Direct Digital Control Systems

Specifying Interoperability

By Paul Ehrlich, P.E.
Associate Member ASHRAE
and
Ofer Pittel, P.Eng.
Member ASHRAE

The era of interoperable direct digital control (DDC) systems has begun, and the future holds the promise of more full-featured and competitively priced offerings. This critical time for our industry is challenging for owners, consultants and suppliers. Standards are being set, new products are in development and the industry is learning the advantages and disadvantages of this new technology. Consulting and specifying engineers are facing the challenge of determining what an owner needs from an interoperable system, and then writing a competitive specification to achieve those needs.

Why Specify Interoperability?

Owners need interoperable DDC systems to help them accomplish a number of goals. The first goal is to have a method to connect smart systems together in a horizontal manner (i.e., to connect similar systems to each other and have them communicate [see *Figure 1*]).

An example of this might be a building on a campus that was built with controls from Vendor A. The successful bidder for the next building on the campus might be Vendor B. Without an interoperable solution, the owner would be forced to accept the price provided by Vendor A to have the two buildings communicate.

Second, interoperability also is needed to connect many of the pieces of "smart" equipment that are used vertically in today's buildings (i.e., to connect components of various origins to make one system [see *Figure 2*]). The desire is to connect this equipment and allow it to function as a single cohesive system without needing to write custom software. Examples of this include components from chillers to VAV terminals, to variable speed drives, and even to smart sensors.

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Difficulties in Specifying

While many consulting engineers are experts in HVAC system design, the same cannot be said for their depth of expertise in the design and specification of DDC systems. This has developed into a reliance on the expertise of suppliers in the industry. Unfortunately, this has resulted in many specifications for DDC systems based on a particular vendor's guide specification rather than on the client's needs.

A vague or unclear specification can cause a large disparity in bid prices and may allow an unscrupulous contractor to cut corners. With such a specification, each supplier may consider providing a system different from the other suppliers because the envisioned systems are based on their own interpretation of a specification—a specification that may be interpreted in many ways. The owner's representative will have problems accurately assessing the incongruity in each supplier's bid. In addition, the consulting engineer will have a difficult time enforcing and defending such a weak specification.

Now, take this situation and compound it in an attempt to specify a complete, cohesive DDC system where the system will be constructed from multiple suppliers' components. This is what happens when specifying an interoperable system. The system must be specified clearly so that any two (or more) bidding vendors' equipment and systems are designed and coordinated to work together. An even stronger need exists for a clear, concise, impartial, performance-based specification to make this a reality.

Prescriptive and Performance-Based Specifications

A specifier may use a prescriptive or a performance-based style for the specification to obtain the desired results. Often, prescriptive and performance specification styles may be combined to yield the best outcome. Both methods offer unique benefits.

The first method is to prescribe the method or product that a vendor must use. An example of this is to specify that a controller shall have a 12-bit analog-to-digital converter. This defines a portion

About the Authors

Paul Ehrlich, P.E., is the Tracer Summit product manager for Trane Building Automation Systems located in St. Paul, Minn. He is a member of GPC-13P, Specifying Direct Digital Control Systems.

Ofer Pittel, P.Eng., is a controls specialist with Rose Technology Group Ltd. of Toronto, Ontario. He is a member of ASHRAE Technical Committee 1.4, Control Theory and Application and chair of GPC-13P.

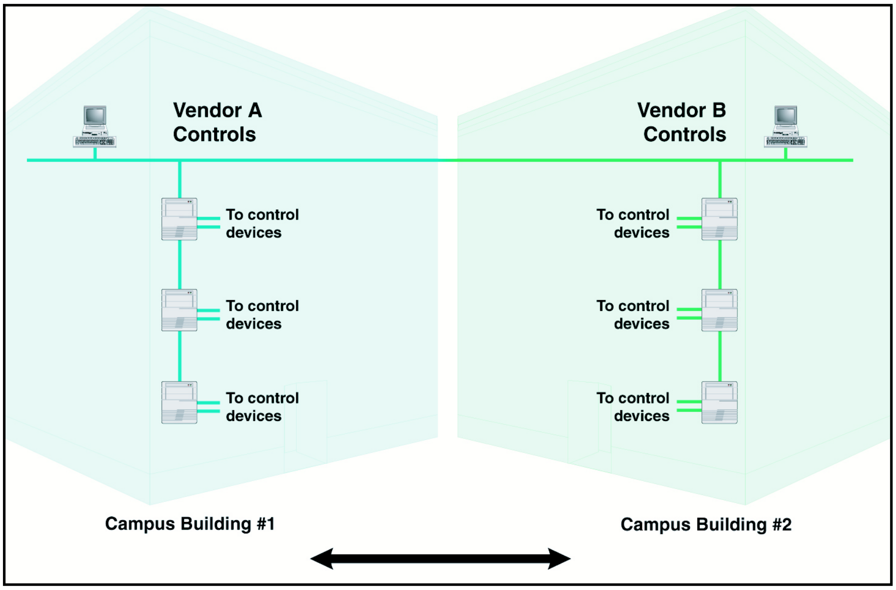

Figure 1: Horizontal connectivity.

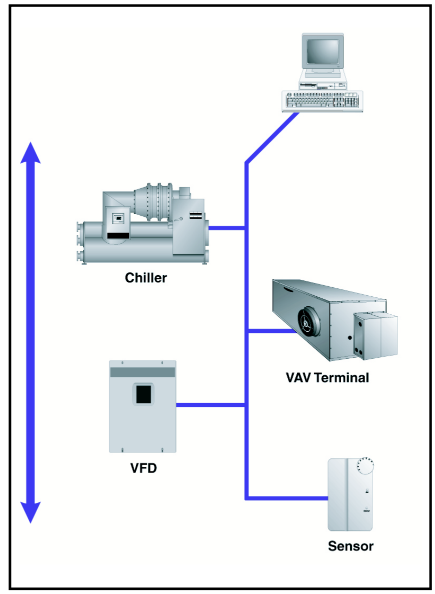

Figure 2: Vertical connectivity.

of the hardware and so implies the expected result. An alternate approach is to specify desired performance.

An example of a performance specification for a controller would be that the system should have an end-to-end accuracy of ±1°C (the value seen at and used by the controller is within 1°C of the actual fluid temperature). It is the responsibility of the system specifier to determine the critical system performance criteria. The specifier also must determine which of the system's parameters are to be fixed and which can be determined by the contractor.

To write a prescriptive specification, the specifier must have a much higher level of knowledge of the details. However, this method limits the gamut of solutions and products available to the contractor, many of which may benefit the owner both in terms of available technology and cost.

In general, a performance-based specification will provide the best value. It ensures that the owner receives the identified benefits, while allowing the contractor to select the most cost-effective solution. It tells the vendor and contractor exactly what functionality is expected, rather than what equipment to use. Another positive outcome of a performance-based specification is that it can serve as a standard template that a specifier can use for years to come. This is because it relies on specific criteria, *not* on products.

When specifying an interoperable system, it is necessary to provide the required foundation to ensure that the products of several vendors on a project will be able to interoperate. This may require the use of some more definitive prescriptive language. The extent that an interoperable specification can be performance-based or prescriptive depends on the nature of the project. Let us look at a number of different project types and what makes the most sense:

1. New installation, entire system provided by one vendor: A pure performance-based specification should be used. This will allow the most economical solution to be applied. Future additions to the project will follow the same communication options and protocols installed in the first phase.

2. New installation, system provided by various suppliers: For example, this might be a system where the HVAC controls are bid and provided under Division 15900, but the chillers that communicate with the system are bid in another section, and the fire alarm that also communicates with the system is bid in a third area. In this case, the specifier must be prescriptive in describing the characteristics of the systems that connect together.

3. Expansion of an existing installation: In this case, the specification needs to be highly prescriptive because the new equipment must connect to the existing systems.

Addressing Interoperability

In the United States, most architects and consulting engineers create specifications that follow the formats dictated by the Construction Specification Institute (CSI). Others follow formats provided by the American Institute of Architects (AIA). CSI provides a standard format for all sections of the specification. HVAC controls are typically placed in Section 15950.

However, a specifier may choose to place HVAC controls in other sections of Division 15000 (mechanical systems). Control systems that integrate HVAC and fire and life safety controls are often placed in a special Division 17000. This is rarely done today because most systems have separate, stand-alone HVAC and fire and life safety systems.

CSI dictates that each section will consist of three parts. The first part is *General*. It includes approved manufacturers, codes and standards, performance, and references. The second part is titled *Products* and covers things such as hardware devices, software and system architecture. The third part is *Execution* and includes installation details, setup of software and operator's workstation, sequences of operation, checkout and testing and training.

Including interoperability into a specification written in this format requires insertion of targeted language at critical points. In Part 1, the System Performance Article needs to incorporate the acceptable time delay for values and alarms to be passed from device to device. In Part 2, the description of products needs to include the required communication protocol(s). It may include the operator's interface devices (e.g., the personal computer) and all controllers. Part 2 also may include a section on communication protocol(s) and communication wiring media. In Part 3, the issues of system integration and wiring are addressed.

Functions of Interoperable Systems

To write an effective interoperable DDC system specification, the specifier first must have an understanding of the technology. There are many possible options for achieving interoperable systems. These will vary in their cost, effectiveness and expandability. Some methods connect equipment but leave the building owner committed to a single supplier for future maintenance and upgrades. Others may allow owners to select the supplier of their choice.

It is important to note that the goal of interoperability between different manufacturers' control system components is the reliable and timely function of reading and writing data between the devices. This functionality is required at all the levels of the network where different manufacturers' devices must interoperate.

In addition to read and write, other functions, such as the exchange and manipulation of alarms, schedules, and trends, may also need to occur in an interoperable environment. Invariably, however, this communication happens at the PC workstation and building controller levels. There is a broad range of functions for use in DDC systems. In an interoperable system, several of these functions may be required.

Examples of an Interoperable System Specification

The following examples are excerpts from Part 2 of Section 15950 in a specification that could be used to specify a DDC system.

Methods for Achieving Interoperable Systems

Proprietary Protocols

Protocols are sets of rules that describe how data is transmitted across the wire. Traditionally, DDC systems have relied on proprietary protocols. This means that each supplier created their own protocol, which they used to achieve system functions and communications. Typically, each supplier optimizes their protocol for their applications. As the protocol is proprietary, the owner must deal with the original manufacturer for any modification, enhancement or addition to the system.

The first step in making proprietary systems interoperable was to use a device called a gateway. A gateway (also called an integrator or translator) is a device that converts one protocol to another. Fundamentally, it is like an electronic foreign language dictionary. You enter a word into it in French, and it comes out in English. Physically, the gateway may be a PC or an embedded controller that mounts on the wall.

Gateways can be used to accomplish a number of functions. Gateways commonly are used to convert one proprietary protocol to another. For example, they may be used to connect a variable frequency drive or a chiller to an existing automation system. The communication through gateways can be two-way (i.e., either device can initiate communications) but is typically one-way. This means that the automation system initiates communications and the other device or system acts as a "slave."

Gateways that convert proprietary protocols may be difficult to maintain. In addition, gateways must be updated whenever either of the protocols changes. In the future, the most common use of gateways will likely be to connect existing proprietary protocols to open standard protocol systems such as BACnet™.

Open Protocols

There are many standard or open protocols that have been developed internationally. These include Modbus, FIP, Profibus, and CE Bus. However, the most promising protocols that are oriented for use in DDC control of HVAC systems are BACnet and LonMark. These two protocols are fundamentally different in how they were developed and how they operate.

BACnet™

BACnet (Building Automation and Control Network) is an ANSI/ASHRAE standard protocol that has been developed using an internationally recognized method of standard development. This means that the standard has had input from a broad range of sources including owners, suppliers, and consultants. The BACnet standard also has been extensively reviewed and modified to meet the suggestions submitted by reviewers. Because BACnet is a standard, it only can be changed with consensus approval.

BACnet addresses how data is shared between systems and also what data is shared. This is accomplished by modeling common functions into groups called "objects." BACnet defines many different objects, but the most basic ones are the analog input and the binary input. These allow information such as temperatures and status to be shared between systems.

Echelon LonMark

The LonMark protocol uses LonTalk, a privately developed protocol for communication. LonMark is an industry organization that developed rules for applying LonTalk to HVAC products, as well as for other industries. LonMark is gaining broad acceptance in the HVAC industry. While this protocol did not follow the rigorous open consensus-building method used by BACnet, changes now are controlled by the LonMark organization and are unlikely to change arbitrarily. ■

This example is entirely performance-based. It is appropriate for a project where an interoperable system is desired and there is no preference on the technology that the supplier provides:

> *2.2 Communication*
> A. All control products provided for this project shall comprise an interoperable network.
> B. The Contractor shall provide all communication media, connectors, repeaters, hubs and routers necessary for the internetwork.
> C. All controllers shall have a communication port for connection with the operator interfaces.
> D. A device on the internetwork shall be provided with a 28,800 baud modem that will allow for remote operation. Remote operator interface via this modem shall allow for communication with any and all controllers on this network as described below.
> E. Communication services over the internetwork shall result in operator interface and value passing that is transparent to the internetwork architecture as follows:
>
> 1. Connection of an operator interface device to any one controller on the internetwork will allow the operator to interface with all other controllers as if that interface were directly connected to the other controllers. Data, status information, reports, system software, custom programs, etc., for all controllers shall be available for viewing and editing from any one controller on the internetwork.
> 2. All database values (e.g., objects, software variables, custom program variables) of any one controller shall be readable by any other controller on the internetwork. This value passing shall be automatically performed by a controller when a reference to a object name not located in that controller is entered into the controller's database. An operator/installer shall not be required to set up any communication services to perform internetwork value passing.

In a prescriptive specification, the specifier must detail the basis on which the system must be designed. In the case of control systems, the communication parameters form the basis—the physical media type and the protocol to transfer the information. If these details are not fixed at the start, additional cost, which typically has not been allowed for in any budget, will likely be necessary to provide the added hardware for interfacing equipment (gateways, routers, and bridges) and time to link various portions of the systems that are otherwise not compatible. At present, there is no practical alternative to using this style of specification for specifying DDC system communication when multiple suppliers are providing product.

This second example is for a system where components that need to communicate are being specified in various sections of the specification. In this example, BACnet™ communications have been included in prescriptive language. If an alternate protocol was desired, then it could be included using similar prescriptive language.

Advancing Our Knowledge About Specifying Interoperability

With the advent of interoperable systems, providing the tools and techniques to advance our industry in specifications of controls is more critical than ever. It will be especially important for consulting engineers to invest in education on the most effective method for specification of these systems. ASHRAE is sponsoring several initiatives to further this initiative.

An ASHRAE committee is developing a guideline for writing specifications for DDC systems. The GPC-13P committee has been working on this project for several years and issued the guideline for public review in April 1998. Final publication will follow a successful review process.

This guideline consists of a sample specification and guideline text describing options for each paragraph of the specification. For example, the sample specification lists a certain grade and accuracy of humidity sensor but goes on to describe the costs and benefits of using higher or lower grades of sensors. It also describes the basics of DDC and provides information for the specifier on system architectures and other basics, such as how to properly size control valves and dampers. The guideline includes discussion for interoperability. ■

> *2.2 Communication*
> A. All control products provided for this project shall comprise a BACnet internetwork. Communication involving control components (i.e., all types of controllers and operator interfaces) shall conform to ASHRAE Standard 135-1995, BACnet.
> B. Workstations and Building Controllers shall be installed on an ISO-8802.3 network (Ethernet).
> C. The Contractor shall provide all communication media, connectors, repeaters, hubs, and routers necessary for the internetwork.
> D. All controllers shall have a communication port for connections with the operator interfaces using the BACnet Data Link/Physical layer protocol.
> E. A device on the internetwork shall be provided with a 28,800 baud modem that will allow for remote operator interface using the BACnet PTP Data Link/Physical layer protocol. Remote operator interface via this modem shall allow for communication with any and all controllers on this network as described in Paragraph F below.
> F. Communication services over the internetwork shall result in operator interface and value passing that is transparent to the internetwork architecture as follows:
>
> 1. Connection of an operator interface device to any one controller on the internetwork will allow the operator to interface with all other controllers as if that interface were directly connected to the other control-

System Functions For Interoperability

Regardless of the method selected to achieve interoperability, the DDC system should be expected to perform five basic tasks. These are:

Data Exchange: The exchange of data between two devices (e.g., PC workstations, building controllers, custom application controllers, or application specific controllers) is the most basic of interoperable functions. This function allows for the viewing (or reading) of data as well as making changes (or writing) of this data. For example:

A building controller has a temperature sensor that measures the outdoor air temperature. This is modeled as an analog input object. If we wanted to view the outdoor air temperature we could use a PC workstation and ask for (or read) the present value of the analog input named "outdoor air temperature."

In the same manner, we can change setpoints (write) to the values of analog and binary output objects and value objects. These basic functions can be used to share setpoints between controllers, provide data for graphics on a PC workstation, command the lights to come on, or sample data in a trend.

These functions are supported by all interoperable protocols. In fact, entire interoperable systems can be built by just using data exchange functions. The following advanced functions may be better suited for use in large installations and in remote operations of multiple buildings.

Alarms and Events: This function provides the operator with notification of off-normal conditions. A controller that has determined that an event has occurred is able to send an alarm message to a predetermined location. For example:

A program that periodically compares the space temperature to a user-entered alarm limit in the building controller detects that the space temperature is too high. When the temperature exceeds that limit, the building controller generates an alarm and sends it to the PC workstation. At that workstation, an operator reads the alarm and acknowledges it.

Schedules: This set of functions allows for the editing and creation of schedules on a PC workstation that will be executed in a controller. For example:

The operator wants to change the stop time of the fan in the auditorium from 6 p.m. to 9 p.m. Using the scheduling function, the operator is able to load the schedule from the controller, change the stop time, and have the modified schedule executed at the controller.

This function will typically occur between a PC workstation and a building controller.

Trends: The ability to sample, store and read trends is a valuable function. Trending is a tool for collecting data on system performance and energy usage. While trends are typically stored for archival purposes on a PC workstation, there are a number of reasons to sample them in a controller. This will reduce network traffic and also will allow for sampling of data if a PC is not continually connected to the controller.

Network Management: This final interoperability function provides the ability to manage the devices on the network. It includes tasks such as monitoring for a loss of communication and coordinating the time-settings of the clocks in each controller. ■

lers. Data, status information, reports, system software, custom programs, etc., for all controllers shall be available for viewing and editing from any one controller on the internetwork.

2. All database values (e.g., objects, software variables, custom program variables) of any one controller shall be readable by any other controller on the internetwork. This value passing shall be automatically performed by a controller when a reference to a object name not located in that controller is entered into the controller's database. An operator/installer shall not be required to set up any communication services to perform internetwork value passing.

Conclusions

An effective performance-based specification tells the vendor and contractor exactly what functionality is expected rather than what equipment to use. It also specifies only those components or properties that can be checked to ensure compliance. A specification is only useful if the final product can be readily verified. However, when more than one source is used for equipment, enough detail must be provided to define the interaction and communication. By definition, this must be prescriptive. Hence, a performance-based specification, in combination with the appropriate prescriptive language, will provide the best results.

With interoperable systems constructed from multiple suppliers' components, the need for a clear, concise, impartial, performance-based specification is even more critical. As interoperable systems become more common, owners and consulting engineers need to educate themselves on the available products and methods for achieving interoperable systems. ■

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