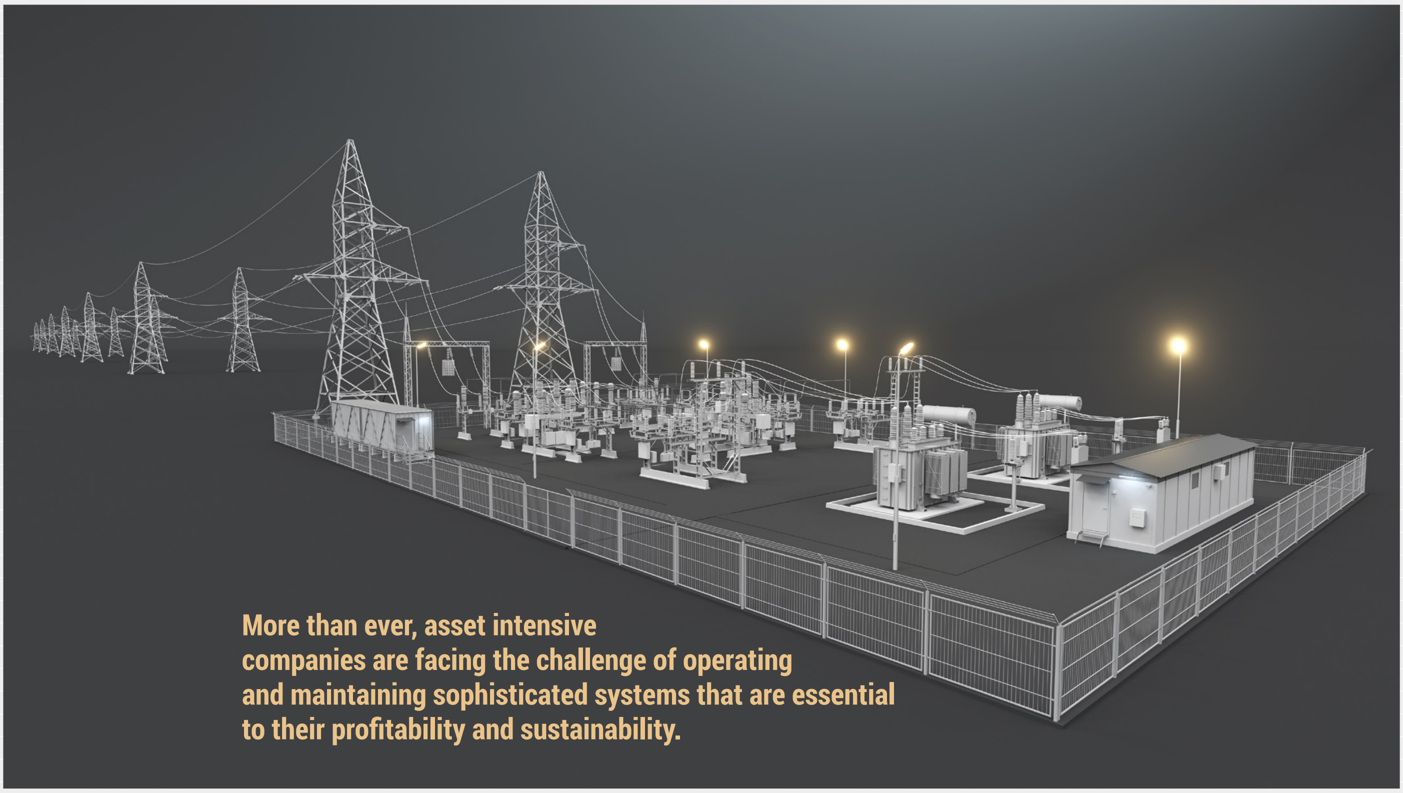
Digital Twins | Applied to Power Grids

HEXACODE SOLUTIONS



All new infrastructure projects today are delivered using Building Information Modeling (BIM). The challenge for most organizations is to find ways to take advantage of data and information generated during design and construction to optimize operations during the lifecycle of the assets involved. This implies defining, before design activities are taking place, which information needs to be supplied in the 3D models to support both commissioning and operations activities.

More than ever, asset intensive companies are facing the challenge of operating and maintaining sophisticated systems that are essential to their profitability and sustainability. Electrical utilities are dealing with supply chain problems due to high energy demands and assets nearing or exceeding design life. The integration of distributed energy resources adds a new level of complexity. Utilities also have to manage an aging workforce which brings a knowledge gap difficult to solve.

In order to respond to these challenges, today's asset management systems are evolving towards condition-based, predictive, and prescriptive solutions. We are also witnessing the emergence of Artificial Intelligence solutions that will ultimately enable us to better anticipate failures. The evaluation of the condition of assets and components require the deployment of Asset Performance Management (APM) solutions capable of dissecting assets down to their most significant components. This detailed (component level) inventory is not only essential for condition assessment and predictive analytics, but also for the application of Artificial Intelligence/Machine Learning algorithms. The level of detail in the 3D model used during the design and construction phases has to be determined with these requirements in mind.

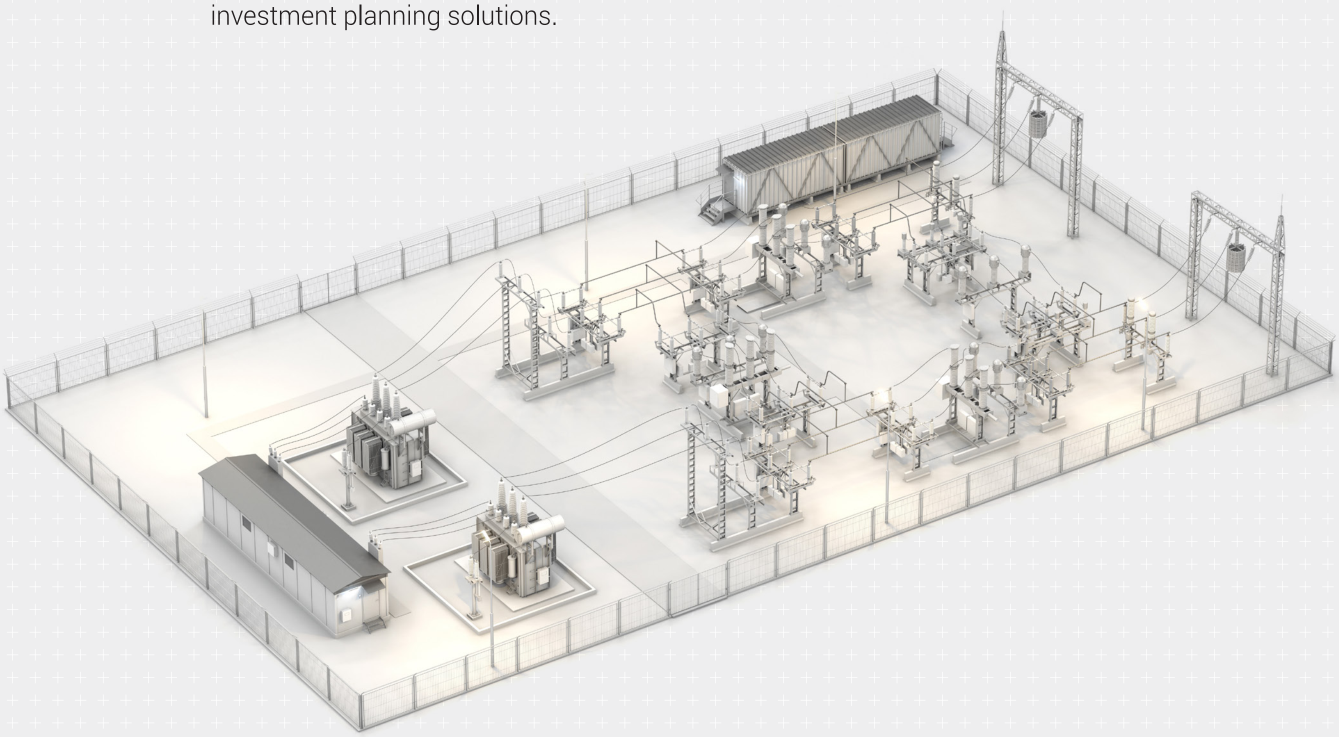
Solutions provided by many technology suppliers meet the accepted definition of a digital twin, e.g., a digital representation of an intended or actual real-world physical product. The word intended refers to the design and construction/manufacturing. The word actual refers to assets in operations. Digital twins in the design phase include activities such as digital simulation, computer-aided design, clash detection, work sequences, and stress analysis.

Digital Twins in the operations phase have various value propositions. For instance, one proposition could be to deliver dynamic rating of a power transformer taking into account the thermal model of the transformer, load forecast, and expected environmental changes such as temperature and wind.

There are three types of digital twins:

- Digital Twin Prototype (DTP): designs, analyses, and processes to realize a physical asset.
- Digital Twin Instance (DTI): digital representation of an individual process or asset.
- Digital Twin Aggregate (DTA): asset or system data and information for prognostics, performance analyses, and learning.

We will focus on applying a DTA in the form of a next generation Asset Performance Management (APM) solution that extends assets and components life by applying degradation algorithms at the component level. We will cover some important elements in creating digital twins such as level of details, integration with existing IT/OT systems, scalability, component level analysis and integration with asset investment planning solutions.



3D model and Level of Details

As we saw earlier, the DTA collects data and information generated during the design and construction phases. The use case we are presenting here requires a level of detail that allows the identification of the main components and sub-components. As this level of detail is not required for the design stage, the 3D models used for design and construction do not normally include this information. It is also important to consider that a higher level of detail also leads to a significant increase in the 3D model file size, making it difficult to manipulate during design, construction and operations. The detailed information is normally supplied by manufacturers documentation (instruction manuals, drawings, 3D models) and integrated directly in the models hosted in the APM. These detailed models also apply to assets that were commissioned before 3D models were in use.

Photo: Hexacode

In order to apply both simple and complex degradation algorithms to a large number of assets and components, the introduction of asset and component models in the APM is essential. These models can be generic or specific to a manufacturer. They contain the basic characteristics used to specify the asset or component, and to select the proper condition assessment and predictive analysis calculations. Each asset and component in the APM inventory are linked to a model. Information such as asset location, loading, environment, usage, performance is then captured in the APM by integrating with existing IT/OT systems. The APM detailed inventory allows to dissect assets down to the component level and to follow changes during the entire lifecycle.

Building Information Modeling (BIM) has different levels:

- BIM 3D = Geometry
- BIM 4D = Time
- BIM 5D = Cost
- BIM 6D = Sustainability
- BIM 7D = Operations

The APM use case that we are presenting is BIM 7D+ (the plus sign means real-time). This APM supports the integration of artificial intelligence algorithms at the component level. It can host the AI/ML algorithms or integrate the results. In fact, the APM can have the AI/ML coexist with its knowledge-based algorithms. Another important element to consider is that components of an asset can be replaced over time which has a positive impact on the overall condition of the asset. A digital twin has to be able to track these changes during the entire lifecycle. This is enabled by introducing the concept of component commissioning and the use of an event driven database.

APM Integration with Existing IT/OT systems

Accessing, validating and updating various data sources is a costly process, replete with inefficiencies. Information generally originates from different business units, IT and OT systems. The source of information can either be 3D models, GIS, Excel spreadsheets, EAM/CMMS, SCADA, ERP, Historian, databases or probes. The integration can be done through scripts, API, protocols or data extractions. The APM extracts or host information and data that are essential to perform condition assessment, and predictive analysis calculations and support decision making. The APM also incorporates data va-lidation capabilities and share results in a bidirectional way with IT/OT systems.

In critical infrastructures the need for real-time calculation capabilities for an APM is mostly associated with degradation mechanism such as vibrations. To capture these events time stamps of 1 ms are necessary. For most of the other parameters, the APM has to be able to integrate them either through probes, test instruments or visual inspections in order to perform interpretations and calculations. The APM also needs to be able to send alarms if one parameter is out of a prescribed range (including those collected through visual inspections).

Scalability

When dealing with electrical utilities, the number of assets is staggering. Utilities must deal with station equipment (power transformers, circuit breakers, inductances, and switches) and cover millions of transmission and distribution assets (power lines, poles, distribution transformers, underground cables, and lines) of various costs and criticality. Most of the APM in the market today are derived from existing EAM designed for industrial applications where the number of assets and components rarely exceed 10,000. When managing millions of assets, these APM technologies may encounter performance issues (user interface responsiveness, calculation speed, time stamps, level of detail).

Importance of Condition Assessment at the asset and component levels

If properly implemented, condition-based asset management brings vital information for OPEX and CAPEX optimization that asset monitoring cannot deliver alone. If a system monitors each important parameter of an asset or component but doesn't provide condition score 0-100% based on the state of degradation of these components, setting priorities on maintenance activities or capital planning decisions becomes extremely time consuming or impossible because of the number of assets involved. If you add the complexity of determining the impact of failures in order to evaluate risks, decisions makers have to rely on accurate condition assessment information, not just degradation curves.

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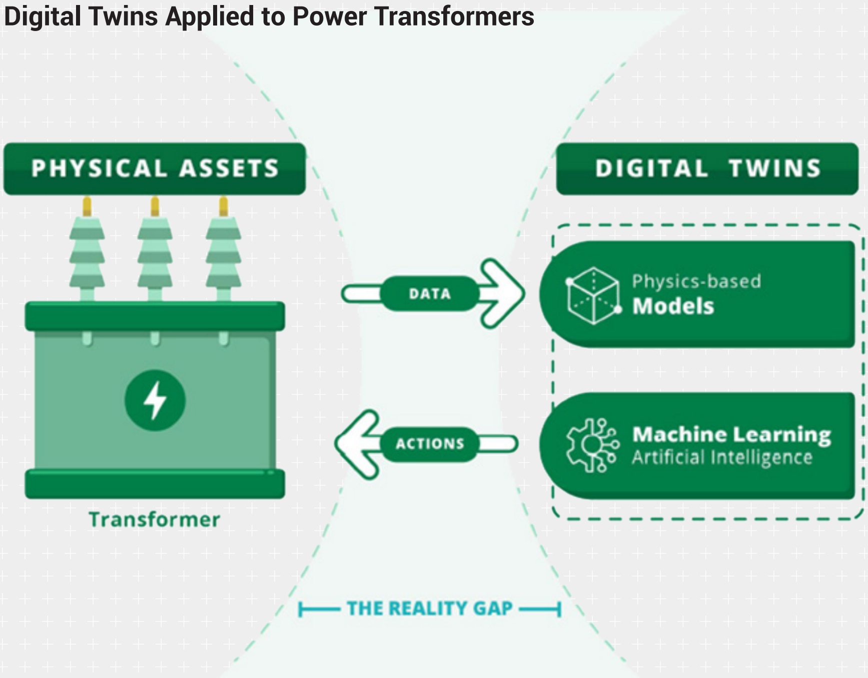
The APM must also be able to go back in history to access inventory changes down to each descriptive field and also for inspections and tests results and statistics at the model level. This functionality enables management to gather information on which changes have been made to assets and how the condition of specific asset model has evolved between two specific dates.

Integration with Asset Investment Planning solutions

Asset Investment Planning (AIP) software solutions are providing mid to long term investment scenarios based on statistics and available asset data. These systems use degradation curves that rely on statistics as well as criticality, financial information and business objectives. In order to improve the accuracy of the overall investment planning process, several infrastructure owners now require that the investment scenarios be based on condition assessments derived directly from inspections and tests. This is where component and asset level condition results combined with predictive and prescriptive analysis can make a huge difference by providing the latest and most accurate asset information to the existing AIP. A scalable APM that assesses assets and their components, takes available asset information for OPEX and CAPEX optimization to another level.

Digital Twins Applied to Power Transformers



Source: CIGRE JWG Proposal:
Transformer Digital Twin – concept and future perspectives, February 16th 2022.

Photo: Hexacode

A new CIGRE working group was created to evaluate the functional behaviors of power transformers in real-time, to understand the 'reality gap' and to integrate digital twins in utilities operations and maintenance systems. This working group, which takes into consideration the knowledge-based and machine learning approaches, will lead to a better understanding of complex assets. This confirms the soundness of our design allowing the two approaches to coexist at the component level.

In light of the recent developments in the digital twin field, and in phase with CIGRE's initiatives, HEXACODE proposes an innovative APM solution that solves both scalability and complexity issues associated with electrical utilities assets.

Hexacode's Digital Twin allows the use of complex degradation algorithms to generate at the asset and component levels, the Condition Assessment (CA), the Asset Health Index (AHI), and predictive analysis.

HEXACODE Solution

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HEXACODE's APM main characteristics:

- Allows information gathering from various IT/OT sources.
- Generates an operational inventory and provide links to photos, documents, drawings, 3D, GIS, and URLs relative to specific assets or components.
- Generates predictive analysis (alerts, warnings, notifications).
- Multilingual.

Key Differentiators:

- Tracks inventory and asset description changes at any given date.
- Manages inspections and tests data specific to asset and component models.
- Isolates any sub-component and calculates in real-time the Condition Assessment, the Asset Health Index and Alarms (based on its specific degradation mode).
- Time stamp of 1 ms.
- Allows the coexistence of multiple calculations based on different methodologies.
- Creates relations between assets (i.e., identify isolating points/sources in systems).
- Capability to generate diagnostics and prescriptive analysis at the component level.
- Provides real-time dashboards for asset status visualization integrating Geohash with Google Maps, and Leaflet maps.
- Offer an ultra-responsive user interface (< 500 ms).
- Generates real-time and historical statistics for assets models and categories.
- Manages offline inventory modifications, inspections and tests.
- Manages millions of assets and components on-premise or in the Cloud (25 million objects per server).

Conclusion

Altogether, the HEXACODE solution delivers accurate data at the component and asset levels in order to generate meaningful insights for OPEX and CAPEX optimization. This information is critical for today's asset intensive businesses. HEXACODE's APM is differentiated by an advanced Condition Assessment and Asset Health Index methodology applied at the level of components.

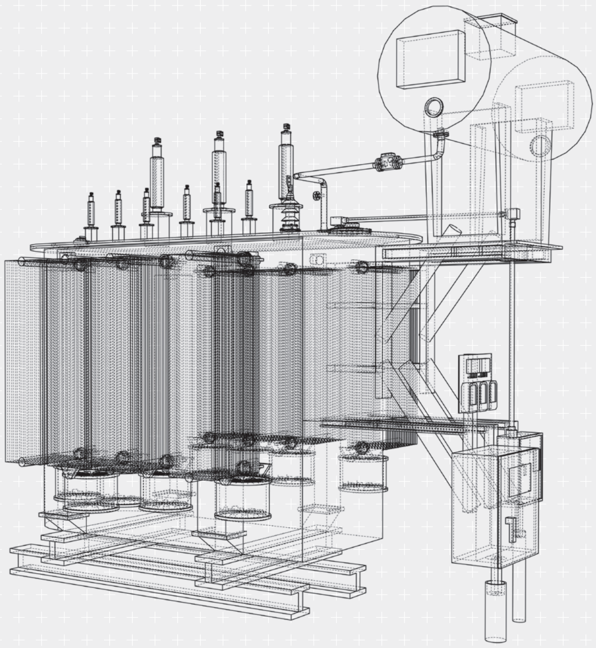
Hexacode's Digital Twin allows the use of complex degradation algorithms to generate at the asset and component levels, the Condition Assessment (CA), the Asset Health Index (AHI), and predictive analysis. It can use/create/adapt degradation models from various sources (normative, state of the art, scientific, and customer expertise), consequently allowing collaboration and partnerships. Also, several algorithms' calculations can coexist for the same component in real time, allowing the selection of the most accurate degradation interpretations.

Hexacode's APM can be applied to any electrical, mechanical or civil assets, including assets that where not modeled using 3D. The deployment of the functionalities can encompass all assets or only the critical ones. It can also be applied to industrial processes and other critical infrastructures including rail transportation, data centers, telecommunications, airports. The existing IT/OT architecture remains the same and the APM extracts or host the asset information under a single easy to use mobile interface.

Condition assessment, predictive and prescriptive analysis support sustainability objectives by extending assets life while managing risk and are positively impacting today's most pressing asset management challenges.

Jean-Pierre Girard, has over 35 years of experience in the electronic and electrical equipment field, with management responsibilities in application engineering, service, product safety, process improvement, quality management, and electronic business. He has acquired expertise in asset management applied to critical infrastructures and has been a speaker on this subject internationally. He worked at Siemens for 22 years and held several management positions. From 2001 to 2008, Mr. Girard was Executive Director responsible for Hydro-Québec and SNC-Lavalin, representing all Siemens business units. Mr. Girard was a member of the Board of Directors of the Quebec Electrical Industry Association. He has been involved internationally on numerous business committees and company-wide transformation initiatives. He is the founder of HEXACODE Solutions. (jpgirard@hexacode.ca)

Photo: Hexacode



Bibliography

[1] ISO 19650-2:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets
[2] ISO 19650-3:2021: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 3: Operational phase of the assets,
[3] An innovative approach: Digital asset management for rail systems. 05.2021, Siemens Mobility GmbH Authors: Dieter Barnard, Roland Brill, Ekkehard Toensing
[4] CIGRE JWG Proposal: Transformer Digital Twin – concept and future perspectives, February 16th 2022.