

Evolutionary Stages Of Data Center Controls

BY DONALD L. BEATY, P.E., FELLOW ASHRAE; DAVID QUIRK, P.E., MEMBER ASHRAE

The controls industry, in general, has migrated from pneumatics to electronics to direct digital controls (DDC) to Internet Protocol (IP) based controls. Each evolutionary step has also included changes to the communication protocols, programming approaches, and has even changed the primary stakeholders responsible for the design and implementation of various aspects.

For the mission critical environment, these changes have been disruptive and have resulted in divergent philosophies to the approach of achieving reliable controls in mission critical applications. This column will explore the past and discuss the reasons for so many possible approaches to mission critical controls today (each with their own merits) and where mission critical controls are headed.

Evolution of Controls

In the days of pneumatic controls, there was a close-coupled relationship and ownership of both the mechanical system operation and the controls by a single stakeholder: the mechanical engineer. With this approach there was nothing lost in translation. All of the requisite details were included in the design and project documents and no compensatory interpretation was required by the installing contractor.

As controls have migrated to electronic and DDC, translations have been required to convert descriptive sequences of operations written in plain English to cryptic computer programming languages. These translations are one of the primary reasons for many unreliable control systems in mission critical applications today.

Pneumatic Controls

Pneumatic control systems could be characterized with the following attributes:

- No loss of design intent because one stakeholder had end-to-end responsibility;
- No misinterpretation of plain English written sequences to control sequences;

- No lack of ownership by the design engineer; and
- Typically engineers and system operators equally understood how to operate the systems.

Pneumatic systems consists of power supplies (compressed air), sensors, logic devices (and, or, and timer devices, thermostats) and control devices (modulating and two-position actuators, relays). Pneumatic systems are simple in design with relatively standardized components between manufacturers. With no software or custom programming logic, troubleshooting these systems is straightforward.

Electronic Controls

When electronic controls were introduced, pressure and temperature switches replaced pneumatic sensors, pneumatic logic devices were replaced by electrical thermostats, electric relays wall switches and push buttons, and compressed air power supplies were replaced with electrical sources.

This was the beginning of the divergence where another stakeholder with education and experience outside of the traditional mechanical engineer had to be introduced in order to design, implement, and even operate a controls system.

This meant that electrical engineers suddenly became an integral part of the controls system engineering. Further, there was a change in the implementation with new training and evolution necessary for the controls contractor. Pneumatic control systems and proportional

Donald L. Beaty, P.E., is president and David Quirk, P.E., is vice president of DLB Associates Consulting Engineers, in Eatontown, N.J. Beaty is publications chair and Quirk is the chair of ASHRAE TC 9.9.

integral derivative (PID) controllers were still used for closed-loop control, thereby further expanding the expertise required for control system design.

Direct Digital Controls

Then along came direct digital controls (DDC), and with it the advent of microprocessor-based programmable logic controllers, commonly referred to as PLCs (Note we are using PLCs generically to include both industrial and DDC programmable controllers).

PLCs allow for much greater sensor resolution and control precision than pneumatic systems making it the de-facto standard for industrial process, mission critical, and commercial HVAC automation. Pneumatic systems and components still play an important role in certain applications and industries typically where speed, low maintenance and safety are paramount.

An article published in *Data Center Journal* in 2012 discussed commercial DDC versus industrial PLC-based automation in mission critical data centers.

A data center's unique reliability/redundancy requirements and continuous operation push commercial DDC systems to their limits. Most commercial systems are incapable of providing sufficient data monitoring, histories and trending necessary to support continuous commissioning and optimization. Yet with proper holistic designs (i.e., close coordination of mechanical with controls), the complexity and importance of the building automation system (BAS) can be reduced, making commercial systems attractive.

Ultimately, evaluating various commercial and industrial options against the owner's project requirements (OPR) for all aspects of the BAS, and doing so while looking beyond first costs, will deliver the best total solution.

The cross-functional knowledge to address this sort of evaluation is now delivered from a new industry resource known as the master systems integrator (MSI). MSI's have emerged as agnostic solutions integrators for DDC and other related-building systems.

Internet Protocol (IP)-Based Controls

Today's DDC systems have expanded even further into the Internet with connections to all sorts of web-based applications (cloud) and additional desktop software applications.

New forms of DDC solutions have emerged that are natively programmed using Internet Protocol languages

such as XML (extensible markup language). These solutions open the door to a new arena of potential programmers and support personnel (i.e., anyone trained in IP computer languages or computer science majors).

While solutions such BACnet (ASHRAE Standard 135) are developed to be in compliance with OSI Model and various internet protocols, BACnet is *not* a native Internet programming language and still requires special interpretations to develop and implement.

Further the BACnet Standard provides incredible flexibility where each manufacturer can pick and choose how much above the minimum requirements (Object profiles, BIBB's, etc.) are included in their controllers. This variability with each manufacturer still makes BACnet a unique proprietary solution when viewed from the reliability lens of operations and service and support.

In addition, most BACnet solutions are still supported by manufacturer's distributor channels that are territory specific.

IP-based solutions are now more commonly integrated with traditional DDC solutions creating hybrid solutions for mission critical controls.

Pursuit of Solutions

Some argue that the solution lies in making the mechanical engineers provide more detail on the required sequences of operations. Lots of research is being poured into how to solve this problem, even within ASHRAE. However, there is a question about what the market will truly accept or tolerate.

Typical fees for HVAC design on mission critical projects will rarely support more than performance-based designs. Many efforts are under way to produce "standardized" sequences of operations, which may help close the gaps between prescriptive and performance approaches.

Current industry guidelines and standards activities related to more advanced and developed sequences are as follows:

- ASHRAE research project: 1455-RP, Phase I Air Distribution and Terminal Systems; and
- ASHRAE Work Statement 1711, Phase II Central Plants and Hydronic Systems.

Unfortunately, even the most prescriptive English-based sequences of operations still require interpretation and translation to a programming-based language.

Performance vs. Prescriptive Approaches

Listing physical points, device variables, soft variables, logic statements, etc., in the sequence narrative adds clarity by moving from a performance to prescriptive approach. This is a lot more detail than the industry is providing now.

This will add cost and effort for the mechanical consulting firm *and* to the system integrator because of the prescriptive nature of the approach (they can't copy and paste what they typically have done in the past). Owners will need to understand the business case and ROI (Return on Investment) by taking this more detailed approach.

Further, this greatly limits the design professional resource pool as this approach requires an enhanced level of controls expertise, typically at the experience level of a MSI or a controls engineer with industrial PLC experience.

Mission Critical Controls Approaches

There are many approaches to mission critical controls, but for the purposes of this column, we will summarize them in the following categories and briefly describe their merits:

- Industrial PLC-based;

- DDC-based; and
- IP-based and advanced (analytics, machine learning, supervisory data engines, etc.).

PLC-based controls use advanced programmable-logic controllers to perform the control functions of the HVAC plant serving the data center.

As defined in IEC 61131 PLC controllers are required to meet programming language standards such as ladder diagram, function block diagram, structured text, or instruction list and others. Commercial DDC controllers aren't held to a similar standard and programming look, feel and functionality can vary widely between vendors.

Industrial PLC-based systems outperform in the areas of speed, resolution, historical data, trending, and reliability. In addition, redundancy functionality comes standard with many vendors. However, the initial cost and OpEx of these solutions can make the ROI and business case difficult to assess.

DDC-based controls can be provided with or without third-party supervisory controls. The key difference between the two is the introduction of another integrator and service vendor into the mix with the third-party

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supervisory controls.

Third-party supervisory controls can include a supervisory layer above equipment control for zone, system or facility control, often necessary for spaces served by multiple pieces of equipment or redundant systems. Additionally, this may include a separate integration layer and graphical user interface (GUI).

This approach can certainly provide advanced control scenarios and monitoring features. However, the additional integrator, hardware, software platform/layer and GUI can greatly increase the coordination effort, complexity and cost.

Advanced approaches can include integrated analytics as part of the closed-loop control to optimize reliability and efficiency of the system. These solutions range from rules-based fault detection criteria to advanced machine learning and pattern recognition.

Additionally, several BAS and data center information management (DCIM) solutions contain complex proprietary data engines used to determine optimum control conditions and control data center Computer Room Air Handlers (CRAHs) and central plant systems.

To achieve high reliability in the case of PLC or DDC, a distributed controls approach is commonly used where each piece of controlled equipment has its own dedicated controller. This helps ensure that any network communication or supervisory control errors do not affect more than one unit.

Future Trends

Today's mission critical control systems require a brute-force method to achieve a reliable solution. Plain English design intents and sequences of operations must be interpreted and converted into programming language and then reinterpreted back into plain English by a third-party commissioning agent, building operator or service technician trying to troubleshoot an operational problem.

These manual conversions and interpretations in different languages are equivalent to thousands of individual dialects of spoken languages all cohabiting in the same house. The potential for failures is incredible.

Open protocols have increased the flexibility in solutions and solution providers, but have also increased the potential for failures through the co-mingling of so many stakeholders with varying interpretations of what represents the right approach.

To address this problem, some approaches have included

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a single product-neutral integrator, removing third-party supervisory controls, or moving past manual interpretations to systems and tools that automatically communicate using standardized approaches and protocols to do so.

Tomorrow's solutions will enable co-simulation of both building energy modeling and controls systems modeling, along with direct export of the simulated controls language directly into the building controllers.

This approach will enable early programming of the building systems during the design phase of a project. This concept is currently being tested in national labs and is not novel; in fact it takes us full circle to the days of pneumatic controls.

Closing Comments

Mission critical control systems have gone through four generations of major evolution. With each evolution, the typical mechanical engineer has become more distant from the "control" of the mechanical systems to achieve their design intent.

Perhaps achieving a reliable mission critical controls

system requires reverting to the spirit of the approach used in the past by pneumatic control system designers, but updated to apply to today's DDC, PLC-based, and smart instrumentation technologies. Unlike data centers, industrial process control systems designs use a prescriptive approach and provide extremely detailed designs of all the components and all the sequence details.

Industrial owners understand the importance of the mission and the value achieved by eliminating the vagueness and potential for misinterpretation by contractors and integrators. Are data centers best suited by the commercial approach, industrial approach, a hybrid approach or some other approach?

Eliminating all the written sequence misinterpretation potential and taking cues from industrial system design is needed to improve current data center control systems. Current tools do not enable mechanical engineers to design the systems end-to-end as they once did with pneumatic controls. In the meantime, new resources like MSI's have emerged to fill these gaps. ■

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