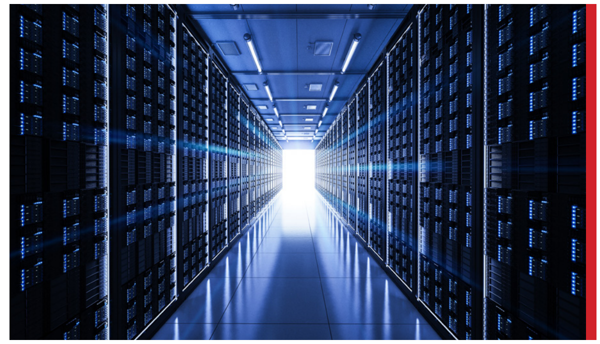
Data Center Design Validation with Simulation



3KEYMASTER™ Simulation Assisted Engineering platform helps engineering teams uncover design issues during the buildout of complex cooling, power, and control systems through a virtual platform

Organization: A global hyperscaler with large data center assets building next-generation infrastructure to support artificial intelligence (AI) and cloud workloads.

Challenge: The client needed to validate the design and control systems of a large data center prior to construction.

Solution: Curtiss-Wright's 3KEYMASTER™ Simulation Assisted Engineering (SAE) platform provided a real-time, SAE-level simulator focused on the main hydraulic and electrical systems.

Results: The engineering team identified and resolved design issues in parallel to construction, reducing risk, avoiding delays in commissioning, and improving operational readiness.

Unique Engineering Challenges Demand Advanced Simulation Solutions

To support the rising demand for artificial intelligence (AI) and cloud services, a global hyperscaler developed a large data center (more than a 100 MWe load) featuring advanced thermal systems, high-density racks, and control infrastructure. With both liquid and air-cooled technologies in play, the facility's complexity required a high-fidelity, two-phase, multimedia thermal hydraulic modeling tool to accurately capture and predict the integrated system's behavior of this facility.

To reduce uncertainty and mitigate late-stage issues, the organization turned to Simulation Assisted Engineering (SAE)—a modern approach to infrastructure validation that replaces late-stage fixes with early-stage insight and discovery. SAE enables real-time testing of mechanical, electrical, and control systems in a unified simulation environment—eliminating surprises during commissioning.

At the core of this effort was Curtiss-Wright's 3KEYMASTER™ platform, a high-fidelity simulation environment originally developed for nuclear power plants. Built in C++ with a drag-and-drop modeling interface, 3KEYMASTER allows engineers to model complex systems, simulate real-world conditions, and iterate rapidly—all without writing custom code.

What Is SAE and Why Does It Matter?

SAE originated in the energy sector to support large-scale upgrades, conversions, and first-of-a-kind projects. It has since become essential in validating the performance and safety of highly integrated systems across industries.

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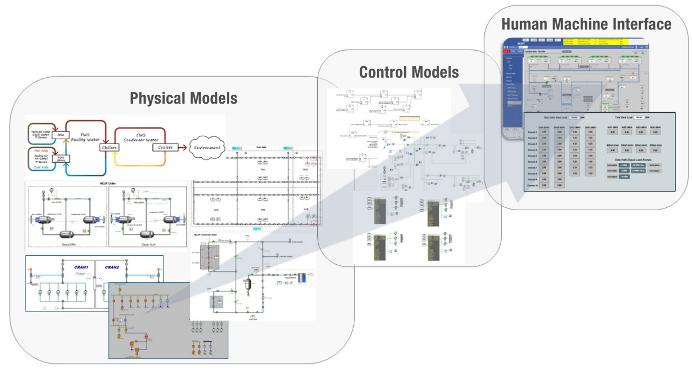
SAE allows engineers to perform virtual commissioning—such as testing startup, shutdown, and failure scenarios—in a controlled environment. From verifying I/O points to tuning control logic systems and validating digital narratives, SAE reduces risk and saves time by catching flaws early.

In this project, SAE enabled the hyperscaler's engineering team to uncover critical design issues before the build phase, avoiding costly change orders and startup delays.



SAE allows teams to verify control logic, test interdependencies, and simulate failure modes before system buildout—transforming the commissioning process from reactive to proactive.

Real-Time, Full-Scope System Modeling

Working closely with the client's engineering team, Curtiss-Wright developed an integrated simulator representing all key plant systems:

- **Facility Water System (FWS):** Circulates chilled water to data halls
- **Technology Cooling System (TCS):** Transfers heat from IT racks via cooling distribution units (CDUs)
- **Condenser Water System (CWS):** Discharges heat via chillers and towers
- **Cooling Air System (CAS):** Delivers conditioned air through fan coil assemblies (FCAs)
- **Computer Room Air Handling and Computer Room Air Conditioning Units (CRAH/CRAC):** Manages airflow, temperature, and humidity
- **Containment Systems:** Maintains thermal efficiency through aisle segregation
- **Electrical Distribution System (EDS):** Includes uninterrupted power supplies (UPSs) and diesel backup
- **Digital Control & Information System (DCIS):** Manages flow, pressure, temperature, and human machine interface (HMI) displays

All components were modeled in an integrated environment, enabling real-time system interaction and feedback. Operators could simulate valve closures, pump trips, setpoint changes, and component failures, and instantly observe cascading effects throughout the simulated digital environment.

Finding Faults Early, Improving Design Continuously

Through iterative testing in the simulator, the engineering team identified and resolved dozens of issues that could have compromised performance, reliability, or safety had they been discovered during physical commissioning. These included:

- Control logic misfires and improper sequencing
- HMI display gaps and missing alarm data
- Communication faults between programmable logic controllers (PLCs) and other types of controllers
- Setpoints and process flows that led to equipment trip conditions

In one case, a chiller pump system reached its flow cap earlier than anticipated, causing extended low-pressure runouts and unstable cooling performance, with pumps unable to increase speed to compensate. The simulator revealed that the flow cap was set too conservatively compared to the pump's actual capability. Engineers used the simulation environment to test an optimized setpoint, validated against the pump's head pressure curve. The adjustment improved system stability, eliminated flow restrictions, and restored consistent cooling performance—achieving a robust solution without physical trial and error.

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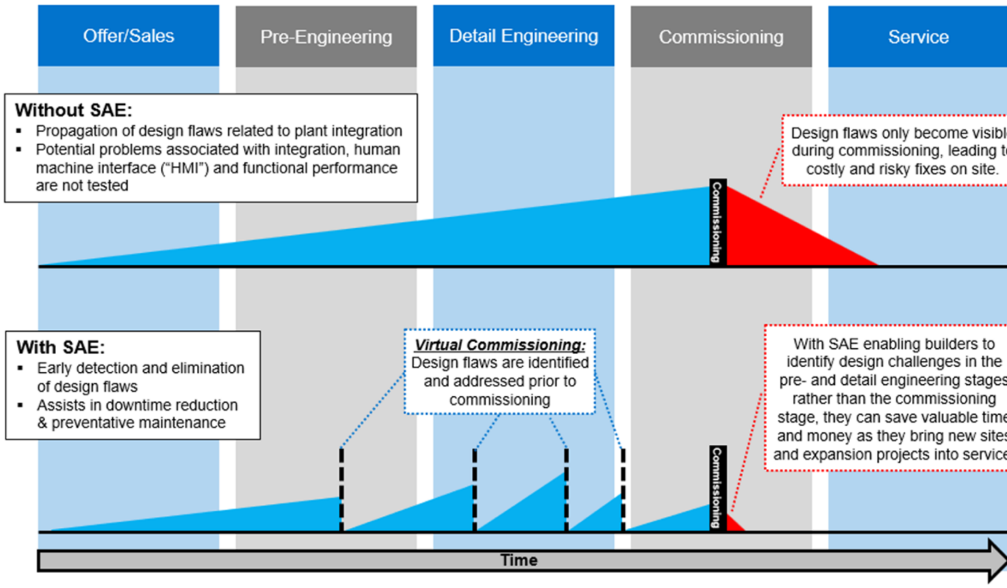


(Left) SAE saves valuable time and expense by uncovering and resolving design issues (including control systems) prior to implementation of actual system.

In another test, the sudden closure of pressure-independent control valves at the cooling distribution units caused a spike in differential pressure, tripping facility water pumps and triggering an unstable staging sequence. Flow rates fell below minimum chiller thresholds even at 100% pump speed, while bypass valves failed to engage in time due to misaligned timers. Thanks to SAE, the team reconfigured stage-down logic, timer settings, and bypass valve behavior—all within the simulator—resulting in a validated fix without hardware risk.

A Living Digital Asset with Lasting Value

Following validation, the simulator became a permanent asset in the client's data center development process. The hyperscaler uses the 3KEYMASTER platform to:

- Develop and validate standard operating procedures (SOPs), maintenance operating procedures (MOPs), and emergency operating procedures (EOPs)
- Train operators using realistic HMI interfaces
- Test "what-if" scenarios and system upgrades
- Inform future data center designs and standardization efforts

The environment also provides a trusted sandbox for testing future upgrades, equipment changes, and operational contingencies.

The client can adjust, retest, and refine its models—maintaining alignment between design, operations, and performance goals.

Looking Ahead: SMRs and the Future of Data Center Power

As AI and digital infrastructure drive energy demand to record highs, many hyperscalers are exploring alternative, co-located power solutions. According to a report by the Boston Consulting Group (BCG), data center energy use in the U.S. is projected to triple from 2.5% of total electricity consumption in 2022 to 7.5% by 2030, stemming from technologies like generative AI[1].

One promising approach involves co-locating Small Modular Reactors (SMRs) to provide reliable, clean, on-site baseload power while minimizing dependency on local grids.

To explore this scenario, Curtiss-Wright has discussed the possibility of integrating a generic SMR plant with the data center model—capturing the interaction between generation, distribution, cooling, and automation in one seamless environment. The integrated model could reveal how on-site nuclear generation could power and cool the facility, complete with electrical distribution, control logic, and thermal flow—all simulated in real-time.

[1]: Demand Growth Offers Opportunities for Data Centers: https://cpowerenergy.com/demand-growth-offers-opportunities-for-data-centers/

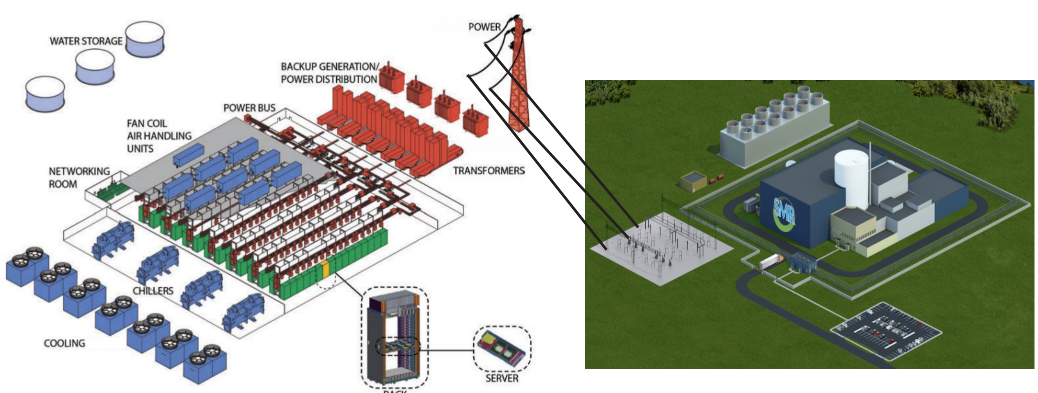
Data Center Design Validation with Simulation

Curtiss-Wright is uniquely positioned to simulate:

- Nuclear/SMR systems and transients
- Data center infrastructure and I&C
- Grid interface and microgrid behavior
- Startup, failure, and islanding scenarios

As interest in co-located SMRs grows, the ability to simulate full microgrid environments gives hyperscalers a strategic advantage in designing next-generation facilities.

SMR + Data Center SAE—Combined Simulation



Simulation of combined SMR and Data Center infrastructure: Curtiss-Wright's 3KEYMASTER environment can model the entire facility—including power generation, distribution, cooling, and digital control systems—in one real-time simulation.

About the Curtiss-Wright Simulation Business Unit

The Curtiss-Wright Simulation Business Unit, part of the Plant Information Monitoring & Control (PIMC) group, operates out of Frederick, Maryland and serves clients worldwide. Since 1995, the business has delivered more than 225 simulation solutions, including critical infrastructure in energy, marine, and industrial markets.

The team provides full-lifecycle simulation services—from system modeling and controls validation to the creation of Standard, Maintenance, and Emergency Operating Procedures that help reduce operational risk.

Curtiss-Wright's commissioning strategy emphasizes real-world failure modes, stress testing, and operator readiness—helping to ensure new facilities launch safely, efficiently, and on schedule.

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