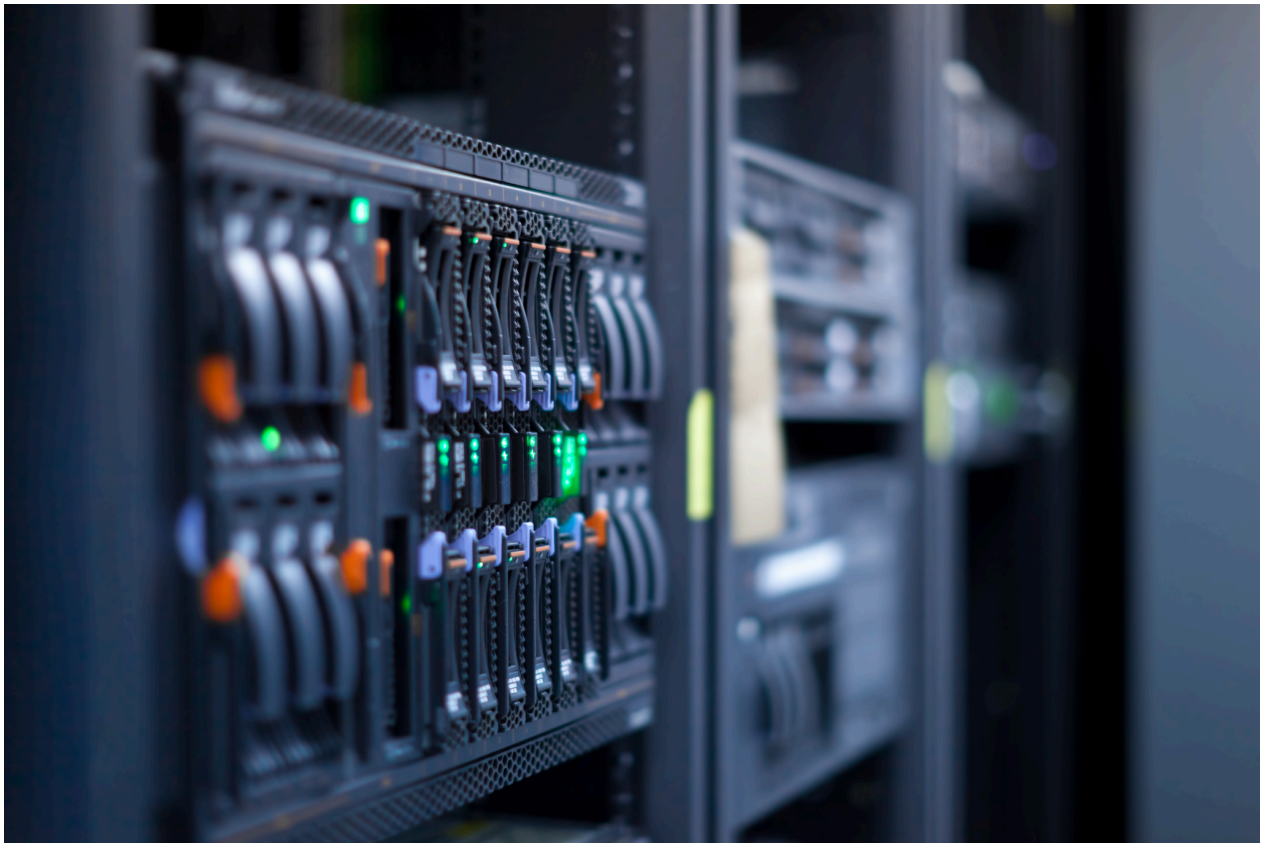
Application Case Study: Continuous Level Control in Data Center Refrigeration



Introduction

This is a fun one, so we'll get right into it. In early 2025, a design/build mechanical contractor reached out to us with a few questions regarding a new big-tech data center's central refrigeration plant they were designing. Their goal was to identify a sensor solution that would help unlock their automation platform's more advanced performance management capabilities. After a quick introduction, the contractor described the application as using ammonia liquid

levels to control cooling tonnage and preempt safety issues using predictive analytics and machine learning software. Say no more, we were in!

About Us

As a veteran-owned small business, Whitman Controls is dedicated to supplying premium quality, reliable, technologically advanced instrumentation for use in nearly any application. Our Bristol, CT manufacturing facility embodies over 40 years of engineering, fabrication, and customer service expertise, serving both end-user and manufacturing customers nationwide through direct and distribution channels.

Application Summary

Modern data centers can perform any number of miracles when it comes to information technology (IT) and digital connectivity, but from a strictly mechanical engineering perspective, data centers are essentially big thermal engines that turn electricity into waste heat. Data centers are large commercial buildings that contain massive quantities of IT equipment (mainly server racks and networking gear), along with the associated utility equipment that powers and cools this equipment. In a nutshell, these servers provide computing capacity for data hosting, processing, and distribution over the internet or private networks.

No matter what purpose a data center serves, all of its servers' CPUs and GPUs (central and graphical processing units, respectively) dispel massive amounts of heat which must be mechanically removed in order for the servers to perform safely and reliably. As data centers grow larger and more power-intensive, cooling becomes increasingly critical and complex – a fact driving development of a whole new generation of mechanical data center cooling technology as we speak.

Challenge

As a Design/Build Mechanical Contractor, our customer had been awarded the HVAC (heating, ventilation, and air conditioning) and Refrigeration scopes on a new data center project being built in the upper Mid-West. The contractor's scope carried full responsibility for the engineering, design, procurement, installation, and commissioning of these packages. In particular, the refrigeration portion of this scope included a complete central refrigeration plant that would serve both the data center's HVAC systems as well as the direct server liquid cooling systems. Not a bad project!

The contractor had selected a flooded ammonia refrigeration system to cover the wide load span expected between the data center's HVAC and technology cooling systems, complete with multiple compressors, central thermal storage, and many other features that provided extreme scalability. When they called us, they were examining the finer details of the system, looking for control options that would achieve two specific goals using Rockwell Automation's FactoryTalk HMI platform and its embedded machine-learning capabilities:

- Maximum Cooling Efficiency – with a refrigeration system this large, sophisticated, and variable, maximizing cooling energy efficiencies were second only to safety. Even a few percentage points of excess power draw would result in incredible energy costs over a year. In addition, under-supplying cooling to the servers by the same few percentage points would impact computing performance and stability, resulting in equally high client costs.

- Safety and Predictive Upset Protection – catching issues before they manifest is a critical operating requirement of ammonia refrigeration systems, and the contractor wanted to gather as much process data as possible that could be used to build a predictive model of the system over time. Ammonia leaks, unsuitable system charge levels, and unideal fluid-to-gas ratios are just a few early indicators of safety issues that the contractor wanted to model against.

Quote

"It seems like such a minor detail overall, but upgrading from point level to continuous level for our receivers makes a huge difference. With these [Whitman L96] sensors, we can adjust charge balance, system pressure, and flood levels all from our HMI on the fly. Everything's been working as expected since we installed, and so we started using the sensors to trend [refrigerant] levels over time so we can fine tune alarms and residuals. It's great!"

- Project Manager, Confidential Design/Build Mechanical Contractor

Solution

Working with the contractor's project engineers, we collectively penciled out a solution that centered around getting them better process data from the refrigeration system via unique instrumentation. Here's how that came together:

- For each refrigeration compressor loop, ammonia refrigerant levels could be monitored directly in the receiver vessels where liquid and vapor streams coexisted.

- The traditional point levels switches used for receiver level monitoring could be replaced with a single analog level transmitter, which would provide continuous measurement of refrigerant levels across the full span of the receiver.

- To make this concept work, an analog sensing technology compatible with ammonia (and other refrigerants) would be needed. We established that capacitance level technology would be the best fit, which safely measures hazardous materials by detecting the varying dielectric constant values between liquid and gas medias.

- By installing a capacitance level transmitter into a standpipe outside of the vessel, we could gain a direct read on liquid level without entering the main receiver body – ideal for maintenance, safety, and stable readings (dampening out vapor boil-off fluctuations occurring in the receiver).

- Once continuous receiver level readings were available, a host of advanced control functions suddenly became available to the refrigeration control platform, including:

    - Multi-stage level control for wide heat load swings, which were frequent in this data center as AI racks and daytime user loads ramped up and down.

- Automated seasonal pressure tunings, scaling running levels instead of the traditional method of physically adding or removing refrigerant charge volume.

- Leak detection, via level trending over time.

- Maintenance and Test-Out Modes, which would temporarily adjust compressor pressures to raise or lower receiver levels for specific test procedures (such as testing control valves and alarm points).

- Additional alarm verification points that would avert common system upsets and auto-shutdowns that stem from single instruments elsewhere in the system.

With these parameters laid out, we brought our review back to the original two challenges at hand. Capacitance analog level monitoring gave the contractor valuable real-time information on how their refrigeration system was running that couldn't be achieved as accurately or economically using other solutions. With this data input, the contractor could tune and optimize their central refrigeration plant's cooling performance down to fractions of a percent. In addition, the contractor could set up many overlapping protection loops and escalating alarm points to ensure maximum system safety. So long as we helped the contractor acquire a continuous level signal from their refrigeration receivers, they could unlock all these options (and more) using their Rockwell Automation FactoryTalk control platform's Predictive Analytics technology.

With the above functionality in mind, we knew just which sensor to recommend: the Whitman Controls' L96 Series Capacitance Continuous Level Transmitter, selected for the below core features.

- Combo Continuous Analog and Relay Switch Outputs
- Analog: Available in 0-5V, 1-5V, 0-10V, and 4-20mA Ranges
- Switch: Available with a SPST Latching Relay, 16A @ 250VAC or 24VDC
- Supply Power 12-65VDC
- Modbus Protocol RS485

- Scalable Output from 0 to 99% of Level
- NPT, BSP, and Flanged Connection Fittings (multiple sizes and specs)
- Stainless Steel Wetted Materials (304/316) with Optional PTFE/PFA/Special Coatings
- Aluminum, Non-Hazardous Transmitter Housing (IP66/68 Rated)
- Probe Lengths from 50mm to 3,000mm
- Operating Temperature Range from -20°C to 100°C (-4°F to 212°F)
- Extended Temperature Range Available from -30°C to 200°C (-22°F to 392°F)
- Operating Pressure up to 300 PSI (max 500 PSI)
- Accuracy +/- 1% of Full Scale Output
- Repeatability >95%
- Resolution 16 Bit Over Span
- Option OLED Digital Display
- ISO 9001 Certified Manufacturing Process

Results

No doubt about it, data center refrigeration systems are a marvel of modern engineering. During installation, our customer sent a few photos of their central refrigeration plant which we can only describe as massive and beautiful, in the way that only square piping and symmetrical industrial equipment rows can be. Not just to have us ogle their installation work, the customer sent the photos to show us how they had installed our L96 level transmitters into the ammonia refrigeration receivers in that compressor room, just like we had planned with their designers. At last check-in, the system had just finished three months of live operation. The contractor confirmed that they were seeing all the expected benefits using continuous level monitoring on the receivers, and that the predictive analytics they were getting were holding energy efficiencies to tighter tolerances than they had estimated themselves. That's a job well done to all involved!

Data Bullets

- 100 kW average server rack cooling load for this data center
- 100% reduction in downtime associated with servicing ammonia receiver level sensors

- 5% actual energy consumption accuracy to predictive model, and improving over time
- 1-2 week's lead time on capacitance level transmitters

Footer

Here at Whitman Controls, our values drive us to provide the highest level of servant partnership that you can find. To discuss your applications or to learn more about our capabilities, please contact us at (800) 233-4401, via email at info@whitmancontrols.com, or online at www.whitmancontrols.com.