21, rue d'Artois, F-75008 PARIS
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The Evolution of Asset Management in the Electricity Sector

G. MCEACHRAN
S&C Electric Company
United Kingdom

SUMMARY

Asset management is a core function of every electricity grid owner. Grid utilities operate in an asset-intensive industry, with significant investment required to inspect, repair, refurbish, and replace assets to maintain and improve safety, reliability, and resilience.

Asset-management practices have evolved over time to meet changing sector needs. In simple terms, approaches which were largely "reactive" have become more "proactive" and ultimately "predictive." A greater emphasis is placed on monitoring asset health and identifying risk of failure.

Today, the sector faces a range of new challenges, from supporting the energy transition to addressing climate change threats, all while meeting customers' changing needs. Concurrently, asset management is becoming increasingly sophisticated, thanks to technological and digital innovations. These developments have implications for asset management's future, and this paper explores the trends.

First, the paper outlines the history of asset management and how it arrived at the present "risk-based" approaches. It then considers the drivers of the evolution of asset management and the challenges and opportunities they present. Finally, it sets out why regulation will have a critical role in supporting the evolution of asset management using examples from a range of countries.

KEYWORDS

"asset management," "energy transition," "climate change," "digitalization," "innovation," "regulation," "asset risk," "whole system solutions"

grant.mceachran@sandc.com

Introduction

Asset-management practices are well-established in the electricity sector. In a number of jurisdictions, grid utilities have ISO 55001 [1] certification, an international asset-management system standard designed to help optimize investment and asset life cycles. Despite this, asset management is not a static practice; it has evolved and continues to evolve.

This evolution is important because grid utilities face growing challenges. Federal and state governments have made decarbonization commitments, and the energy sector has a key role in meeting targets. Climate change results in more severe and frequent weather-related events, while cyber and physical attacks pose increasing threats. It means there's a need for more reliable and resilient grids that can withstand threats and respond quickly to minimize service disruption. Effective asset management will be critical.

This paper explores the evolution of asset-management practices and where it might lead the sector.

A brief history of asset management

Asset management in the electricity sector has evolved over time. In the initial stages, the changes were gradual, including during periods of significant grid investments in the 1960s and 1970s. Traditional approaches to asset management were grounded on "rules-based replacement," with investment driven by expected asset lives. The key shortcoming of this approach is asset lives are not linear; they can be impacted by geography, climate, and use.

Over time, the focus of asset management shifted to "reliability-centered maintenance," an approach designed to optimize investment by reflecting better information on individual asset conditions. The speed of change has accelerated since the 1990s, with the use of failure modes and impact analysis.

The product of these trends was "condition-based risk management" (CBRM) [2]. Developed in 2002 by EA Technology Ltd., working with UK utility company Electricity North West Ltd., the approach combined available asset information with engineering insight and firsthand experience to provide a profile of asset condition and performance.

This overall trend in approaches to asset management was clearly outlined by R.P.Y. Mehairjan in his book "Risk-Based Maintenance for Electricity Network Organizations" reproduced in Figure 1.

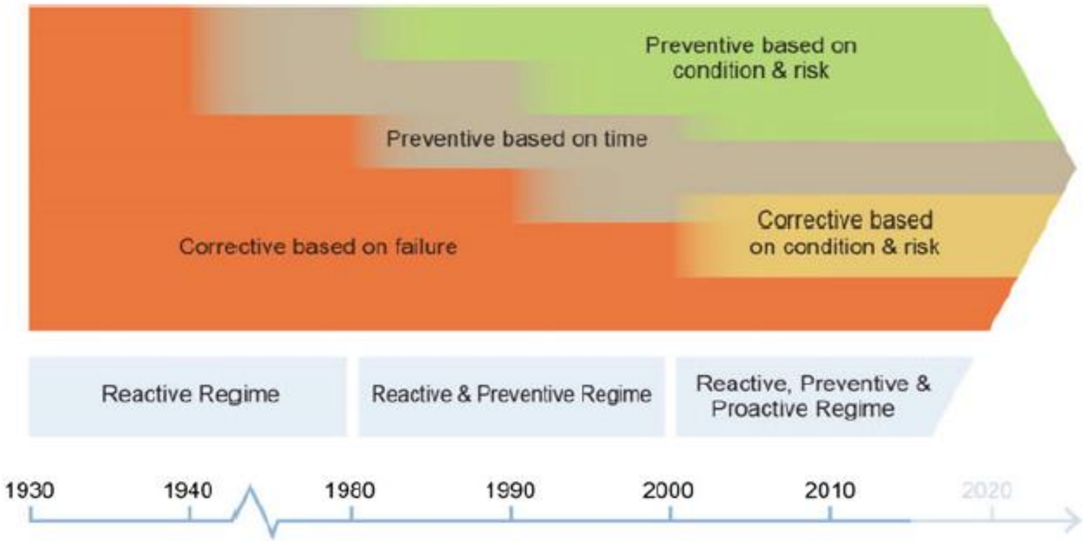

Figure 1: Evolutionary Stages of Asset Management. [3]

The present state of play

“Best practice” asset management now combines detailed information on the condition and reliability of assets, with an understanding of the consequences of failure and the costs of asset intervention. The overall trend is from “lagging” to “leading” indicators, i.e., toward predicting the impact of future changes.

In Chapter 2 of his book, Mehairjan notes: *“... the state-of-the-art maintenance policy is the risk-based version, which is guided by the principles of risk management. A risk is composed of a stimulus (i.e., the root cause) and its consequences. The risk-based approach refers to the quantitative assessments of (1) the probability of stimulus (event) and (2) on business values [key performance indicators].”* [3]

A risk-based approach enables utilities to prioritize investments based on the optimization of asset risk against the costs of intervention instead of purely on asset-age profiles. For consumers, it improves cost efficiency and performance. Inefficient investment in older assets that remain in good condition is avoided, and factors such as reliability, safety, and environmental impacts can be embedded in decision-making.

The implementation of a risk-based approach to asset management is not the end of the journey. Under the umbrella of risk-based approaches lies a broad spectrum of measures. The Institute of Asset Management developed a “maturity” scale that provides a way to consider this evolution. This model is shown in Figure 2.

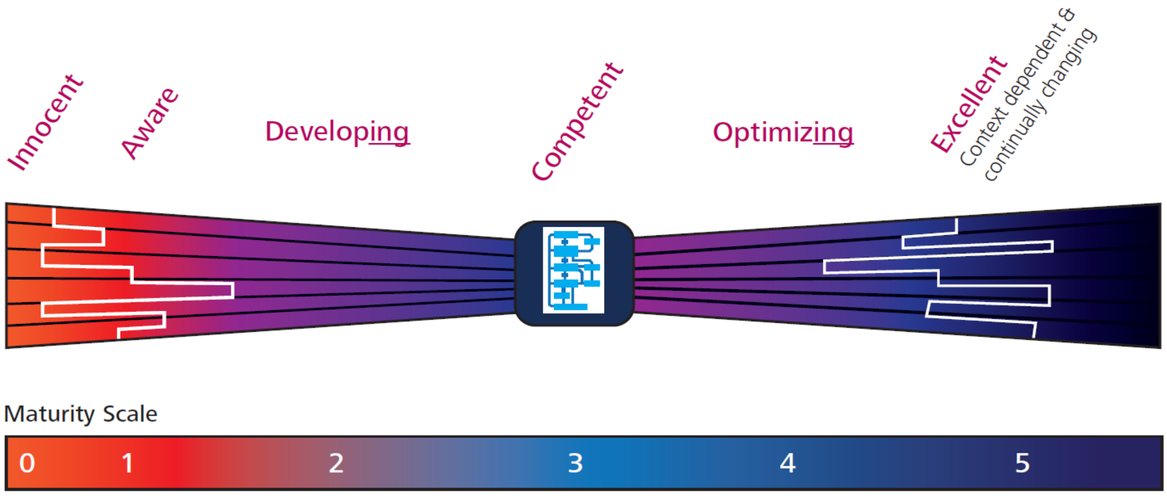

Figure 2: Maturity scale for asset management activities. [4]

The IAM describes a "maturity journey" from "innocent" at one end of the spectrum to "excellent" at the other, the latter stages (levels 4 to 5) being characterized by the "optimization" of activities.

Importantly, the end point is not definitive, recognizing the evolving nature of risk and thus of the potential of asset management. In the electricity sector, the emergence of a range of challenges and opportunities in recent years would be expected to have further refined the definition of "excellent" and the position of grid utilities on the path of optimization.

Key drivers of evolution – the challenges

The energy transition

Global electricity demand is predicted to double from 22,390 TWh in 2020 to 44,403 TWh by 2050. [5] This will reflect an acceleration in the use of carbon-free energy generation coupled with increased electrification of heat and transport.

This change is underway and is impacting the role of the electricity grid. The demand for interconnections has risen exponentially. Recent estimates indicate the average utility manages 10 times the volume of devices it did 20 years ago. [6] Further, this trend is continuing. The challenge for grid utilities is to manage the growth efficiently.

Climate change

The threats posed by climate change continue to increase. Wildfires, ice storms, extreme heat, or tropical storms all impact electricity grids. Utilities must maximize grid resilience, and that has implications for asset management.

One consideration is where assets are installed. Traditionally, the higher costs of undergrounding resulted in more attention on overhead solutions. As the threats from climate change increase, rising maintenance costs make the economics of undergrounding more appealing. This has led to extensive undergrounding programs in areas as diverse as Florida and Scandinavia. This trend is discussed by S&C in its paper "The Changing Economics of Utility Investment in Undergrounding." [7]

The changing needs of end-use customers

End users are more engaged in the energy sector than ever before. They are increasingly managing their own use and providing services to the grid through the ownership of "behind-the-meter" resources, such as residential solar panels. Also, as levels of electrification rise, then so does our reliance on electricity and the consequences of an interruption to supply.

End users already experience varying levels of reliability and resilience. An increasing area of focus for grid utilities is improving performance for customers in "worst-served" areas, i.e., those that experience a greater likelihood of disruption. This means an evolving focus for asset management toward the grid edge, where the challenge is proportionally greater. This change is critical to ensure all customers benefit from the energy transition.

Key drivers of evolution – the opportunities

This is also a period of opportunity in the field of asset management to take advantage of a range of technological and digital innovations that continue to emerge as well as the potential offered by distributed energy resources (DER). These areas are interlinked.

Technological advances

Increasingly, the focus has shifted to automation that enables the grid to respond to threats. Smart switches, reclosers, sensors, and other such devices are examples of this shift. Automation solutions include managing outages, keeping voltage within predefined limits (Volt/Var management), and adjusting protection schemes.

There is also a greater focus on grid segmentation and switching to isolate and thereby minimize the impact of events. The trend is from a traditional "hub-and-spoke" design to more interconnected systems that allow the grid to automatically detect outages and instantly reconfigure to provide power to the greatest number of customers. This reflects a shift to a "self-healing" system with associated reliability and resilience benefits.

Digitalization

Besides physical assets, grid utilities have access to better-quality data, enabling them to prepare for the threats they face and to achieve the most efficient response. The opportunities provided by advanced analytics are vast. Not only is live information on assets available, but forecasting capability is significantly enhanced.

One of the most discussed advances is the role of "digital twins." Digital-twin technology enables utilities to create a digital representation of physical assets and to test those assets under a range of conditions. This offers opportunities to enhance decision-making for asset design, maintenance, and replacement. Digital twins will enable utilities to save time and money and provide customers with improved performance at a lower cost.

Increasingly, artificial intelligence (AI) is playing a leading role in asset management. A number of electric utilities are using advanced machine learning algorithms enhanced by the use of drone or satellite information to help protect grids from a range of threats. The potential is huge and the endpoint difficult to predict, but advances in this area will undoubtedly shape the future of asset management.

The role of DER

A key trend in the energy sector is the increasing volume of generation connecting to the distribution grids. DERs are generally small, clean-energy sources such as solar photovoltaic, wind, energy storage, demand response, and electric vehicles. DER will contribute significantly to the energy transition and also have the potential to support system stability at times of stress.

The challenge is the grids were not designed for two-way power flows. For grid utilities, this means a range of challenges, including power quality, voltage control, losses, and a range of protection problems. It also means weighing up the use of DER flexibility against traditional grid investment.

For asset management, the challenge is to optimize asset performance to enable DER to operate at the highest possible level of efficiency. The solution partially lies in technology, such as enhanced control of inverter-based resources. It also lies in digitalization with enhanced monitoring, measuring, and predicting capability, enabling operational efficiency of a more decentralized system.

The critical role of regulation

To enable the opportunities offered by more sophisticated approaches to asset management, regulation will have a key role. The obvious starting point is a framework for assessing investment.

In a regulated sector, the levels of investment available to grid companies drive asset-management choices. Many jurisdictions have aging asset bases, and investment will be essential to meet the threats and prepare the grids for the energy transition. The challenge is enabling efficient levels of investment reflecting both present and future needs.

One common tool regulators and utilities use is Benefit-Cost Analysis (BCA). This enables an assessment of the potential benefits and costs of an approach as a means to determine its suitability. This is illustrated in the Figure 3 diagram, which highlights the diminishing value of returns from investment and the ability to identify a point at which benefits are maximized ("the point of maximum yields"). This can be applied as a way to determine the efficiency of asset-management actions.

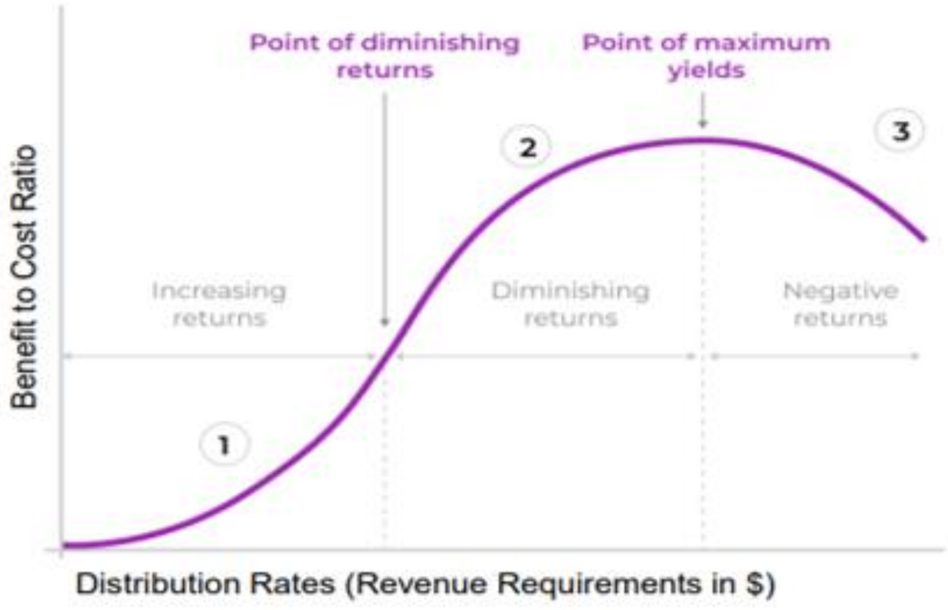

Figure 3: Law of diminishing returns curve. [8]

BCA must increasingly consider a role for anticipatory investment. An example is supporting the rollout of electric vehicles (EVs). In the U.S., numerous states have "make-ready" programs providing investment in EV charging infrastructure and the grids that support that infrastructure. Critically, investment is taking place "ahead of need." For BCA, it means factoring in the potential for stranded assets but also the risk that not investing will prevent many programs that will drive the energy transition and lead to higher long-term costs to consumers.

Measuring Asset Risk

A key challenge for regulators has been how to measure asset risk. A range of different approaches can and have been adopted, but increasingly there has been a trend toward the use of "risk metrics." These can be formulated in different ways, but the model highlighted in Figure 4 represents an overview of the broad approach that captures the two dimensions of likelihood of failure and the impact.

The impact has a scale ranging from a position where events have an insignificant impact to a position where events are "almost certain" and the results catastrophic. Increasingly, utilities have used this approach as a way to classify the health condition of individual assets and thus of determining their approach to asset management.

		Impact				
		Insignificant Any failure that can be resolved without an outage under normal maintenance schedules and has no impact to health and safety.	**Minor** Any failure requiring repairs to avoid an outage but has no impact to health and safety.	**Moderate** Any failure that is likely to result in an outage and may have non-life threatening impact to health and safety.	**Major** A failure resulting in potential life threatening impact to health and safety.	**Catastrophic** Severe impact to health and safety.
Likelihood		1	2	3	4	5
Almost Certain The event is expected to occur in most circumstances.	5					
Likely The event will probably occur in most circumstances.	4					
Moderate Given time, likely to occur.	3					
Unlikely More likely not to occur under normal conditions.	2					
Rare The event may occur only in exceptional circumstances.	1					
Severe Risk	Discontinue operation and/or immediate corrective action required.					
Significant Risk	Proactive short-term action indicated in maintenance and inspection plan.					
Moderate Risk	Short-medium term attention indicated within maintenance and inspection plan.					
Minor Risk	Implement practicable medium-long term control measures.					

Figure 4: Example of an asset risk register. [9]

Monetizing Asset Risk

A further logical step to improving the maturing of approaches to risk is attaching value to asset-management actions. One trend in Great Britain is the move to “monetized risk,” reflected in the Network Asset Risk Metric (NARM) framework. [10] This approach involves Britain’s distribution network operators using asset-health data to calculate a “long-term asset risk value” and then setting a target (“output”) for reducing the risk value during an investment period. A penalty is applied for an unjustified under-delivery against the target.

Long-term monetized risk is a way to measure asset health in both the short and long term. This is shown in the Figure 5 diagram. The green-shaded area represents the impact of asset intervention on monetized network risk, with the long-term benefit seen beyond the present regulatory period (RIIO-2).

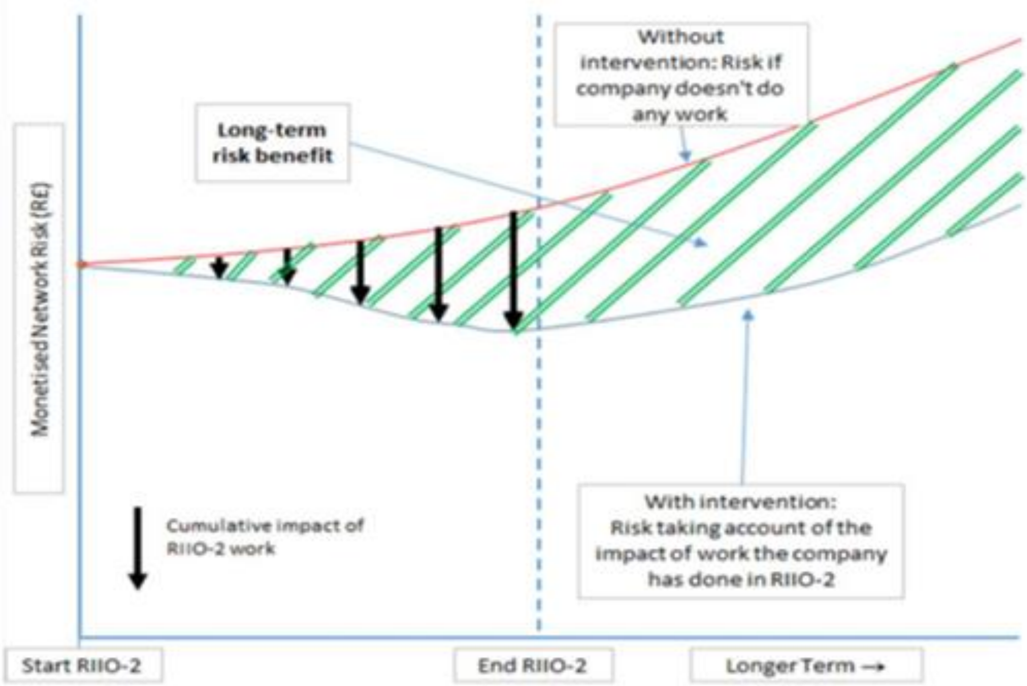

Figure 5: Methodology for Calculation of Long-Term Risk Benefit. [11]

It is possible to see trends in this direction in other jurisdictions. In Canada, Toronto Hydro previously worked with EA Technology to develop asset-health models based on the Common Network Asset Indices Methodology (CNAIM), the precursor to NARM in Britain. In New Zealand, transmission grid owner Transpower will introduce new asset-health metrics in a pilot project aimed at informing the setting of revenue and quality standards for future revenue-setting periods. [12]

Overall, the assessment of long-term asset risk value is in its early stages and would be expected to be refined over time. Further evolution in this area will be important in a sector with long-life physical assets.

The future of asset management

A growing focus on resilience

As our reliance on grids grows, resilience becomes increasingly important and a greater focus for regulatory mechanisms. Ofgem in Great Britain is proposing to "work with DNOs and other interested stakeholders to develop a wider resilience metric," [13] and the Australian Economic Regulator (AER) is highlighting "scope to consider incentives in regard to major events." [14]

One particular resilience challenge for asset management is dealing with High Impact Low Probability (HILP) events. HILP, or "black swan," events are characterized by being uncommon but having a high magnitude of impact on the grid, including the risk of long-lasting blackouts. This is an area better understood and tested in other sectors, including nuclear, but is increasingly a focus of grid utilities as the threats, such as extreme weather events, magnify.

Finding whole-system solutions

Traditionally, the electricity and gas sectors have planned investment separately to meet energy needs. Even within the electricity sector, independent asset-management processes drove decisions at transmission and distribution voltages. Looking forward, the threats and opportunities are increasingly not limited to one sector. The challenges cut across multiple sectors, including energy, transport, communications, and water. This means a greater focus on “whole-system solutions” with asset-management decisions being taken in more holistic way.

Conclusion

After a number of decades of gradual evolution, asset management is now one of the most dynamic areas in the electricity sector. Recent years have seen rapid changes in how asset-management tools are used, driven by the challenges and opportunities facing the grid. The potential of AI continues to expand, and it is recognized that thinking must extend beyond the grid.

The ultimate aim is an approach that can use advanced physical and digital technologies to coordinate all grid users’ needs in the most cost-efficient way possible. Safety and reliability will remain key priorities but are joined by drivers such as stability, flexibility, and increasingly resilience.

The advances in the last few years have been significant, as risk-based approaches have become more sophisticated and new technologies have been developed that can improve performance. However, there are areas that require focus, including how to address HILP events, expand the use of monetized risk as part of BCA, and ensure joined up approaches across sectors.

For a long time, achieving a “smart grid” was seen as the pinnacle for the sector. Now, even this language is starting to sound outdated. Asset management will be a key tool to maximizing the benefits from the energy transition but may look quite different, even in the near future.

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