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## CIGRE US National Committee 2021 Grid of the Future Symposium

### **Creating the Electric Distribution Management System that Enables the Clean Energy Transition**

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#### **SUMMARY**

An Advanced Distribution Management System (ADMS) is a software platform comprised of a group of control room-based applications and hardware used by electric distribution operators and engineers to visualize, monitor, and control the electric grid. Modern grid complexities such as electric vehicles (EVs) and other nonconforming loads, distributed energy resources (DERs), and an increasing amount of data from remote grid devices are creating a complex operational landscape. The ADMS supports continued safe and reliable electric grid operations with the added complexities of the modern grid. Advanced applications and algorithms in the software incorporate real-time grid status and measurements on a common network model to optimize operational decisions and processes. The ADMS will expand situational awareness and visibility of future predicted states with respect to system operations, support the proliferation of DER interconnections that require additional system capabilities to maintain efficient and reliable operations and create a platform to enable utilization of exponential growth of remote monitoring, control, and distribution automation. National Grid has taken a phased approach to implement the ADMS, incrementally rolling out advanced distribution management applications, upgrading the existing outage management system (OMS), and implementing an integrated distribution-specific SCADA system dedicated to the monitoring, control, and automation of the distribution networks.

#### **KEYWORDS**

Advanced Distribution Management System (ADMS), Outage Management System (OMS), Unbalanced Loadflow (UBLF), Restoration Switching Analysis (RSA), Distributed Energy Resource Management Systems (DERMS), Distributed Generation (DG), Non-conforming Load, Variable Generation

**Background:**

In 2016, National Grid USA Service Company took a strategic step to roadmap a framework for modernizing its electric distribution system management practices, outlining the implementation of platforms and tools to support our vision of the future of operations. An Advanced Distribution Management System (ADMS) pilot project was carried out to help understand the present Outage Management System (OMS) and Energy Management System (EMS) vendor’s capabilities, as well as internal changes required to support a full-scale rollout of ADMS functionality. In 2019, National Grid formally initiated a project to deploy the ADMS project in increments. Phase 1, which is tailored for monitoring, will be deployed across all of its North American service territories by November 2021. The capabilities include basic Distribution Management System (DMS) applications like operational Unbalanced Load-flow (UBLF), Restoration Switching Analysis (RSA), as well as the procurement and installation of the hardware and software infrastructure on which additional capabilities would be built. Phase 2 and Phase 3 focus on both upgrading the core capabilities of our Control Rooms (CR) as well as the steps required for integrating autonomy into a complex grid.

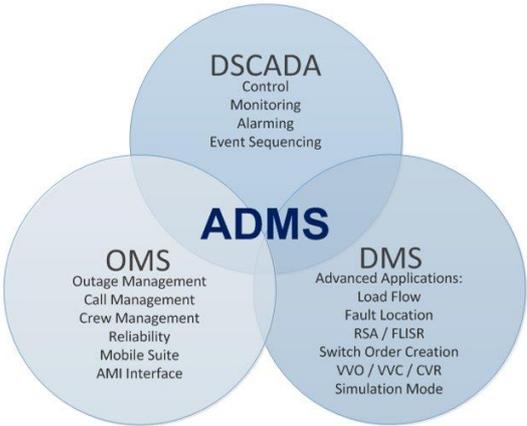


Figure 1 - Components that make up the ADMS

In all our operating jurisdictions, Massachusetts (MA), New York (NY), Rhode Island (RI), our regulators and customers expect leadership in the affordable clean energy transition. The regulatory framework has enabled many solar, wind renewable generation systems to come online. These projects, commonly referred to as Distributed Generation (DG), vary from as little as a residential rooftop to a 5 MW farm. A rapidly increasing number of energy storage projects are also requesting interconnection to our electric distribution system. In some regions of our service territory, such as Western and Central MA, the interconnected generation capacity had far exceeded the typical load on the feeders. Depending on the time of day and weather conditions, the generation variability creates bi-directional power flow between transmission and distribution systems. With continued incentives and ambitious renewable energy goals, the traditional top-down distribution system model is likely to become the exception rather than the rule, and the erratic impacts of DGs on the voltage and load profiles of distribution feeders will stress the system in new ways. System Operators will need to be equipped with the data, analytical tools, and training to optimize electric distribution and ensure safe and reliable energy delivery to customers. As the number and complexity of data points increase, we envision the real-time distribution system analysis platform provided by the ADMS will be critical to providing the dependable energy network of the future.

# National Grid's Electric System Summary

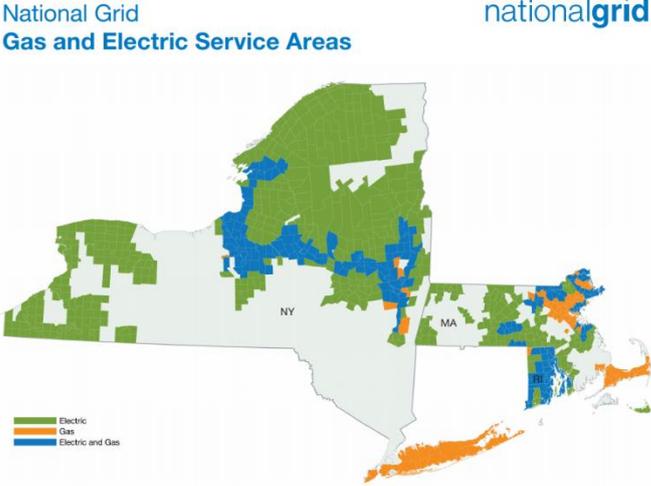


Figure 2 - National Grid's Electric and Gas Service Territory as of October 2021

National Grid's electric distribution service territory extends from Eastern Massachusetts to Buffalo New York and is managed by four regional Distribution Control Centers (DCCs). The DCCs manage circuits below 69 kV, comprised of mainly 15 kV class feeders. Typical to the Northeastern United States, vegetation coverage and growth (e.g. tree branches, vines) are the most significant driver for system outages since most of our construction is next to roadways and right-of-ways. Cloud coverage and weather events (rain, wind, heatwaves, major storms, etc.) are frequent and create volatile conditions throughout the day.

The ADMS project solely focuses on the 15 kV and higher voltage distribution feeders. These circuits are primarily protected via ground and phase overcurrent relays. Overhead line reclosers are common for remote sectionalizing, monitoring, and protection of the system. Our grid modernization and asset management programs target devices such as line reclosers, capacitor banks, and Line Voltage Monitors (LVMs) to comply with the latest communications standards and enable connection to our SCADA systems. Voltage regulation is mainly performed at the substation via power transformer Load Tap Changers (LTCs) or per-phase voltage regulators (VREGs). An increasing number of feeders are also equipped with a third-party VVO/CVR solution that autonomously controls station voltage regulators, line voltage regulators, and capacitors through the SCADA network.

The density of renewable generation generally increases as population density decreases due to economic reasons. This creates a high generation low load scenario in rural regions during the day and leads to load profile changes in the transmission system as well.

## The Need for ADMS at National Grid (The Why)

In a traditional power system, energy is generated at large power plants and delivered from electric transmission to the distribution system. Thus, having a robust operational and long-term transmission network model and analytical capabilities can be sufficient for efficient and reliable operation.

In MA and NY, the advocacy for transitioning into non-fossil fuel energy resources has been very strong. The solar and wind generation combined with the electrification of heat and transportation is leading to a more multi-dimensional, time and weather-dependent energy flow in the distribution system. We're also seeing the impacts in the transmission system where costly upgrades may be necessary to make sure the regional energy infrastructure continues to be dependable.

The majority of the solar and wind generation systems in our region are much smaller in size (up to 5 MW) and the appetite to add more Distributed Generation (DG) continues both from an investor and regulatory perspective. We are also starting to experience issues with disconnecting DG customers during abnormal system conditions or when the primary point of interconnection (feeder) is not available. A power system simulation environment that can predict system conditions in real-time is necessary to govern such granularity cost-effectively. This is the only way to provide the same reliable service to our customers and continue to enable the next generation electric distribution grid.

Resiliency is also becoming ever more important. As we are advancing into a more electricity-dependent society, power outages are becoming more impactful to our daily lives. Thus, any solution to quickly restore or eliminate the interruptions is important for customer satisfaction. Feeder restoration can be automated with localized systems but the true benefits are available when a centralized system is capable of developing complex scenarios to keep the lights on for as many customers as possible.

Our current Distribution System Operations (DSO) group does not have a tool for short-term operational studies to address the prior needs. A key capability that ADMS provides is the ability to take the real-time system information (as-operated model, SCADA analog values) and perform a near-term future simulation. Prior to this the control rooms would either perform ‘back of the napkin’ calculations or for complex requests reach out to our long-term planning group to model a scenario. This involved some lead time as a model first had to be built and then updated with system conditions. ADMS will now allow our DSO to group to build a model on the fly using the current as-operated state of the model. Unlike in our planning group where one model is built and used for an 8760 study, Operations needs to build 8,760 different models. ADMS will let us do that.

### ADMS Capabilities

The north star objective of the ADMS is to serve as a foundational power system platform to maximize the intermittent distributed energy resources to the electric grid. The ADMS provides an operational interface to accommodate increased data throughput and to monitor, manage, and control equipment in response to system conditions reported by external or DMS-native automation systems, smart metering technologies, distributed energy resources, demand response programs, and modern field devices. The core capability of the DMS applications is unbalanced load-flow. Using real-time measurements in conjunction with static model data, the DMS calculates and presents the circuit parameters including power, current, and voltage for each phase at every node in the model. This not only affords System Operators greater visibility into the real-time status of blind (unmetered) sections of a circuit but also generates data to be used by downstream analysis and automation tools. With high penetration of variable generation and nonconforming load, real-time load-flow is a critical tool for monitoring overall system health (voltage levels, equipment loading, etc) under both normal and abnormal operating conditions.

### Electricity generation, transmission, and distribution

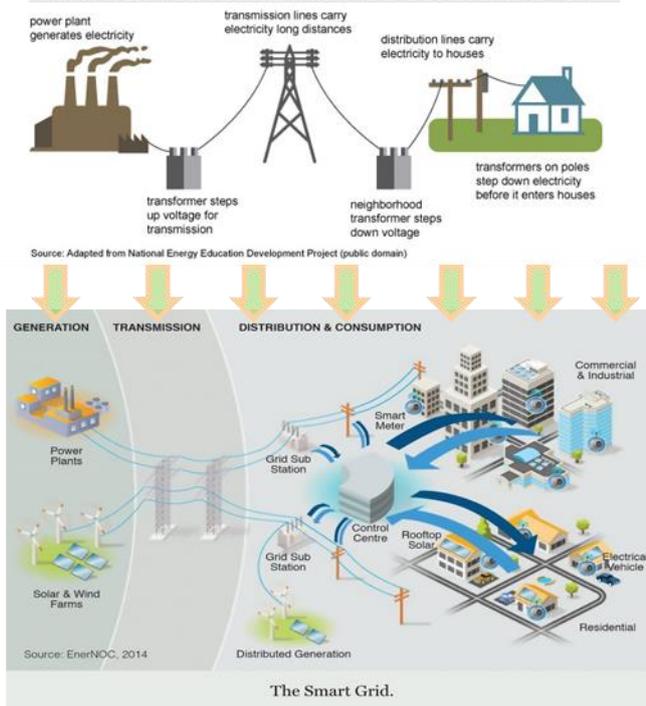


Figure 3 - A depiction of how our electric distribution system is changing over time

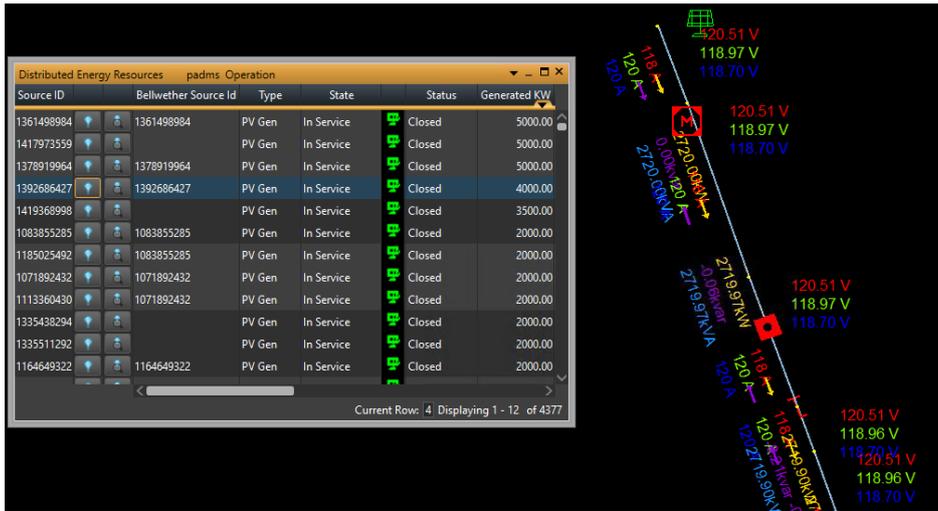


Figure 4 – Hitachi Energy example power-flow solution view showing voltage, current, active and reactive power in real-time.

The increasingly complex and unpredictable nature of modern distribution circuits introduces risk to traditional methods of assessing the viability of a feeder reconfiguration and makes comprehensive planning studies impractical. Restoration Switching Analysis (RSA) uses the real-time load-flow to identify available feeder reconfigurations and calculate circuit parameters in the reconfigured state. Switching summaries are presented to system operators outlining switching steps, expected equipment loading (including overloads), and abnormal operating conditions like reversed regulators and reclosers. Programmatic analysis of feeder reconfigurations improves efficiency in manual switch order development. The ability to use real-time and forecasted load and generation models, enables optimized switch strategies, reducing the need for overly conservative estimates to maintain safe operating margins.

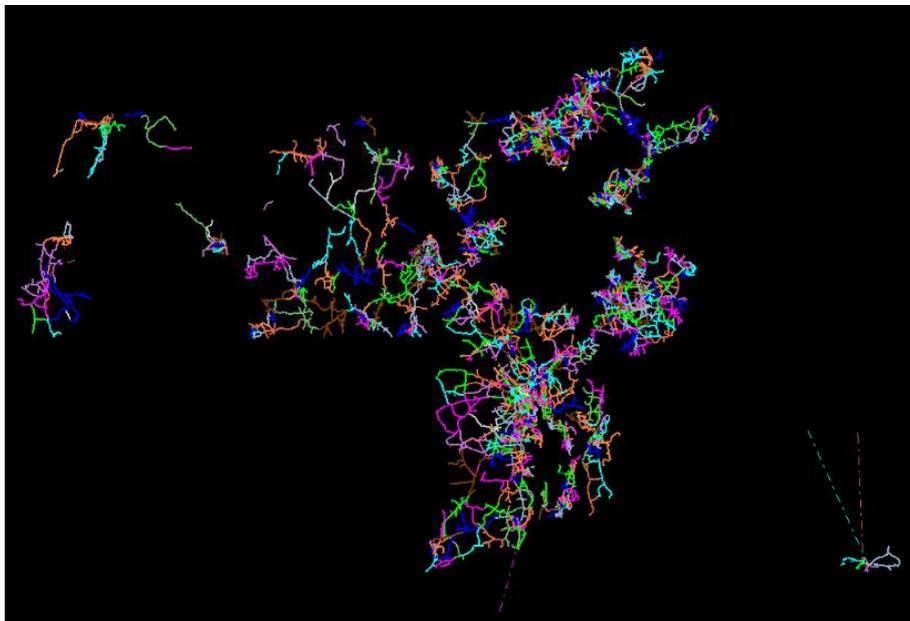


Figure 5 – Hitachi Energy ADMS Geographic Overview of National Grid’s MA and RI Service Territory

In the future, the RSA engine can serve as the backbone of centralized FLISR solutions, eliminating the need to study and deploy FLISR schemes individually. Improved system monitoring from LVMs and AMI, combined with the ADMS network model solutions, will enable more sophisticated VVO/CVR deployments, delivering better power quality more efficiently to customers. As technology, regulatory frameworks, and market structures mature, we envision the core capabilities of the ADMS integrating with market management systems like DERMS, supplying optimal power flow solutions, system

limitations and restrictions, and network topography to negotiate the security-constrained economic dispatch of distributed energy resources.

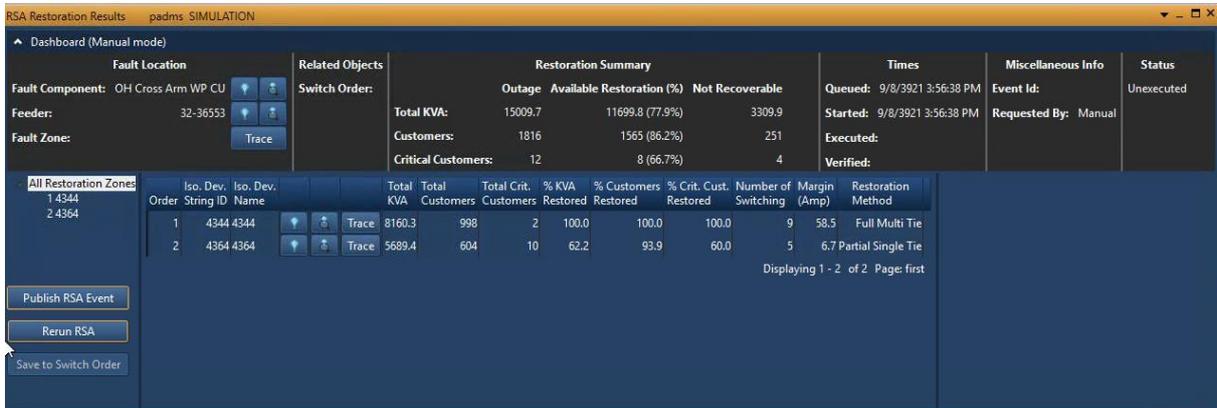


Figure 6 – Hitachi Energy Restoration Switching Analysis View. The result window shows ~251 customers will be unserved after the restoration steps are initiated.

## ADMS Project Execution Overview

At the start of the project, it was recognized that building a fully functional ADMS project would be a multi-year, resource-heavy undertaking that would require both capital (servers, software licenses, facility upgrades, etc.) and integration effort from many disciplines. In order to realize benefits as they become available and execute a gradual change process, the leadership had developed a strategic roadmap to split the project into 3 phases that will be completed in the next 5-7 years. This strategy also provides agility to adapt internal variables within National Grid as well as external factors such as technological improvements, new products, and developing vendor capabilities.

ADMS Phase 1 brings the product to life by providing “monitoring” capabilities to each regional control room. There are a select number of feeders (~5% of total feeders per jurisdiction) that are 90% or more accurate for system operators to adapt to the new capability. This also provides immediate benefit to the DSO by enabling better visualization of the system, including awareness of where DER is installed in an operations-focused model. Phase 1 has been completed in New England and is preparing to go live in NY by Nov 2021. The ADMS at this stage runs on a discrete system to all other core capabilities of a control room.

The first part of Phase 2, Phase 2A, targets the upgrade and integration of ADMS into core foundational applications that control rooms rely on every day. This enables us to bring our core systems on par with the latest distribution system control technologies with an integrated operational studies platform within the outage management systems. In parallel, we will continue to monitor and contribute to key initiatives in data governance, distributed energy management environment, and digital transformation.

Later phases of the project will be implemented via various release trains that enable multiple products to be developed and go live concurrently. Phase 2B, C, and Phase 3 will focus on adding new capabilities such as grid modernization and autonomy integration, advanced metering infrastructure, and extensive DERMS integration capabilities. Important to note is the 2B and beyond phases remain agile to ensure we are in line with the developments in our industry and organization. We’re aware that a rigid approach in transformational projects of this size and length may not always create the best value for our customers.

## **Distribution System Data Transformation**

Any simulated system is only as good as the underlying data. In order to produce reliably accurate and useful results, the ADMS requires complete and detailed asset data for equipment settings, protection coordination, and network connectivity. The localized nature of the electric distribution system along with fast-paced growth and transformation in the industry had resulted in data silos and variable recording practices across National Grid's service territory. This has been sufficient for traditional system operations and engineering processes like outage management, scheduled and emergency switching, and planning and protection studies. When considering only the most conservative scenario (e.g. Summer peak load) for decision making, it is possible to rely on much less granular and approximated data via engineering judgment. However, ADMS creates value when we can dependably predict system conditions at any given time. If a feeder section with large DG customers needs to be transferred to an alternate source on sunny, 75°F (aka blue sky day) weather, ADMS should be able to predict if the alternate feeder is capable of keeping all customers online whilst providing the same service quality. Thus, traditional data governance practices do not satisfy the fast-paced, time-dependent analysis requirements of operating and automating the increasingly complex and mercurial distribution system. In addition, dissimilar systems, applications, and data formats require considerable effort to consolidate and translate to the ADMS. Even relatively complete data sets need to be massaged to accommodate the ADMS vendor's data requirements and design philosophies.

SCADA systems have a long history, burdened by constraints on the communication infrastructure and data throughput. Many stations and devices return minimal data or, at best, only what was fashionable or useful at the time. Although the communication standards have been left relatively unchanged, evolving standards for specific measurements returned, units, and sign conventions have resulted in a collection of incomplete, inconsistent, and often incompatible data points. In order to return reliable, actionable results, the ADMS needs reliable and complete real-time measurements. Existing SCADA data needs to be thoroughly homogenized, expanded to include voltage and other measurements needed to refine ADMS solutions, and diligently maintained to adhere to the newest standards as remote monitoring capabilities grow exponentially.

Although parallel projects to expand remote feeder monitoring and to correct and consolidate asset data are ongoing, short-term solutions and workarounds to data deficiencies need to be implemented to keep the ADMS on pace with other grid modernization initiatives like AMI and DERMS. With the ADMS expected to be the arbitrator of real-time operational information, constantly sending and receiving data to other systems of the modernized grid, close collaboration between data owners and the groups responsible for information technology/operational technology deployment is critical.

The reliance on distributed resources for a cleaner and more efficient energy consumption continues to be paramount in jurisdictions. The ADMS promises to be a vital platform for operating in an ever-increasing complexity, which had allowed us to act as the catalysts to the data transformation efforts at National Grid.

One of the additional benefits realized with ADMS is that we are using existing data in a new way which has led to the standardization of the data. By taking a weekly extract of our GIS system to update the network model, we are finding GIS data errors in a timelier manner. This lets us close the loop on things such as design standard changes not being followed or identifying increased training needs for designers much quicker than in the past.

### **Down to the Weeds: What is an "ADMS Ready" Feeder?**

The ADMS feeder models consist of multiple data sources such as GIS, Ratings, field SCADA points, large customer consumption information. Engineering and IT teams had developed a process and database to upload the bulk data into each region's system. This system is also capable of taking weekly incremental updates with a reasonable level of error/conflict identification. However, some of the key

data import still relies on manual and sound engineering effort which poses a risk to the sustainability of the product support process.

A distribution feeder to be considered “ADMS Ready”, the general rule of thumb is to make sure it solves with +/- 10% accuracy to the SCADA actuals recorded at the time of the solution. This level of accuracy produces credible results and assures the end-user during operational scenario planning. The engineering team analyzes each section of the feeder to make sure loading is distributed very similar to real-life; even in sections with no SCADA points. Our objective for Go-Live at each region was to make sure ~5% of the feeders match these criteria. A rapid increase in ADMS Ready feeders is only possible with a digital solution where we integrate all data sources to a data lake and develop algorithms to build feeders with more precise information. This capability enables our limited number of engineering talent to spend less time improving the accuracy of each feeder.

In addition, as a Minimum Viable Product (MVP), all feeders are successfully in the ADMS but with a default data point for any missing information. (e.g. feeder rating at 500A default) The accuracy varies at this point but some feeders can provide reasonable results and assist in operational studies. Similar to ADMS ready, we would like to increase the MVP accuracy to 80% of actual values using digitalization.

### **Talent Strategy for ADMS**

Complex operational studies are fairly new to many Distribution Control Center (DCC) that operate primarily radial circuits. In the past 7 years but mainly since 2018, National Grid had interconnected ~900 MW of distributed generation projects to its system. In some regions, the DG interconnection demand had triggered impacts to the transmission system, adding to the responsibilities of the regional DCCs. Grid Modernization projects such as ADMS will provide a “tool” to help with DCC decision making but a more overall set of skills in power systems engineering, SCADA systems as well as system operations is needed to support the user adoption of the modernization programs. This “multi-cultural” role also acts as the liaison between engineering and operations as they are capable of understanding both perspectives and contribute to the future development of the program.

The core engineering team capabilities are also fairly different from a traditional long-term system planning role. The ADMS engineers are focused on connecting and matching real-time field data points to their operational models. Thus, a thorough understanding of SCADA infrastructure is a necessity. The studies (aka Scenario Planning) focuses on feeder configuration changes as a result of an upcoming construction or maintenance project. In the later stages of the project, we anticipate creating future scenarios based on weather and short-term system parameters-based algorithms. Thus, the ability to automate and interpret the outcome of these scenarios will be vital in supporting real-time system operations. In addition, engineering will support policy development that enables more DERs to interconnect, remain online during abnormal conditions, and contribute to keeping our system safe and reliable.

One of the early decisions made in the project was to bring in additional outside expertise that could focus specifically on the ADMS project. To this end, National Grid went through a procurement process to select a Business Integrator (BI) that can provide vital guidance. The BI would support the ADMS team with project management, requirements development, business process development, business case review, testing, cutover, documentation, training, and overall change management. Having a BI partner allows us to roll additional resources onto the project in a short period for specific tasks on an as-needed basis. This flexibility has been a key part of the success of the ADMS project.

IT, Security, Telecom, and Digital play a key role in developing the backend support required to transfer data from many different resources into the ADMS Power System Environment. Since ADMS is part of the control center operations, it needs to meet the specific security standards that all other systems within are required to comply with. Thus, the talent that can develop an adequate architecture for ADMS, have the business acumen for integration is vitally important for the product to succeed. The digital

transformation capabilities also create an opportunity to change our organization's traditional practices for a much more efficient and productive way of working.

## **Conclusion**

As our project continues to advance, we will be working closely with our vendors to develop and implement future applications that either use the ADMS network model or data from the ADMS. One of these future products is the ability to do real-time online coordination studies. In addition to the thermal violation analysis we are doing now with ADMS, we hope to enable future adaptive protection and online protection analysis. Without the data model, standardization, and model development is done for ADMS this future work will not be possible.

Intermittency of the distributed generation combined with the electrification of transportation and heat will have a significant impact on how we sustain the same quality service we have provided to our customers. We've built a successful transformation environment where comprehensive, authentic stakeholder management, needs case identification and business acumen had allowed a very challenging change in our control rooms to succeed.

The demand for clean energy resources continues to increase as we continue to face the impacts of climate change. Thus, it is paramount for National Grid to implement all stages of the ADMS project to create and sustain the next generation of electricity networks.