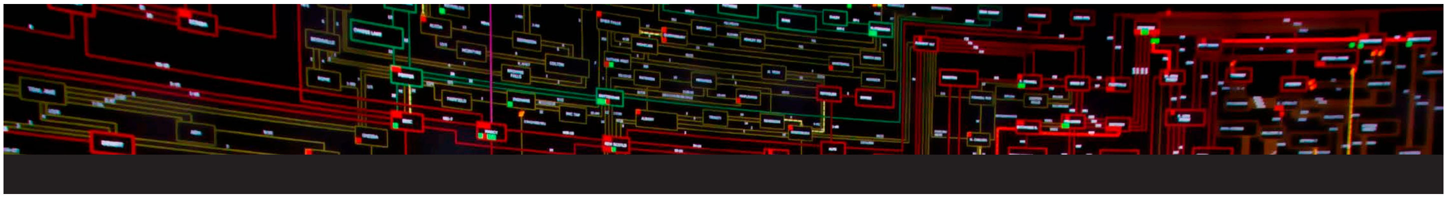
The central component that enables DMS and DERMS to provide value to the control center is a well maintained and accurate grid model representing the as-switched state of the distribution system.[7] However, operators alone cannot be responsible for building and maintaining these models, a process that entails the integration of multiple corporate data systems including GIS, CIS, as well as the billing/meter data management systems. Instead, the control center will need operational planners with a strong background in both modeling and enterprise systems so that next generation grid models can be constructed, refined, and applied.[8] Some of these might be planning staff with experience in verifying and validating system models, as well as systems engineers with a background in data exchanges and integrations. Because one of the primary responsibilities of distribution operational planners will be creating and maintaining grid models, they will also be key resources for operators applying the models in the management of a complex grid.

Load and DER Forecasting

Beyond system models, distribution operational planners will also need access to accurate predictions of the demand and generation at more granular locations throughout the system and at ever shorter time horizons. At one time, near-term distribution load and DER forecasts at the substation or feeder level were out of reach for many

[7] *Distribution Management System: Requirements Reference*. EPRI, Palo Alto, CA: 2017. 3002011003.

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



DCCs; technology advancements and image processing are making those dreams a reality.[9]

In the past, some distribution operators had to rely on historic peak demand readings at a particular location and then roughly scale that demand based on a broad area load cycle, such as from a wholesale market day ahead forecast. The fidelity of these legacy forecasts generally is insufficient to consider the local impacts of DER or support the granular management of grid services. Moving forward, detailed forecasts will provide much needed situational awareness out to the grid edge.

As DCC's integrate DMS load flow analysis into their daily operations, feeder level load and DER forecasts of the daily load cycle will eventually be a core component of the DMS model. With sufficient fidelity to support just-in-time decision making, there is no doubt that access to as switched models layered with granular forecasts will enable the distribution system operator to manage a more complex grid.

As a typical DCC may be managing hundreds of substations and thousands of feeders, the development of near-term load and DER forecasts will need to be accomplished in an automated fashion. A key responsibility of the distribution operational planner will be to define the evolving requirements of the forecast and to ensure the forecast is effectively integrated into the DMS model. One of the emerging challenges in this regard is that forecasts are being fed by an increasingly diverse set of data streams. Regardless of how they are constructed (e.g., top-down, bottom-up, or hybrid), geographically focused forecasts will represent the aggregated contributions from multiple forecasted elements, as depicted in Figure 4.

While system operators ultimately make use of these forecasts, their creation and integration into operational tools will be the responsibility operational planning staff, who have the requisite experience and skillset needed to extract and manipulate data sets from diverse sources. Realizing the benefits of the forecasts will not only require them to be integrated into analytical tools on the back end but will also require them to be visualized through novel human machine interface (HMI) displays and dashboards. To date, system visibility for distribution operators is limited to measurements at select locations (e.g., voltage at transformers and current through breakers and reclosers) and operators must rely on experience and intuition to make inferences about what will happen in the near future. As granular forecasts become a foundational source of information for operators of a highly automated and dynamic distribution system, operational planners will play a key role in ensuring the successful integration into existing and emerging operational tools.

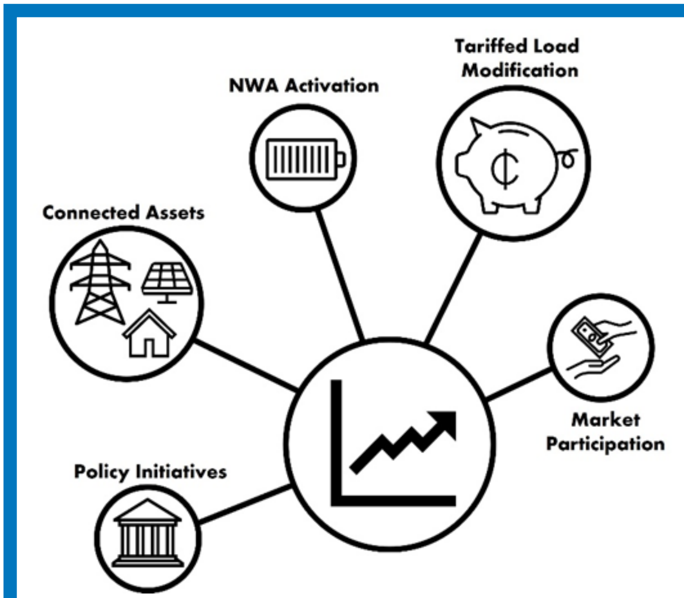
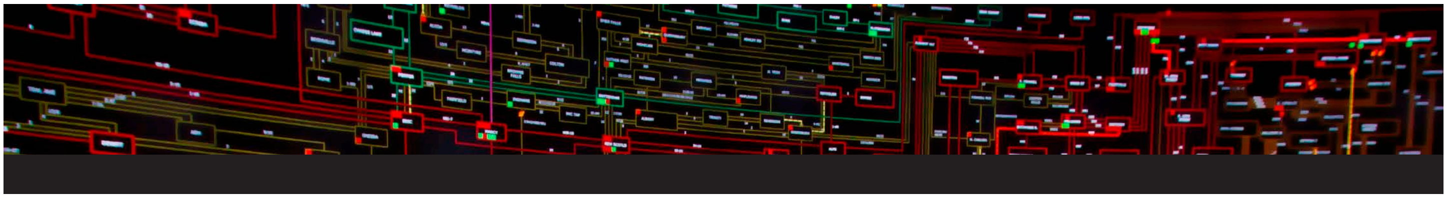


Figure 4. Many data sources may be needed to create load and DER forecasts

Distribution System Evaluation

The ability to perform system analyses will become a central component of the modern DCC. Built on a foundation of high-fidelity models and accurate forecasts, one of the core capabilities of the DMS is a suite of powerful distribution system evaluation tools. However, many utilities are in the early stages of adopting a DMS, and still rely on tools designed for planning applications to address operational challenges. The deployment of advanced DMS presents the control center with the opportunity to perform 'what if' analysis at a moment's notice, where they once relied on planning and protection engineers with a longer turnaround time. Quick answers to questions that measurement and sensing alone cannot answer gives the control center the independence needed to operate the grid more efficiently and effectively than ever before.

[9] *Load Masking in Planning Forecast: Assessment of PV Modeling and Load Disaggregation*. EPRI, Palo Alto, CA: 2021. 3002021439.



The ability to complete distribution system assessments accurately and in a timely fashion is a hallmark capability of operational planning. While the DMS is certainly an operational tool, operators will not be the only users. It is likely that a diverse team of operational planners, with backgrounds in planning, distribution engineering and automation, and system protection, will support system operators by performing a wide variety of studies that span the day-ahead, just-in-time, and post event analysis time frames. With increased visibility and situational awareness stemming from grid evaluations, operators will be able to better manage changing load conditions, make informed decisions when contingencies arise, and optimize the use of available assets better than ever before. Operational planners have the skills and training needed to bring analytical capability to the control center, such as:

Loading Assessments on the As-Switched Model

- An electric distribution company's traditional planning studies typically evaluate the grid under normal, as built configurations. However, the distribution grid is frequently reconfigured to accommodate maintenance, construction of new facilities, or to address other short-term needs. It is therefore important for operational planners to be able to evaluate expected grid performance in the "as-switched" configuration to ensure equipment will operate within ratings, that protection and control schemes respond as desired, and that service quality is maintained within prescribed criterion.

Short Term DER Hosting Capacity

- Like traditional planning, DER interconnection studies generally consider operating conditions that were applicable at the time of interconnection, and typically focus on normal configuration. As DER penetration grows and resources have opportunities to participate in wholesale markets there is mounting pressure to allow DER to operate in abnormal conditions. Therefore, performing hosting capacity analysis with the as switched model using short term load and generation forecasts – or even wholesale market dispatch schedules – will become a foundational component of distribution operations.

As-Switched Evaluation of Control and Automation Schemes

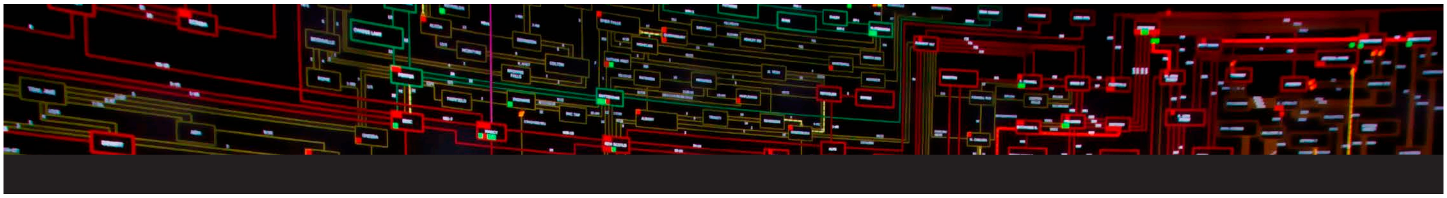
- Protection and voltage control equipment (regulators and capacitor banks) operate autonomously based on preset control settings. These settings are usually determined based on the as built grid configuration and have traditionally been established well outside of the control center organization. If the grid is to be operated in an atypical configuration more frequently, the appropriateness of the existing control schemes should be evaluated to ensure service quality standards are maintained. Distribution System State Estimation (DSSE) is a powerful tool that shows promise for assisting in these evaluations. Eventually the operational planner will assess the settings and configurations for these algorithms.

Many of the changes under way on the distribution system will require analytical capabilities to execute studies with a focus on near term or operational outcomes. While these studies differ from those traditionally performed by dedicated planning departments, there is significant opportunity to borrow from the skill sets and experience embodied by system planning and integrate those qualities into the control center.

Development of Near-Term Operational Action Plans

The results of distribution assessments will be critical to informing distribution and transmission system operations when preparing for deliberate actions and responding to emergent issues. The ability to use high fidelity system models to evaluate current and forecasted conditions furnishes accurate details about the constraints and flexibility of the system, lending to a nimbler and more responsive operational stance. In turn, DSOs have the confidence to create and execute action plans that maximize the use of grid assets while maintaining exceptional service quality and reliability for all customers.

One day the DSO will be asked to implement a DER dispatch plan from the TSO or ISO. How will the DSO be prepared to determine if the dispatch plan is able to be supported by the Distribution System? The analytics developed for scenario and strategic planning are making their way into DMS algorithms to allow on-the-fly optimization of network configuration and DER/demand management. Even if technical and analytical solutions exist to support this decision process, the distribution operational planner will be responsible for preparing an array of action plans, as shown in Figure 5.



Outage Planning	Dynamic Operating Envelopes	Grid Services Activation	Outage Prediction
Planning to de-energize or remove a piece of equipment from service typically involves a distribution system evaluation to assess the risks to the grid and the crews working on it. As loading patterns shift from historic norms, operators will increasingly rely on the results of robust evaluations when creating switching orders.	Distribution utilities can manage resources with flexible interconnection agreements by creating and broadcasting dynamic operating envelopes to DER with flexible agreements. These envelopes establish the bounds for DER operation that maintain safety and reliability on the distribution system.	The use of actively managed resources are beginning to be integrated into distribution grid operations. The DCC will need to appropriately plan for the activation of managed resources to ensure they are operated within the capabilities of the grid and in an economic fashion for the benefit of customers and the utility alike.	Following a fault or equipment failure, the distribution system operator must take immediate actions to transition the grid into a safe operating mode based on available real-time information. Outage prediction can minimize the time customers are impacted by preparing restoration plans and dispatching crews.

Figure 5. Near term action plans will become a key responsibility for distribution operational planning

Action plans allow DSOs to confidently dispatch field crews knowing that safety and reliability will not be compromised in the face of increasing automation and rising DER utilization. Where once a rules-based approach to DER management was permissible, increasing reliance on distribution connected assets is requiring DSO to maximize DER availability over a wider range of operating conditions. But who will develop these action plans? Since planned switching has a major impact on the operation of DERs, initially the switch writer role may expand to perform broad operational planning functions. The operational planning role may also perform traditional planning type functions on a much shorter time horizon, requiring the fast-decision-making skills and even-tempered composure embodied by DSOs as well as the technical skills found in planning departments. Control center organizations that currently have dedicated engineering staff may be well suited to have the engineering group perform many if not all of the operational planning functions.

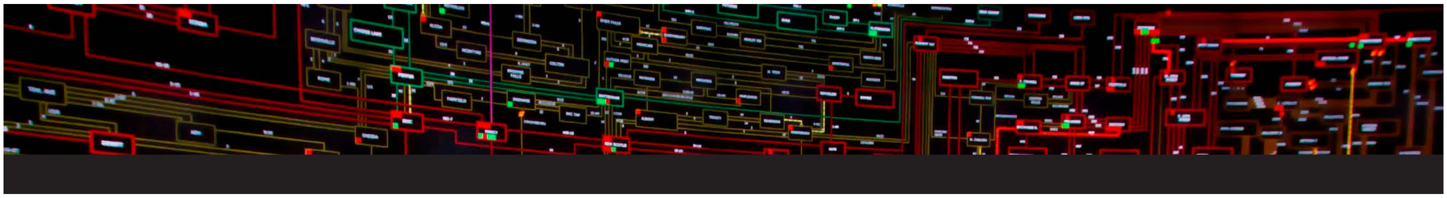
Measurement, Verification, and Forensic Studies

Investigating misoperations and correcting errors on the distribution system used to be a hands-on, resource intensive process with a strong focus on human performance as well as protection systems. With an influx of data collected by modern, digitized assets, there is growing opportunity to apply novel analytics, including artificial intelligence to identify events that were never before discoverable.

In addition, distributed energy resources are pursuing opportunities to provide services to both the distribution and bulk power systems. The vision for this growing class of prosumers includes both supplementing the fleet of centralized generators and supporting aging or overstressed infrastructure. As DCC operators actively manage the grid with DER, it will be important to monitor the performance of the DER, their planned versus actual impacts on the grid metrics, and any financial settlement with 3rd parties.

Orchestrating the management of modern, automated assets while keeping tabs on the uncharted behavior of resources controlled in aggregate is creating a towering stack of investigative responsibilities for the control center. That doesn't even include the complexities introduced by the potential for cyber-attacks on distribution control systems. Operational planners will need to be fluent in all of these systems and weave these disparate data sources into a cohesive forensic explanation.

Measurement and verification is an important building block to enable DER-provided grid services. Some aspects of this responsibility will need to be integrated into day-to-day operational duties, where a combination of data sources can be dissected in near real-time to identify risks to reliability, safety, and security. If a DER service provider does not meet their contractual obligations the distribution operational planner will need to initiate corrective action.



Other aspects of this role will continue to be focused on data driven investigation of human, asset, and control system performance. While the digitization and modernization of the electric power delivery sector has expanded the capabilities of the control center manifold, so too has it increased the complexity of both the operation of- and investigation into the system. Distirbution operational planners skilled at data science, communication systems, and root cause analysis will be vital for utilities to maintain a posture of continuous improvement and vigilant response to internal and external threats.

Summary

Distribution system operations is evolving to meet future needs and realize new opportunities. A primary example is the emerging prospect for DER to participate in wholesale markets. This is driving a desire to allow DER to operate beyond static minimum hosting capacity levels and in abnormal conditions. The application of hosting capacity analysis using short term load and generation forecasts with the as switched model– or even wholesale market dispatch schedules – will become a foundational component of distribution operations. High-fidelity grid models, granular load and DER forecasts, and powerful analytics are becoming readily available, providing the catalyst for control center modernization. However, leveraging these essential technologies will require utilities to rethink how they staff the control center, and will even necessitate new roles – like operational planning. This paper lays out some of the key responsibilities and capabilities the operational planner will need to have to support real-time operations as well as the value of having such a role. To date, approaches to this have varied from leveraging the planning department to an additional staff member within the control center dedicated to these activities. Regardless of approach, utilities can begin to identify which capabilities they need today and over the course of the next few years to ensure they evolve their DCC to meet the needs of a changing distribution system.

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Note

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