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Advanced Maintenance Through Digital Twins

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SUMMARY

In North America, the distribution grid was built mostly in in the 1975-1995 timeframe. As such, utilities across North America are facing rising costs related to maintenance, for which they may not have the financial or technical means to respond to. Before the energy death spiral utilities will probably face a reliability death spiral which may push them to the brink with their customers. As outages grow, the costs to large customers for even the shortest outages can be counted in hundreds of thousands of dollars if not more. Utilities will be held responsible by both regulators and their customers for their lack of reliability and their cost may grow out of proportion. According to the Energy Information Administration in the USA, TOTEX (CAPEX+OPEX) expenses for utilities have increased by 64% in the 2000-2019 timeframe. A similar trend is happening in Canada as well.

Distribution utilities have usually had either a run to failure approach to their maintenance or pre-programmed systematic inspections. Both these methods were acceptable when the network was young and information was scarce, however with the current technology and scarcity of resources, these methods become unsustainable for utilities.

While using analytics, it is not rare that utilities will face large issues with data quality which skews their results. As such, the algorithms are correct, but if the input data is skewed, or the topology is incorrect, there will be a large level of false positives or false negatives.

Faced with this prospect, utilities need to find ways of creating simple, affordable, and effective digital twins, which can be linked to real-time and transactional systems. As such Hexacode Solutions, CIMA+, have partnered to develop a full scope approach which allows utilities to manage their assets from cradle to grave.

This approach includes mobility, which allow for quick and efficient capture of field data including inspections, tests and sensors data. The Asset Information Management System (AIMS) calculates both at the asset and component level the Condition Assessment (CA), the Asset Health Index (AHI) alarms and statistics. Results are then made available through an API for engineering systems, GIS, Enterprise Asset Management and Asset Investment planning systems.

Once the information has been digitized or integrated with a high degree of confidence, the utility can finally have their own asset digital twin. This methodology allows for the use of inspections and tests interpretations, and degradation algorithms calculation on a large scale. It integrates operational parameters that influence the evolution of the condition of assets. The model-based calculations will then run on a continuous basis allowing for the utility to update their risk matrix with regards to their grid architecture.

The AHI and the corresponding remaining life will then allow the utilities to plan up ahead for which assets will likely fail in the coming years and how to optimize the maintenance plan and replacement strategies in order to minimize costs and customer disturbances.

KEYWORDS

real-time, digital twins, risk-management, strategic asset management, asset health index, strategic planning

In North America, the distribution grid was mostly built in the 1975-1995 timeframe. As such, distributors are starting to face ageing and reliability problems they are less accustomed to. The US Energy information agency (EIA) has found that distribution spending has increased by 64% from 2000 to 2019, while the number of customers increased by 21% and retail sales have grown only by 11%. As the EIA shows, these numbers have increased mostly in capital investments rather than in customer expenses and O&M for which the numbers have remained relatively stable over the years.

What can be deduced from this information, is that the network is reaching its mid and end of life, and that utilities across North America must now find ways to reduce their capital investments while maintaining their service continuity.

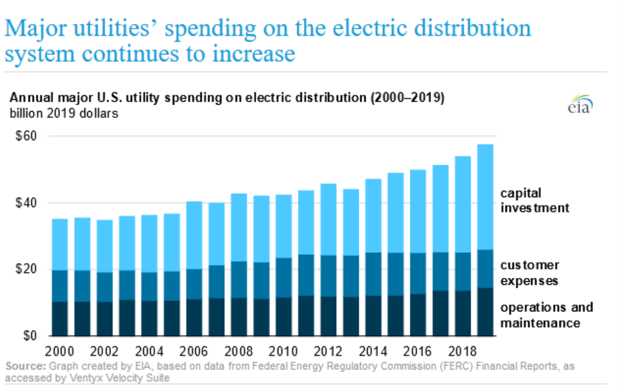

Figure 1: Annual Major US Utility Spending on electric distribution (Aniti, 2021)

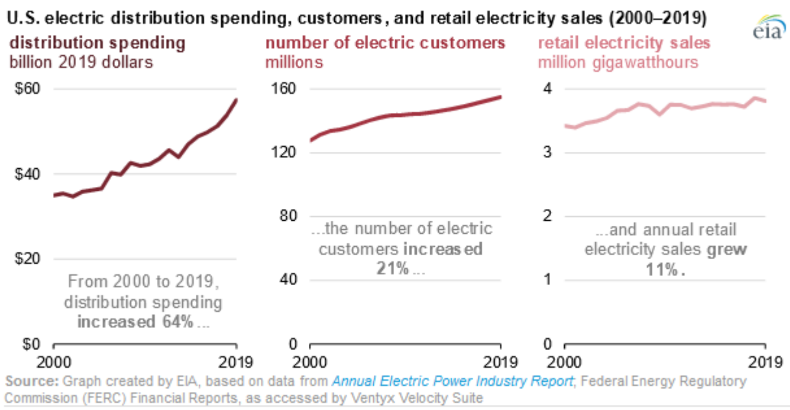

Figure 2: Comparison of spending in different categories (Aniti, 2021)

Faced with such a situation, distribution utilities often must judge and justify to their regulators what is the correct course of action and what type of investments are prudent allowing them to manage risks, reduce capital as well as operational expenditures and how to optimize them in the field without jeopardizing their current activities.

This paper will present a methodology which can help utilities build an asset investment case which will allow them to balance all aspects of this very complex equation. It will also show the importance of creating a digital twin at the centre of the solution.

Planning Process

When building an asset management strategy, the asset manager must look at both the top down and the bottom-up approach. The pyramid in Figure 3, which was developed by (Mehairjan, 2017) illustrates that asset managers need to balance different goals from different ends of the organization in order for an asset plan to be developed. Strategic objectives will examine business issues and are often examined through a holistic understanding of the business, for which risk, annual budgets should be minimized, and total performance should be maximized. This approach will be similar in all utilities and will often clash with the tactical and operational views of the managers which need to plan and perform maintenance.

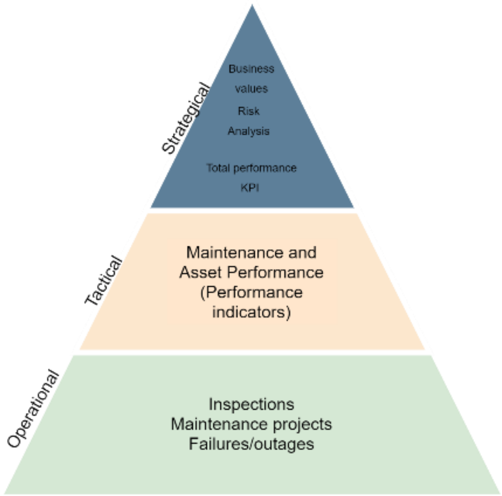

Figure 3: Asset Management Framework Hierarchy (Mehairjan, 2017)

To address such an issue, the asset manager needs to understand the risks and the outcomes of any actions he may take such that the right decision be made at every moment depending on his parameters of action. Having access to a digital twin of its grid will enable the asset manager to do just that.

Digital Twins

One way to define a digital twin is to consider it as a digital representation that creates a real-time digital counterpart of a physical object or process. The digital twins are made of dimensional and non-dimensional information. It could be a 3D model or a GIS combined with other non-dimensional information such as calculation based on thermal model that provides dynamic rating of a power transformer, finite element calculations that provides mechanical stress representation, condition assessment or predictive analysis calculations.
When applying digital twins in the context of asset management, we have to integrate the fact that assets are made of multiple components each having its own degradation mechanisms. The real-time aspect of it means not only that the digital twin is updated when components are changed but also when their operational contexts or conditions are evolving. The evaluation of the condition and the prediction of its evolution implies the integration of transactional and operational information (i.e., temperature, thermal pattern, load, load forecasts, vibrations, dissolved gas concentration…).

To build a digital twin, the asset manager needs therefore to step away from generic tools and move onto more sophisticated ones which will allow a more precise representation of the behavior and conditions of the assets in the network. Considering the fact that utilities assets can be counted by millions, the digital twin platform has to be capable of managing such a large operational inventory and also to calculate in real-time degradation algorithms applied down to the components. The platform needs to integrate data from different sources, apply validation rules, make calculations and share results with the various systems. An Asset Information Management System (AIMS) provides the latest non-dimensional asset information by integrating data from existing IT/OT systems. The asset information can be drawings, 3D model, book value, maintenance cost, thermal limits calculations, replacement value, training material, inspection and tests results, inventory changes, condition assessment, asset health index, alarms and statistics.

As it can be seen in Figure 4. the system architecture of utilities today includes a multitude of systems such as: Geographical Information System (GIS), BIM (3D models), SCADA, Historian, Enterprise Resource Planning (ERP), Enterprise Asset Management system (EAM) and an Asset Investment Planning system (AIP).

Each one of these systems has a specific focus and will support different roles within the organization. Only through data exchange between each one of these systems and the AIMS, can the asset manager really access a fully deployed digital twin using the latest information.

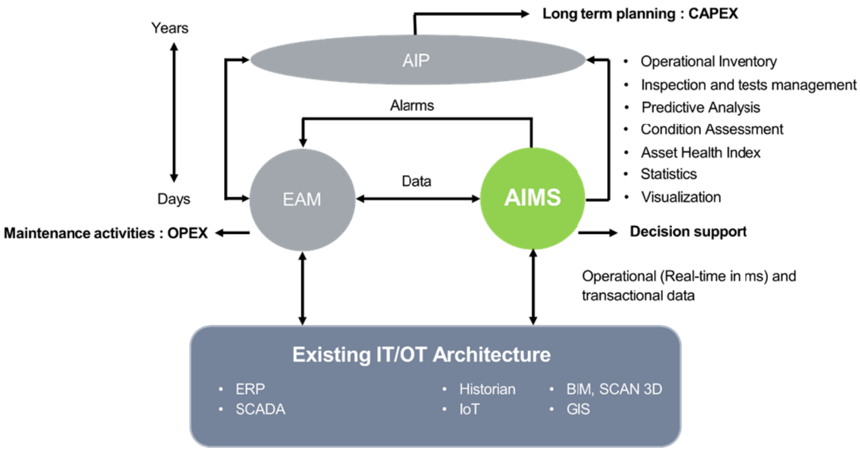

Figure 4: IT/OT Systems AIMS integration

Both Tactical and Strategic

The AIMS must be a real-time system which allows all information sources to be leveraged in order to support decision making. It becomes what is referred to as the single source of truth for asset information and it supports not only the CAPEX but also the OPEX optimization. As such, an AIMS has the ability to manage assets operational inventory down to the components level, asset models, associated degradation algorithms, AHI calculations and generate alarms and statistics. Figure 5 shows the AIMS information sources and functionalities.

Through such a system, the asset manager is able to decompose major asset classes such a transformer and obtain information at the composite and at the component level such that he can understand directly how the asset and its components are performing. Figure 6, is a screen capture from the AIMS developed by Hexacode Solutions which shows a Condition Assessment, an AHI and Alarms for a power transformer at the composite level by considering its individual components, statistical degradation methods as well as condition assessment information which may come from inspection or internal OT systems such as probes or digital gas analyser. The system allows the coexistence of several degradation calculations for the same component in order to identify which one is the most accurate. The individual components of the power transformer such as bushings, tap changer, radiators have their own analysis done in the same way.

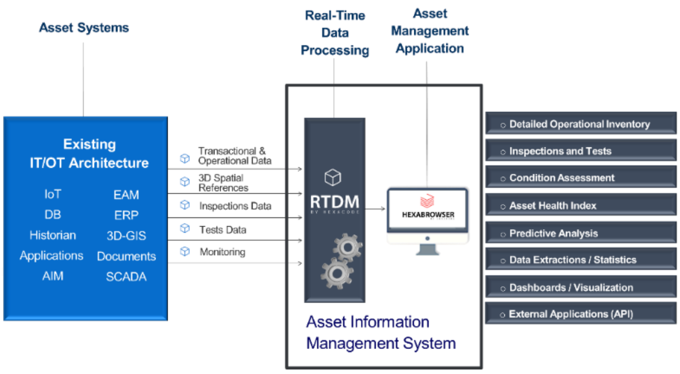

Figure 5: AIMS information sources and functionalities

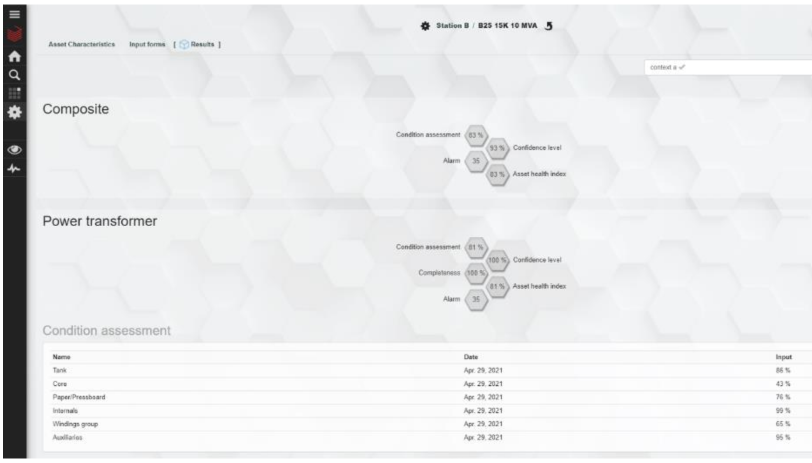

Figure 6: Composite CA, AHI and components scores

On its own the composite AHI provides a global appreciation of the condition of an asset. As such, it serves as an input for capital planning since there is a correlation between the AHI and the probability of failure. The access to components scores brings a wealth of information about the source of a problem without having to ask experts to review the inspections and tests data. It provides the asset manager a clear picture about the condition of the asset and a means to optimize the lifecycle decisions. In addition, the calculation of an alarm score provides the severity of the issues associated to the assets. In fact, an asset with an AHI of 80% may have several issues at the component level that necessitate immediate attention. The system is designed to generate alarms for each inspection element and test performed based on thresholds that are model specific.

The AIMS supports risk-based decisions by providing the latest composite AHI and alarms scores through its API. The visualization module allows both the tactical and strategic analysis by models through the use of filters and dashboards. The system also provides statistics of the entire network CA and AHI at various date and time. It can also be specific to a particular model. The Figure 7 shows the visualization with Google Maps and the associated dashboards.

Figure 7: Visualization of Alarms, Condition Assessment (CA) and AHI using Google Maps

The AIMS helps the asset manager understand where resources are needed and how to reduce risks in the short and medium term.

Strategic planning

It would be thought that strategic planning should be done before tactical planning. This is right, only once an AIMS is ready to pass the right information to the AIP system. To obtain a digital twin of one's network, the AIMS needs to be implemented, and the degradation algorithms and real-world data need to be integrated. Without such implementation, the AIP may render false positives or negatives, which can cause issues in the long run.

The AIP needs to be fined tuned into looking at long term investments and long-term asset degradation. As such, a platform using stochastic analysis needs to be implemented which will allow the asset manager to run different scenarios around risk, financial and manpower availability over a long term. Through such a system, the asset manager can then plan under a different set of constraints, to find its optimal solution. Depending on the risk, availability of Capex/Opex, availability of workforce, the asset manager can plan accordingly and devise a long-term strategy starting on day one. The analysis must be combinatory, which means that the decision making must be based on the parameters inputted and with the asset's conditions will driving the decision.

This approach will give the asset manager a good understanding of the resources required to meet its goals considering the risks identified. It will support the preparation of a rate case and allow him to defend his needs. In any case the asset manager will understand the consequences of the decisions taken today on future risks/investments.

Through the AIMS and the AIP, the asset manager will have access to a digital twin of not only how its grid is today, but it will model how the grid could evolve in the future. It is only at that moment that portfolio management becomes effective.

An AIP solution that uses stochastic-combinatorial simulations, is optimal to evolve individual asset attributes, asset by asset, to determine the optimal policy (e.g., maintenance plan, replacement plan, etc.) to be implemented. Constraints such as budget, capacity, manpower, etc. –are included in the model to produce real and applicable investment plans, in an open modeling platform. The present value of decisions taken in the future (based on the occurrence of intervention triggers) are calculated to find the most feasible and profitable options

Figure 8 is a screen capture from an AIP Solution (DIREXYON), which shows a number a financial and risk indicators under different investment scenarios. This allows the Asset Manager to evaluate which investment scenario is the most appropriate for a specific risk-tolerance/service-level determined by his or her organization.

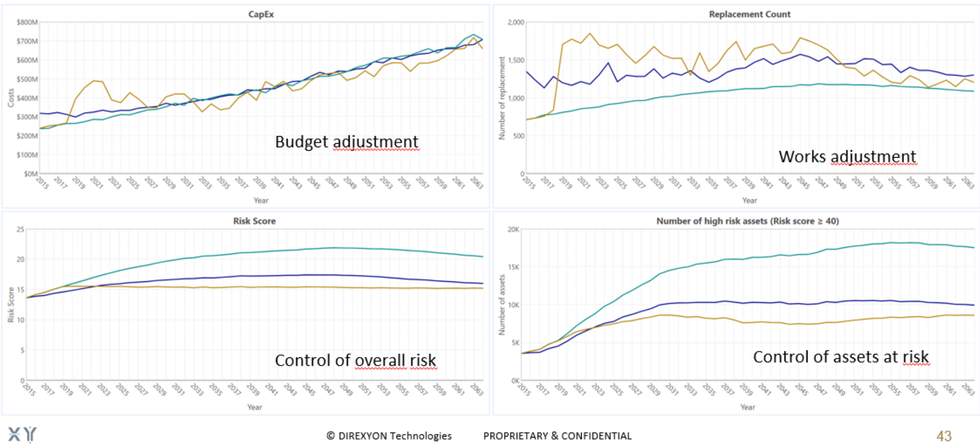

Figure 8: Visualization of CAPEX, Risk Score, Replacement Count and High- Risk Assets under different investment scenarios

Portfolio Management

Often utilities do only portfolio management where projects are placed in competition with one another and through all sorts of different decision mechanisms. A deciding committee or person will decide which projects will go through within a single year. Without using the AIMS and the AIP, unfortunately it may become difficult to choose correctly which projects should be bundled and pushed through. Sometimes low risk projects can be included with higher risk projects as they are co-dependent. It can be very difficult to make decisions when you are only working with project lists and individual risk matrices.

The portfolio management software needs to be well integrated with the AIMS and AIP, as it will use the inputs from the two previous systems to judge which projects should or should not go through. This will allow for a risk management profile which is better suited to reality and business objectives.

Conclusion

A digital twins enable utilities to make decision based on the latest information. The 3D representation is only one aspect of the digital twin. In fact, the foundation for a digital twin is a system that can dissect assets to a level of granularity allowing for the integration of component specific calculations and information.

Digital twins are already being used in other infrastructure industries. In the case of infrastructure information modeling (BIM), new standards such as the ISO-19650 are being developed, one of which covers the operations phase of the lifecycle (7D phase). The 7D phase is the integration of engineering and construction information (Project Information Model) to the operations phase (Asset Information Model) with the integration to existing IT/OT systems. This approach is based on ISO 55000 asset management standards and it can be integrated by the utilities for existing and greenfield infrastructures.

Although the quantity of data and the data quality may not always be perfect; through continuous improvement processes and the right systems, utilities have access today to digital twins' technologies that enable design, operations, and lifecycle optimization. Digital Twins also support asset life extension, while managing risks in a sustainable way, enabling the utility to reduce its CAPEX and OPEX spending while avoiding a reliability death spiral.

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