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Part 2

Digital Twins: Details Of Implementation

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Digital twins in the built environment are digital representations of real-world infrastructure using building information modeling (BIM) software. Applying these tools in a disciplined manner can help solve for elusive answers sought by building owners and operators pertaining to efficiency and optimization of capital, operations, change management, resiliency and much more.

In Part 1 of this article (August 2020 issue of *ASHRAE Journal*), several different use cases were introduced that helped answer the questions of “when” and “why” to use the digital twin application. Once the hard work of when and why have been determined, the equally challenging process of implementation can be explored in further detail.

The implementation process involves evaluation of variables that will have a larger impact on deployment efforts as well as the life cycle of information technology (IT) assets. For example, we’ll answer questions related to the necessity of a homogeneous hardware environment and whether limitations exist to the HVAC solutions that can be modeled.

In Part 2, the focus will be “how” to implement a digital twin, validating the results and putting those results to work. This article will also explore the idea of using real-time calibration as a method of reducing the ongoing life-cycle costs to maintain a digital twin once deployed.

Digital Twin Baselineing

As discussed in Part 1, use cases define the rationale for deploying a digital twin within the built environment by answering some of critical business-case questions. Use cases must define both the reasons for deploying this new technology as well as provide reliable metrics to demonstrate the return on investment (ROI). Without this supporting data, stakeholders are often paralyzed because investment in digital twins (or any integrated software solution) is rarely cost justifiable based on capital expense (CapEx) alone.

The baselineing process begins with surveying efforts of the data center and includes the following elements:

- Built environment data
 - Envelope configuration/dimensional data, materials of construction, thermal properties;
- Supporting infrastructures
 - Power and cooling (HVAC systems, airflow configuration, equipment deployment); and
- Information technology equipment hardware

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- Types/uses (volume servers, storage, blades, HPC, etc.)
- Rack type/form factor, rack population density, equipment types/quantities, information technology equipment (ITE) heat transfer data, ITE deployment (localized high density, uniform density, etc.).

During the baselining efforts, a detailed survey of the site is required to ascertain dimensional data and configuration of the environment, system topologies and components that must be modeled. The level of detail to which each of these must be modeled will vary depending on a host of factors such as:

- Type of modeling tool;
- Defined use cases; and
- Budget constraints (time and cost).

The most difficult aspect of any baselining effort is obtaining the necessary performance details of the IT equipment. The amount of variability in each generation of IT hardware can often be counted in dozens of versions. Another factor greatly impacting the baselining efforts is the degree to which deployment symmetry of ITE across the modeled space can be applied. Where greater symmetry exists, the effort of baselining and modeling becomes less challenging.

In short, the baselining effort is a data gathering exercise that involves the assembly of granular details on systems, equipment and configurations necessary to create a digital model for the purposes of computer-aided simulations. If this baselining effort is not performed properly and to the necessary level of detail, it may yield oversimplified and largely unusable results.

Digital Twin Modeling

Once the baselining exercise has been completed, the predictive model can be constructed. In a manner similar to the baseline development, the modeling process will focus on data inputs, which create an accurate model of the systems to be analyzed. Major activities undertaken will include:

- Tools/software selection;
- Identifying ITE deployment symmetry/boundaries;
- Determining calculation mesh size (balancing component modeling accuracy vs. calculation duration);
- Establishing boundary conditions
- Fluid boundary conditions

- Areas of airflows, velocity profiles, etc.
- Temperature boundary conditions;
- Physical boundary conditions
 - Properties of materials;
- Environmental specifications
 - ASHRAE Thermal Guidelines Recommended & Allowable AI – A4
 - End user-specific service level agreement (SLA);
- System information
 - HVAC equipment manufacturer, model, type, arrangement/spacing, quantity (N), capacity, perforated tile arrangement/type
 - Heat transfer mediums (DX, CHW, direct immersion, etc.)
 - Heat transfer pathways (raised floors, flooded room, hot aisle capture, rack-based cooling, etc.; and
- Operational modes
 - Day-1 vs. ultimate ITE deployment
 - Redundancy ($N+?$), failure scenario planning
 - Thermal ride-through requirements.

Gathering sufficiently accurate data can be a daunting exercise as gaps in information can, and often do, lead to creating a fundamentally flawed model. It is critical to engage with the entire spectrum of stakeholders to obtain the most complete data set possible. Potential sources of information may often include groups such as purchasing, R&D, data center operations, equipment manufacturers and service vendors.

Where necessary modeling information is vague, misleading or unavailable, validated assumptions using industry standard performance values, metrics and representative data is the necessary alternative. Software products that dominate the digital twin space are configured with regularly updated, preestablished databases of IT equipment, system configurations and related data that can be used to supplement the modeling data set. Where database information corresponds closely with planned or in-situ deployments, modeling accuracy and integrity can be continuously maintained.

However, when equipment information or validation is less concrete, the modeling exercise begins to deviate from science to art. It is in this area that modeling experience, real-time monitoring of system variables and a feedback mechanism for model calibration become necessary to ensure creation of a dynamic digital twin.

Digital Twin Modeling (IT Hardware)

For the data center environment, digital twins take on additional importance by providing improved alignment between ITE and HVAC infrastructure rate of change mismatches. IT refreshes (updates) occur at a significantly faster pace and frequency than changes to the data center's power and cooling infrastructure. This mismatch in the rate-of-change often creates disparities between the HVAC system's ability to efficiently meet the requirements for the IT loads. This mismatch can take the following forms:

- Underprovisioning
 - Insufficient cooling capacity
 - Insufficient cooling airflow; and
- Overprovisioning
 - Too much cooling capacity for the load
 - Too much airflow for the load.

Typical data centers are provisioned with ideal assumptions for power, cooling capacity, HVAC airflows, predetermined ΔT s at equipment and ITE assumptions for the deployment of the IT load across the space. As IT adds, moves and changes over the years, those ideal assumptions become inaccurate predictors of actual space loads, often leading to surprises in underprovisioned cooling. In the worst of cases, these can manifest themselves in the form of one or more of the following:

- Uncomfortable working environments in portions of the data center;
- Underperforming HVAC systems (mismatch on ΔT s, etc.);
- Failed HVAC systems (excessively high return air temperatures, going outside control or SLA settings, etc.);
- Underperforming IT systems (reduced processor clock speeds [performance] due to elevated temperatures); and
- IT equipment failures.

Rarely do the original design engineers have visibility into the evolving changes within the IT environment of a given data center. Usually, it is not until a failure or critical limitation has been encountered does the engineer receive a call to "review the problems that recently emerged." A digital twin can and often does identify these problems before they inconveniently manifest themselves.

Conversely, overprovisioning leads to stranded capacity, operational inefficiency (high PUEs and inefficient

energy use) and unnecessary Day 1 CapEx. While typically not as devastating as underprovisioning scenarios, overprovisioning can lead to poor utilizations on power and cooling systems, which result in inefficient part-load conditions.

All HVAC equipment and systems have different ideal efficiency points within their operating envelopes. As loads shift throughout the data center (different areas of varying IT densities, changing load profiles, etc.), the HVAC systems can often be operating at a point that was not foreseen or modeled during design or commissioning. In the worst-case scenario, overprovisioning can lead to HVAC equipment failures if the control systems and equipment safeties are not commissioned to permit such extreme part-load operations. This can occur most often when experiencing rapid changes in ambient environmental conditions, particularly on systems using economizers.

Digital Twin Calibration

Like all representative models, digital twins require calibration to provide reliable output. Calibration is the process by which real-world operating conditions and scenarios are confirmed within the digital model as part of a feedback loop.

Calibration of thermal models has historically been completed in a very manual fashion using field measurements (temperatures, humidity, etc.) and serial tweaking of the model to match operating scenarios and data trends.

Recently, however, technologies have advanced to permit a more automated means of calibration through the integration of real-time sensors that are continuously fed into the digital model. Wireless sensors now can accomplish calibration efforts with greater cost effectiveness than those in which only wired sensors used to exist. Because the quantity and location of wired sensors within a data center was prohibitively expensive, they were rarely used for this purpose. Today's wireless sensor offers compact form factors, long battery life options and a high degree of accuracy, which means deploying real-time calibration tools are possible.

Whether a manual or automated method of calibration is used, the digital twin must be continuously maintained and validated to represent the real-world

conditions within the data center. This is a fundamental precept if the viability of preestablished use cases is to be realized. Ultimately the cost of the calibration efforts must be considered as part of the ROI of the digital twin.

Digital Twin Ongoing Commissioning

Digital twins are functional beyond the “what if” modeling scenarios, particularly when considering real-time calibration methods. Digital twins can serve as ongoing commissioning tools to fine-tune and update a data center’s control system and HVAC over the life of operations as well.

Changes in IT loads often necessitate changes in the HVAC and control system settings and sequences of operations. The necessity of these updates is frequently ignored until some failure mode occurs or an audit is conducted.

Today’s commissioning processes are largely manual and are typically initiated when major changes to

infrastructure occur, such as power or cooling system changes. However, rarely is the commissioning process initiated by major changes to IT infrastructure alone. Examples where IT activities should initiate the commissioning process may include:

- IT hardware additions or removals;
- IT hardware relocations;
- IT hardware density changes;
- IT software modifications (higher CPU utilizations, etc.); and
- IT software modifications (change of software on the servers, etc.).

The above changes can have profound implications on the loads profile or density distribution within a data center and could go completely unnoticed without a tool that continuously monitors these trends. Typical control systems are reactionary to modifications in the system operations, not predictive. Even with artificial intelligence of control systems data sets, the results are historical trend analysis of what has occurred, not

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predictive of what will occur given major changes to the IT infrastructure.

Digital twins offer the unique ability to perform a vital role in predictive and ongoing commissioning of rapidly changing data center environments. IT infrastructure changes much faster than its brick-and-mortar counterparts of HVAC and power infrastructure. As noted, often those IT changes occur without changes to the HVAC and power infrastructure.

Further, IT changes can occur at the software layer and not even include a physical and visible change to IT hardware. Such changes can still have a profound change on load densities, load profiles and load distribution within the data center. These “invisible” changes can often materially impact the efficient operations of HVAC and control systems managing the cooling of the data center.

Last, a means of ongoing commissioning can serve a benefit in the current COVID-19 environment. Travel restrictions, recommended reductions in occupancy

and an increasingly remote workforce provide a natural benefit to deployment of a virtual environment with off-site management capabilities for digital infrastructure. The digital twin provides an invaluable virtual environment, which enables continued analysis and operations of built infrastructure without the need for having a physical presence on site.

Closing Comments

Digital twins offer the ability to incorporate a new world of predictive data center management through modeling of real-world environmental conditions, operational parameters and continuous ITE change.

Through diligent baselining efforts, a reliable model of the data center environment can be created by cataloging data from deployed ITE, existing building infrastructure and in-situ power and cooling equipment. Right-sizing the modeling efforts requires appropriately ranged boundary conditions, mesh densities and modeling assumptions to create a tool with the necessary level of detail to model “what if” scenarios that are commonly expected.

Calibration of the digital twin is a necessary and ongoing activity for realizing the full opportunity potential of the changing data center environment. While manual methods are the current industry norm, automated data collection using wireless sensor technology is now available to provide real-time data integration methods.

Finally, digital twins can be used as a method of ongoing commissioning for monitoring the data center environment. Models can be used to calibrate and validate the operation of building control systems and HVAC settings throughout various changes to IT and any optimization efforts related to energy efficiency.

Ultimately, many businesses still operate with legacy change-management policies, sluggish data collection approaches, and uncoordinated decision-making processes. In an increasingly changing world, digital twins are arguably becoming more of a necessity as they enable rapid decision-making and avoiding the surprises of unsupervised change management in IT environments. A well thought out digital twin implementation process can lead to sustained savings and surprise avoidance throughout the life cycle of the data center. ■

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