Harnessing the power of advanced analytics in distribution asset management

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Digitalization and modern electric distribution grids: highlights and trends

Digitalization represents one of the most significant trends in the evolution of modern electrical distribution systems, and interest has accelerated in recent years as favorable market developments and advances in technology have converged.

On the one hand, the steady transition to low carbon energy production, transportation and heating systems in many countries, the associated proliferation of distributed generation such as rooftop photovoltaics and small-scale wind generation as well as the predicted uptake of electric vehicles and heat pumps is transforming the way distribution networks operate. The transition from passive, one-way-flow networks to digital technology-based active networks that can support two-way flows increasingly requires intelligent hardware and software to provide situational awareness, flexibility, and controllability. A new breed of smart devices is evolving that features flexible-edge computing, field interoperability and communications as intrinsic attributes of their design.

On the other hand, computing and storage are becoming increasingly cost-effective and powerful, as gateway communications come closer to field sensors and controllers, enabling the emergence of both wired and wireless communications links to data sources that were not possible in the past. Moreover, developments in machine learning and artificial intelligence models offer new opportunities to optimize grid analytics. As computing hardware, communication, and sensor technologies continue to advance, the proliferation of intelligent devices and applications in modern grids will continue to grow [1].
IT and OT convergence and the value of asset health management

Historically, information and operational technology (IT & OT) reside in different parts of a utility organization.

The OT side is responsible for execution, monitoring and control of an electrical system, ensuring the network is operating within the allowed ranges of reliability and quality set by the regulations and parameters of the corresponding agencies.

The IT (business) side of the utility is responsible for decision making, energy planning, operations planning, resource and asset allocation, and support of any activities required to facilitate the tasks of the operations group, such as trading, fuel nomination, field crew dispatch, asset maintenance, customer service, etc.

Decision making at the enterprise level usually involves (directly or indirectly) multiple departments within the utility. For example, sending a field crew to repair a transformer will involve field operations (personnel and vehicles), finance, human resources, inventory/warehouse and customer service (if the maintenance task will affect customers). The involvement of multiple departments on any given task or decision making process demands tight integration of systems and applications at the enterprise level enabled by a robust IT infrastructure. Information technology plays a major role in the success of effective decision making at the utility. Data and application integration, business intelligence (BI), hardware capabilities to run complex algorithms and display mapping features, workflow coordination and reporting are some of the elements IT contributes to the business groups for efficient operation.

With the emergence of smart grids, two major issues arise:

1. The need to integrate new types of assets/agents to the electric network and make them “operational ready,” taking into consideration all the complexities of operating interconnected electrical systems. These assets can be electric vehicles, demand response programs, home area networks, distributed generation, as well as large-scale renewable generation (particularly volatile generation such as wind).

2. The need to manage very large quantities of “new” data in near real time that will be available to the operations and business groups within the utility. Data will come from new devices and sensors spread throughout the transmission and distribution networks, metering devices, electric vehicle recharging stations and home area networks, among others.

Both the business and operations groups will face significant challenges in terms of infrastructure, communications, business processes and coordination when trying to deal with these two issues because now, for the first time, there is a real need to integrate (near) real-time operations with business decision-making processes and applications. Such an integration will transform the utility industry like never before. It will increase operational efficiency, reduce costs and make it more environmentally friendly by enabling intelligent assets/agents to be part of the electrical network [1.2].
A typical utility asset infrastructure is composed of thousands of networked asset components (like transformers, circuit breakers, capacitor banks, lines, meters, etc.), which generate large amounts of data. These datasets are not only large in volume, but also vary substantially due to the variety of data types. From a business perspective, what to do with all this data becomes the key question. For starters, it would be beneficial to use the data to assess the level of risk (of failure), so that suitable actions may be taken to optimize asset and system performance. Ideally, these actions would focus on assets where the maximum amount of risk may be mitigated for a given level of investment. Failure prediction, advanced notifications, work identification and prioritization are all relevant use cases.

**Fitting Asset Performance Management (APM) into the utility business process puzzle**

APM has a critical role in utility business processes. This includes various stages of the asset management virtuous life cycle – planning, monitoring & diagnostics, maintenance, and replacement. It informs these processes and aids decision making by answering the key questions below to address both short-term and long-term needs.

Based on the Accenture Model of the High-Performing Utility Process Model, there are six main processes that Distribution Utilities are engaged in [3]:

1. Plan & Manage the Assets, Infrastructure and Energy Portfolio
2. Plan, Manage & Execute Work
3. Manage & Operate the Network
4. Manage the Smart Grid
5. Manage the Meter and Customers
6. Manage Regulatory Requirements and Business Analysis
APM provides business analytics by monitoring the health of field assets and providing prescriptive maintenance advice, related to processes 1, 2 and 6, as described above. From a short-term perspective, the following question is relevant:

Is the asset performing within its accepted limits\(^1\)? If yes, continue “Monitoring and Diagnosis.” If not:

- What happens if the asset is not restored to operation within its acceptable limits?
- What action is required to restore the asset to its acceptable performance limits?
- When is the action needed? That is, when is asset performance expected to degrade beyond acceptable limits if no action is taken (“Do-Nothing”)?

From a long-term perspective, the following question is relevant:

Is the cost of taking (multiple) short-term actions over a period of time to restore asset performance greater than the cost of replacing the asset now? (If no, continue implementing short-term actions; if yes, proceed with plans to replace the asset.)

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\(^1\) “Acceptable” limits could include any number of performance criteria including reliability, safety, environmental, regulatory, etc.
Transitioning from current maintenance strategies to analytics based risk management strategies

Most asset-intensive organizations, such as electric utilities, are realizing they hold huge amounts of untapped data (“Data Deluge”). The power of integration to capture data across multiple organizational silos combined with the capacity of commercially available analytics solutions to leverage this data is helping these organizations see the benefits of past system-wide installations of monitors and sensors. In many cases, combining this information with deep subject matter expertise, as is done in APM, is delivering a great deal of value in the form of fewer hazardous incidents and cost savings due to reduced O&M spending and improved reliability [2].

Building on the early benefits realized by PAS 55 implementation and the publication of ISO 55000, there has been a steady shift in the asset management paradigm. Traditional strategies such as run-to-failure, periodic- and usage-based maintenance are being replaced by condition- and risk-based maintenance for critical assets. Refinement and creation of information and knowledge from raw data is becoming the norm when it comes to making financial decisions. The ultimate goal for these asset-intensive industries is to move to financial optimization at the organizational level, as shown in the figure below, and to adopt the “line of sight” principle, in which financial resources are deployed in the direction that yields the highest risk mitigation.

Figure 2: Comparison of Various Maintenance Strategies: Moving from time-based to Risk-based Strategies
Transitioning current maintenance strategies requires several change management initiatives at the organizational level. While executive sponsorship is a key requirement to success, organizations need to work on the implementation of changes in their internal processes (data collection, for example), tools (BI tools, for example) and personnel training to ensure personnel and the organization are aligned at all levels. As a fundamental building block, a strong data governance process is extremely important to ensure the accuracy, timeliness, relevancy, uniformity and usability of collected data.

**Data processes, data sources and data quality**

Data processes include its acquisition, transformation and publishing. These processes are typically not a one-time migration, but rather a process of establishing ongoing streams of properly formatted data from a variety of sources [4].

The first step is understanding the to-be state of the data, beginning with the required data parameters. Clearly, with increasing data availability there is a higher level of confidence about predicting the health of the asset, when it will fail, and when to take action to avoid potential maintenance issues. In mature APM solutions, this to-be state is defined by the requirements of its internal models.

The second step involves a current state assessment. This is necessary in order to understand all of the data spread across the enterprise, and to identify how it might map into parameters required by the BI tool. The spectrum spans existing digital sources and paper-based information. Much utility data is still paper-based, and is often collected during testing sequences. The assessment of as-is data varies from utility to utility. Those that have expanded through acquisition of other energy providers often find themselves with a collection of diverse and incompatible systems, and islands of data in inconsistent formats.

After obtaining a good understanding of the to-be and as-is states, a gap analysis must be established that describes the process and effort needed to create the required data streams. This might require data transformation after it has been extracted from a given source, and before it is loaded into the BI tool. In IT jargon, this is referred to as the ETL (Extract, Transform, and Load) process.

Discussions about data sources and the to-be state typically lead to deeper conversations about the issue of data governance:

- **Accuracy**: what level of data precision is required?
- **Frequency**: how often must each asset parameter be sampled and/or transmitted?
- **Timeliness**: is there an optimal time to receive each piece of data?
- **Granularity**: how detailed does each piece of data need to be?
- **Retention**: decisions should be made about what data will be kept and for how long.
- **Data ownership**: in most organizations, data is found in a variety of functional silos, which must be linked and coordinated in new ways to enable required data streams in the new paradigm.
Data quality is key to producing results that are valuable and reliable. Therefore, it is important to implement the quality checkpoints at various stages as described below:

— The first level checkpoint is “structural integrity,” which evaluates data for properties like the number of digits. This includes tests to ensure only numerical data (as opposed to character strings) is included for numerical values, along with the appropriate unit of measurement. Errors detected at this level often indicate a need to develop standard procedures, or to train personnel.

— The second level checkpoint relies on a rules-based engine to identify things like unexpected values. If upper and lower boundaries have been defined, for example, the data checking process must be able to identify values outside the specified ranges, which could represent potential errors requiring further investigation. Data identified as potentially incorrect at the first or second checkpoints is rejected, rather than being input into the tool.

— While the first two checkpoints may be implemented even before the data is assessed by the APM application, the third level checkpoint is a “false positive,” which needs to occur within the APM application. When these types of errors are generated, the tool must be able to generate an alert that indicates the problem and suggest corrective actions.

In addition to detecting bad data quality, a lack of data (insufficient data) or missing data must also be detected.

**Putting it all together in an APM Solution**

ABB has built an APM solution (branded as ABB Ability Ellipse APM) which has been in operation since 2015 at one of the largest utilities in North America [5]. At this installation, more than one million electrical T&D assets are continuously assessed for failure risk using advanced data analysis techniques embedded in the form of models within the software solution. In this context, a model is a collection of advanced algorithms designed to assess a particular asset type (transformers, circuit breakers or transmission lines, for example), and is able to ingest large amounts of data in order to provide a relative health and performance ranking of each fleet asset.

Each model is unique, in that it uses one or more algorithms to assess the asset in question. The results provide a combination of health indexes, probability of failure and life used. This is in addition to notifications about impending failures, and recommendations for corrective and/or preventive actions. A list of maintenance actions along with prioritization aids the work management processes.

The figure below provides an example of a model for a transformer. As shown, various data sources are combined along with online sensory data to perform a holistic evaluation of the risk (of failure). Advanced data analytics based on expert systems, advanced statistical analysis and in-house expertise are embedded in the form of the algorithms in the model.
Figure 3: Example of a transformer model in ABB Ability Ellipse APM

The architecture of the ABB Ability Ellipse APM solution allows for multiple models to be used to assess a particular asset. This remarkable flexibility allows for benchmarking the accuracy of various models. It also permits the use of third-party models, including those developed by ABB’s customers. The Ellipse APM solution has since been deployed at multiple locations worldwide in multiple formats – onsite, as a service (SaaS) and as a fully hosted solution.

Blazing the trail to asset performance improvements, cost reductions & risk mitigation with ABB Ability Ellipse APM

ABB has implemented Ellipse APM at multiple locations spanning the globe. Covering millions of field assets over service territories spanning continents, the solution has been in production for the past three years. In this short time, the solution has proven itself by delivering value worth several times the original investment, much to customers’ satisfaction. From a functionality perspective, the solution uses advanced data analytics techniques to:
— assess the risk of failure of field assets
— notify users of imminent and predicted failures
— identify short- and long-term actions necessary to preserve system status quo
— prioritize short- and long-term actions necessary to optimize both O&M and capital expenditures
— enhance asset intelligence

In these implementations, customers have realized demonstrable financial and qualitative benefits. While financial benefits accrue from reduction in O&M spending and more efficient deployment of capital, qualitative benefits come from a variety of quarters: safety, environmental and process improvements. In particular, realized benefits include [5]:

— **Failure prevention**
  Ellipse APM has in several instances identified the imminent failure of large EHV transformers before a breakdown. In these cases, catastrophic failures were avoided by putting these transformers out of service proactively, thus avoiding safety issues and potentially bad press.

— **Process integration**
  Ellipse APM has enabled the integration of various back-end processes, including planning, inspections, maintenance and operations, thus realizing improved process efficiencies. For example, field personnel look up the status of assets on their mobile devices before entering the substation where the asset is located to ensure their personal safety.

— **O&M spending**
  Ellipse APM has enabled the new asset management paradigm by allowing the adoption of condition- and risk-based asset management. A direct benefit of this is the reduction of time-based inspections by nearly half, and the savings that accrue from lower “truck rolls,” field visits and laboratory tests.

— **Asset renewal**
  Ellipse APM informs the process of asset renewal. This enables the efficient allocation of capital so that investments are made in the strategic direction of minimizing risk in alignment with the ISO 55000 “line of sight” principle.

— **Risk visualization**
  Ellipse APM provides users with a thorough picture of the risk associated with field assets (classified in a three tier – Red, Yellow and Green – traffic light system to reflect High, Medium and Low risk levels, respectively). Associated trends enable users to see the impact of actions on the health and performance of each asset.
— **Improved data governance**

Due to its data intensive nature, the Ellipse APM solution requires, and enables, the streamlining of data flows throughout an enterprise from point-of-origin (automatically by sensor, or manually by a service technician filling out an inspection record) to a sophisticated dashboard. This is a huge benefit from an enterprise perspective that supports confidence in decision-making and future investments.

**Looking Ahead**

Digitalization is a process that supports and enables the paradigm, from ‘data in the field to ‘information in the board room.’ The benefits of digitalization for distribution utilities can be found in many applications, such as:

— Asset performance management that enables digital simulations of transformers and other field devices to optimize maintenance schedules.
— Monitoring, control and optimization of distributed energy sources, storage, and demand/response management that can now be combined into an integrated system.
— Maintenance workflow management systems that can be used to schedule the optimal downtime window to inspect and repair energy infrastructure.
— Energy market trading systems that are used in many liberalized energy markets to carry out energy forecasts and trading in wholesale markets.
— Automated digital substations that combine solid state power electronics with fiber-optic digital communications to reduce outage times.
— Wireless standard IP communications technologies that enable use cases, such as smart-metering and distribution automation.
— Smart sensor technology that provides the power to know the system state in both steady state and transient conditions.
— Intelligent switches, transformers and other digitalized grid apparatus that address the requirements for grid flexibility and controllability.

Continued digitalization will result in more operating efficiencies, less downtime for customers and/or equipment, and faster response to issues that occur close to the grid edge. Running analytics software engines on top of this hardware will make the devices and applications even more effective in providing benefits to prosumers and service providers. Distributed hardware supporting advanced analytics that employ machine learning, artificial intelligence, and other techniques will even make proactive network management possible.
References

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