Photo: Shutterstock

Grid Modernization, Enabled by Data

by John McDonald

We live in a data-driven world. For power utilities engaged in grid modernization, however, basic questions remain pertinent to their mission: What is the underlying philosophy supporting big data for power systems? What grid modernization goals can be realized by applying big data? And, perhaps most importantly, what concrete steps can be taken to achieve these goals?

The foundational thinking on grid modernization, in my view, relies on three philosophical points. First, the entire effort must be approached in a holistic manner. Second, data should drive improvements in a power utility's ability to meet consumer expectations for safe, efficient, reliable and affordable power. Third, data is an enabler of value, and to survive upheavals in technology, markets and regulatory models, utilities must embrace data-driven opportunities.

The foundational thinking on grid modernization relies on three philosophical points: a holistic approach, data-driven improvements, and embracing data-driven opportunities.

John McDonald, P.E. serves as a consultant in the electric utility transmission and distribution industry. With 50 years of experience, John holds B.S.E.E. and M.S.E.E. degrees from Purdue University, and an M.B.A. from the University of California-Berkeley. He is a Life Fellow of IEEE, recipient of numerous awards including the IEEE Millennium Medal, and has served in leadership roles including Past President of IEEE PES. John is also a member of the US National Academy of Engineering. He continues to contribute to the field through teaching and publications, and has received recognition such as the 2009 Outstanding Electrical and Computer Engineer Award from Purdue University.

The Journey to Digital Transformation (see Figure 1) requires changes in instrumentation, data collection and analysis, and automation to enable situational awareness. Understandably, many power utilities remain in reactive mode. Moving forward will require a complete inventory and review of all assets on the power network, as well as reviewing each asset's criticality to create a business case for prioritized investments.

Moving from Level 2, a responsive mode, to Level 3, a predictive mode, involves modeling – data will provide the network's actual balance of demand and generation, enable predicting the impact of weather, and understanding the subsequent risk of asset failure. At Level 3, a utility improves its readiness for extreme weather – the leading cause of outages – and applies those insights to assessing asset fleet risk.

A significant advancement that supports Level 3's predictive posture is the concept and application of a "digital twin," – a software representation of a physical asset, system, or process that harnesses real-time analytics to detect or predict operational issues and avoid fix-on-fail scenarios.

Today, enabling Level 4 and Level 5 capabilities is dependent on technological advancements. In Level 4, artificial intelligence (AI) drives application optimization and orchestration from the network's edge to the cloud to prevent or limit outages. At Level 5, the network becomes self-healing, with autonomous operations and limited human intervention. If your utility begins digital transformation today, it will be positioned to take advantage of technology that enables Levels 4 and 5 when it becomes available.

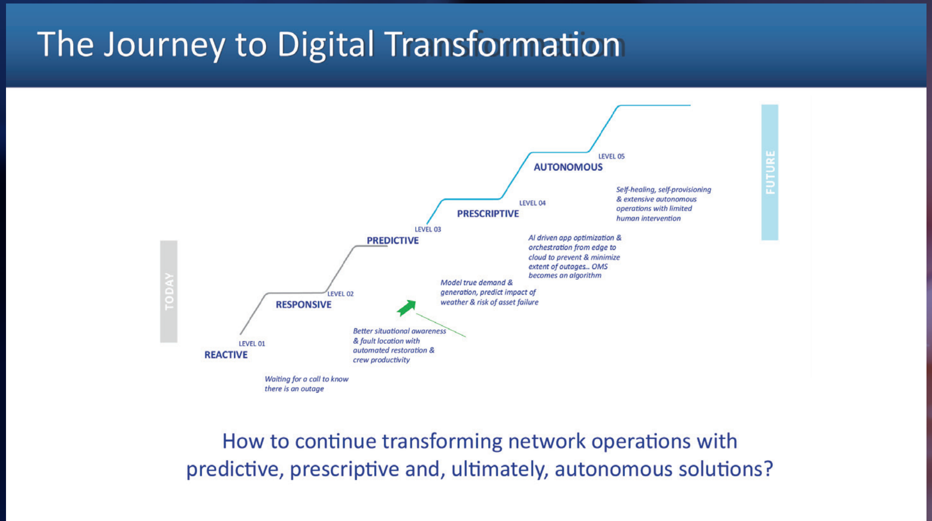


Figure 1. The Journey to Digital Transformation.

Concrete steps

The first step – taking a holistic approach – is conceptual, but it requires heavy lifting.

A utility must view transmission and distribution (T&D) as a single, integrated entity. Its Operations Technology (OT) group must be seamlessly integrated with the Information Technology (IT) group for operational and enterprise data management. (Executive leadership is critical.) The shared goal of all departments must focus on consumer engagement and satisfaction based on improved system reliability, resiliency, and efficiency. A holistic approach requires interoperability

Photo: Shutterstock

between devices, systems, and databases, based on open architecture and standards.

This means that all data-producing devices in a T&D system are mapped to communication channels and networks with the necessary response requirements and the result is routed to both operations and enterprise sides of the organization. This will enable every authorized, internal stakeholder to have secure and timely access to that data for value creation. This should align consumer needs with utility operational business drivers. That alignment should illuminate how to approach data generation, collection, storage, and presentation or access – and how actionable intelligence is applied.

"Strong" before "smart"

Developing a "strong" grid before pursuing a "smarter" grid begins with establishing an information and communications technologies (ICT) foundation based on open architecture and industry standards. Initially, IT and communications groups together determine the functional requirements (response requirements, bandwidth, latency) of every data path – from sensor to end-user – for current and future systems and applications. Having established a "strong" ICT foundation, a utility can proceed to develop a "smart" grid, and map data from sensor to end user.

"Strong" before "smart" also refers to enabling pan-organizational cooperation in pursuit of utility-wide goals; cultural shifts accompany technological advancements.

Observability Strategy

Control room operators must be able to "see" the status and performance of all key elements of the power network and eliminate "blind spots." Pursuing this goal means adopting an "observability strategy." Blind spots should be addressed based on their criticality to the network. Are the right sensors providing the pertinent data for analytical applications that provide visibility? The business case for sensor and application should be evaluated to produce an enterprise-wide total return on investment (ROI). Today, data-producing sensors and devices known as intelligent electronic devices (IEDs) are proliferating on the "D" side of "T&D." IEDs may be standalone sensors, or they can be data-producing substation protection and control equipment such as protective relays, load tap changers, etc. IEDs produce two streams of data – operational and non-operational – that must be fully exploited to create visibility with a solid ROI.

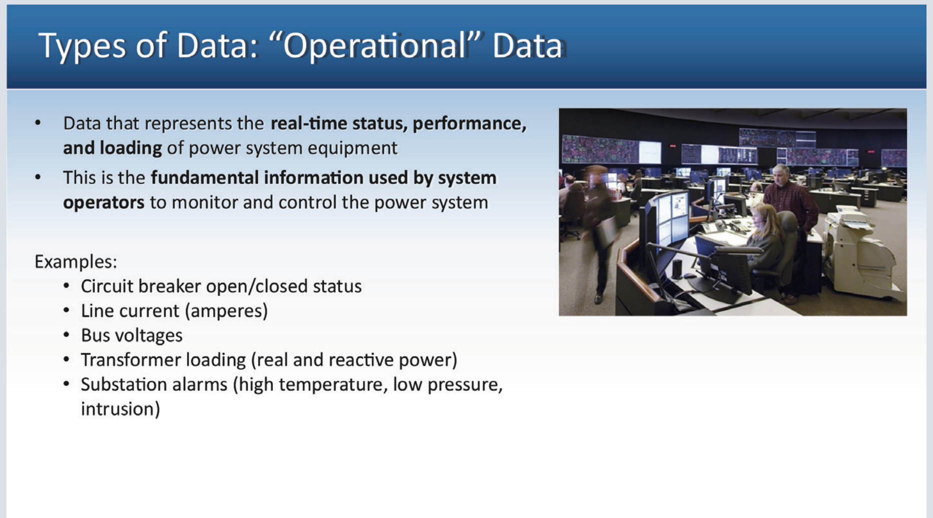


Figure 2. Operational data is routed in real time to operators in control centers for monitoring and control purposes.

Operational & Nonoperational data

These two data sources require different routing and enable myriad means of value creation. Operational data is routed in real time to operators in control centers for monitoring and control purposes (see Figure 2). Non-operational data is routed, stored, processed and made accessible on-demand to both operations personnel and enterprise units for use with their applications (see Figure 3).

Non-operational data can inform enterprise goals for energy efficiency, load shaping and capital deferral. For example, metering data is non-operational data, which can support energy efficiency and reliability programs such as demand response and dynamic pricing (see Figure 4).

To take us one level deeper, each IED has multiple "points" that produce either operational or non-operational data. All the points in a specific IED may be conceived of as a "data map". Each IED and its data map should be matched with one or more communication network(s) that provide the response requirements appropriate to transmitting that data. Operational and non-operational data each have their own communication network response requirements.

Network response requirements

Because various data streams rely on a variety of response requirements, a utility may rely on a variety of communication networks to achieve the desired, cost-effective functionalities. Time synchronization of data is an essential requirement. Data often must be time-tagged to reliably determine correlations or sequence of events.

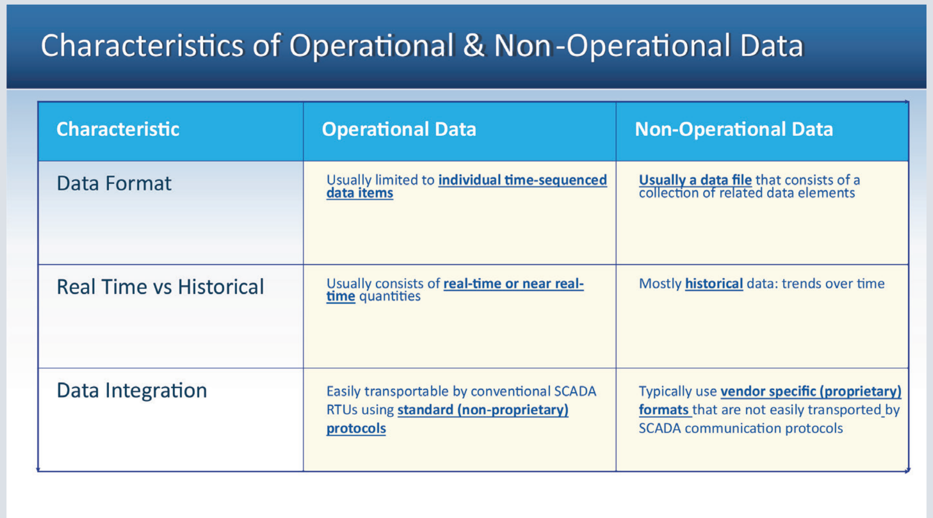
The real-time operational data generated by IEDs typically demand the most stringent response requirements, whether the medium is redundant fiber optic cable ringing a service territory, wireless microwave or UHF.

Yet, operational data is heterogeneous and a utility can take a mix-and-match approach to the communication networks it rides on. Examples include "smart" interval meters that record data every 15 minutes, integrated Volt/VAr Control (IVVC) that requires only 30-60 seconds to switch on distribution feeder-based capacitor banks and, in contrast, Fault Detection, Isolation and service Restoration (FDIR), which requires a 2-second response.

The bandwidth of non-operational data is determinative in selecting a communication network, because a digitized waveform, for example, may require a "fat pipe" to reach the enterprise uncorrupted. Speed, latency, and other metrics of the communication path are less crucial because non-operational data is often used for forensic analyses. Non-operational data is also heterogeneous, so it too can also benefit from a mix-and-match approach to communication networks.

Photo: Shutterstock

Figure 3. Non-operational data is routed, stored, processed and made accessible on-demand to both operations personnel and enterprise units for use with their applications.



Characteristics of Operational & Non-Operational Data

Characteristic	Operational Data	Non-Operational Data
Data Format	Usually limited to **individual time-sequenced data items**	**Usually a data file** that consists of a collection of related data elements
Real Time vs Historical	Usually consists of **real-time or near real-time** quantities	Mostly **historical** data: trends over time
Data Integration	Easily transportable by conventional SCADA RTUs using **standard (non-proprietary) protocols**	Typically use **vendor specific (proprietary) formats** that are not easily transported by SCADA communication protocols

Figure 4. These two data sources require different routing and enable myriad means of value creation.

Integration before automation

Integrating IEDs across the substation and on distribution feeders requires assigning each data stream to the appropriate communication network and routing those data streams to the control center and/or the enterprise. Remember, now that IEDs are synonymous with nearly every piece of power system equipment, including protective relays, meters, transformers, etc., visibility depends on operators seeing their behavior (operational data) and understanding their condition (non-operational data).

The integration challenge can be visualized as a series of layers. At the bottom, transformers and circuit breakers represent the foundation. The next levels "up" include IED implementation, IED integration, and substation automation (SA) applications. The enterprise comprises the fifth and highest level.

Historically, IED integration has often focused only on operational data – for example, instantaneous values of voltage and current. This often ignored the value of non-operational data, which can be, for example, on-demand or event-triggered data of logs of events and oscillography that aids diagnostics and forensics on conditions that lead to outages or equipment failures.

Integration can be complex and costly because it requires that the utility to tie together protection, control and data acquisition functions. To control capital and O&M costs, a utility should use the fewest possible number of platforms and avoid redundant equipment and databases.

The integration of data-producing devices and systems precedes SA. (SA refers to implementing SCADA, alarm processing, and other functions to optimize asset management and operational efficiencies without human intervention.) Determining SA applications initially requires observing the behavior of data over time (daily, seasonally) and diverse conditions (weather patterns) to establish data-based threshold values that can trigger automated responses. In order of importance, the three crucial elements are: data, software analytics, and the user experience. Note the tell-tale shift from emphasis on the "user interface" (a passive notion of how data is presented) to the "user experience." As utilities become data-driven, how data is presented or accessed must become intuitive to support operators in making beneficial, timely decisions.

Integrating IEDs across the substation and on distribution feeders requires assigning each data stream to the appropriate communication network... visibility depends on operators seeing their behavior and understanding their condition.

Photo: Shutterstock

Connecting sensor to data user

The routing and use of operational data is likely old hat to readers, so let's drill down on the routing and availability of non-operational data. This challenge has a technical component, yet I must reiterate the accompanying cultural shift in which formerly autonomous personnel must work across legacy silos, for the greater good. Grid modernization will not happen without integrating and modernizing the utility workforce into an interactive, cohesive unit. This workforce evolution will lead to organizational and business process changes, so it's a fundamentally transformative, irreversible process. It is the first step from a reactive utility to a proactive utility on The Journey to Digital Transformation (see Figure 1).

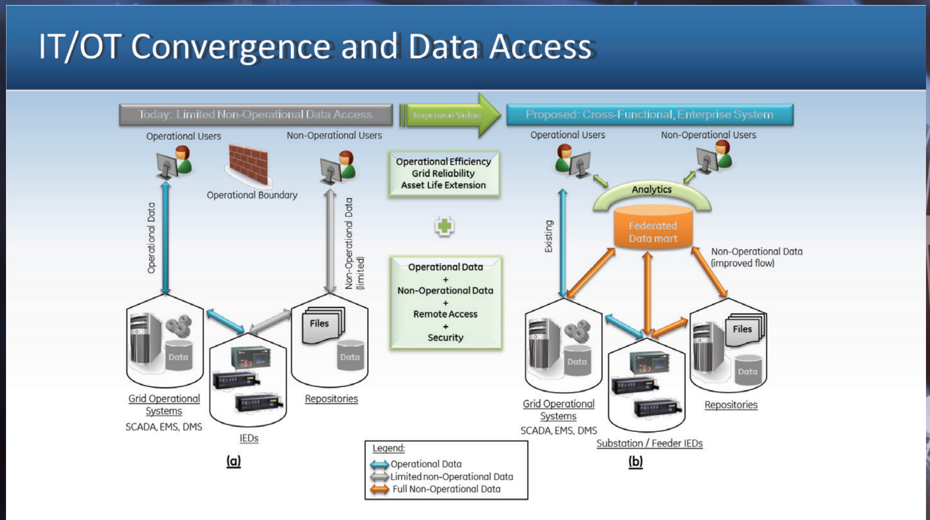


Figure 5. The siloed arrangement, left, typifies many utilities' suboptimal approach to data management, limiting access to non-operational data. On right, all devices, systems and data repositories feed into a federated data mart (FDM), enabling organization-wide access to both operational and non-operational data for improved decision making and value creation.

Coupling organizational change with technology advances, if properly understood and implemented, will unlock significant value in resolving business challenges. Operationally, the step I'll now outline will enable a utility to shift to a more effective and less costly condition-based maintenance approach and support future functionalities.

Functional data paths

Fasten your seatbelt! The design and information architecture that can deliver non-operational data to the authorized enterprise individual or unit for value creation requires the creation of an enterprise-wide "data requirements matrix." The first step in this process involves querying business unit managers on who in their bailiwick needs non-operational data. The process must specify the precise type of data, its form, and at the specific time intervals for documenting that data.

Those being queried should be supported by a presentation on the inventory of IEDs and their data maps (the collection of data-producing points in each IED). This will enable business managers and their personnel to understand what's available to serve their needs. The affected personnel will also need technical assistance to properly understand how they can create value from this potentially new source of data, as well as how to use processing, applications, and presentation technology to achieve that value.

The purpose of the exercise must be clear: enterprise-centric value creation is the goal, not the use of data to support individual or business unit goals. Silo walls must crumble, both culturally and technically.

An inventory of distribution system IEDs must include their data maps and attributes. The next step is complex – to determine which points in each data map can serve value creation by enterprise stakeholders.

The attributes associated with each IED data point might differ among devices by different vendors; they must be accurately documented.

Examples abound. The data sampling rate in one device might vary from another. An end-user might seek a peak value or an average value for each hour of data retrieved. These attributes are referred to as the "aspect of value." It is crucial in this step to determine what data each IED produces and the "aspect of value" to the end user.

Once the IED template (the sensors and their data maps) and the data requirements matrix (who needs which data and its attributes) are established, the project turns to mapping the data source to the end user. And that, in turn, informs the network architecture that delivers non-operational data across the corporate firewall into a data repository/warehouse, where it can be accessed on demand by authorized users. From experience, I can state that rigor and accuracy in this phase are critical to a successful outcome. To extract full value from IEDs implemented in the future, they are simply added to the existing template, matrix, and map. Utilities often rely on a number of physical data repositories, which remain useful in the data mart scenario described here.

Photo: Shutterstock

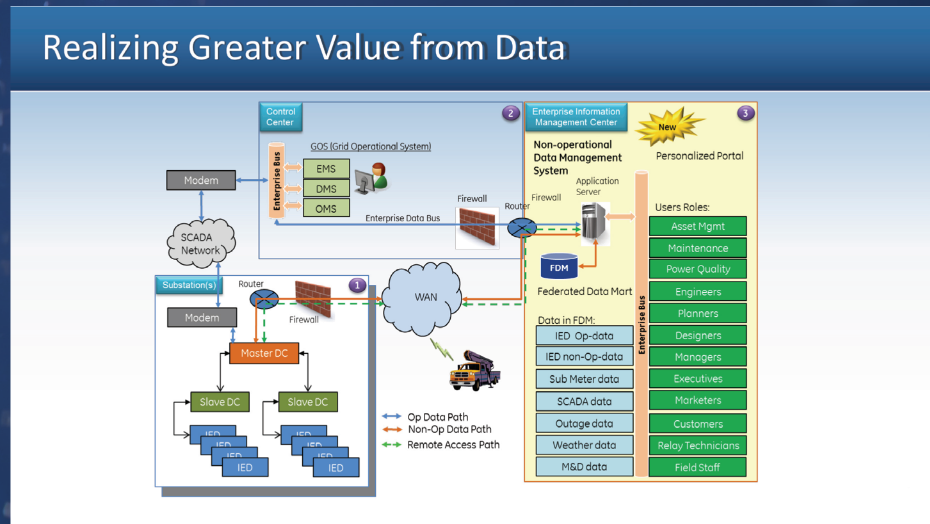


Figure 6. This illustration depicts how myriad data sources ideally feed both a control center and an enterprise information management center. On the enterprise side, data in a federated data mart (FDM) can be readily accessed for value creation by diverse end-users (user roles in horizontal green boxes at far right.

A federated data server can sit atop and access these potentially disparate, legacy repositories, creating a "virtual data mart," which includes both operational and non-operational data. Figure 5 illustrates a typical, siloed approach to data management (left) and how that can be transformed (right) so that authorized users across the utility organization can access both operational and non-operational data.

If this painstaking process is carefully followed, an enterprise end-user can access non-operational data on-demand from a virtual data mart, which has received the data from the operations (SCADA) historian. A data mart also guarantees that users across the enterprise all access data possessing a single, precise value. The data mart user interface should be designed to allow a user to report suspicious data that may reflect sensor, system or process errors or even a cybersecurity breach. Figure 6 illustrates how myriad data sources feed both a control center and an enterprise information management center. On the enterprise side, data in a federated data mart (FDM) can be readily accessed for value creation by diverse, authorized end-users.

The consumer

Readers must surely be aware that "customers" – energy users with their name on the bill – have evolved to become "consumers" (all energy users) and even "prosumers" who own their usage data and expect value for allowing a utility to use it. Ultimately, prosumers will likely shape a utility's business model and how its operations and enterprise staff successfully deliver value. Prosumers, however, are not homogenous and, thus, they must be engaged and that requires understanding their diversity of needs, perceptions, and motivations, which requires an understanding of market segmentation.

All the points made in this article may seem quite distant from our historical notion of "grid modernization," but The Journey to Digital Transformation, coupled with seizing the day on prosumer market segmentation will indeed pave the way to cost-effective, secure, future-oriented grid modernization that is every utility's goal.

Author's note: This topic deserves to be explored at greater depth and I do so in my Chapter 1 in Big Data Application for Power Systems (Elsevier). The book's 2nd edition is in press.)

Readers must surely be aware that "customers" – energy users with their name on the bill – have evolved to become "consumers" (all energy users) and even "prosumers" who own their usage data and expect value for allowing a utility to use it.