Resources for Commissioning Providers: DDC Online and the National Building Controls Information Program

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Synopsis

Commissioning providers need information resources on building controls to maintain their position as authorities on building operation. This paper provides an overview of DDC-Online and the National Building Controls Information Program (NBCIP), two resources that commissioning providers can turn to for credible information.

DDC Online is a web-based catalog of product lines of the leading manufacturers of building direct digital control (DDC) systems presented using a generic architecture and common terminology, thereby simplifying the task of comparing products of different manufacturers. DDC Online is a very useful tool for specifying engineers and commissioning providers tasked with assessing the equivalency of specified DDC systems.

NBCIP provides credible independent controls information based on research, testing, and sound engineering practice. The paper highlights results to date from two ongoing NBCIP projects. The first is a project in which the performance of duct-mounted relative humidity transmitters is being assessed through extensive testing. The second project is a case study undertaken to experience first-hand the extent and nature of control problems in buildings and to document the energy savings from correcting control problems and capturing opportunities where the controls can be improved. The paper also describes two planned projects that will examine fan speed control strategies for variable-air-volume systems.

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Introduction

Studies have shown that control-related problems can be a significant contributor to energy waste in buildings. While the problems tend to be diverse in nature, experience indicates that the underlying cause is often a lack of understanding of building control systems among the individuals who design, install, and operate them. This lack of understanding leads to decisions concerning hardware and software specifications and day-to-day operations that can compromise building energy performance.

To make good decisions, people need good information. Certainly good information on building controls is available, but it can be difficult to locate and recognize. Commissioning providers are expected to be this information source. Commissioning providers are called upon to:

- assess the attributes and shortcomings of various manufacturers’ control systems and control components and provide input on specifications and product selections;
- comprehend and troubleshoot control strategies and identify alternative strategies that improve energy efficiency; and, among other things,
- provide documentation and training to the building operators who are responsible for the day-to-day operation of the building.

Commissioning providers need credible information sources on building controls to maintain their position as authorities on building operation.

The objective of this paper is to describe two such information sources on building controls, namely DDC Online [1] and the National Building Controls Information Program (NBCIP) [2]. DDC Online is a website that provides manufacturer-reported information on product lines of the leading manufacturers of DDC systems for HVAC applications. NBCIP is a program established to facilitate the adoption of energy efficient building control products and strategies through testing, demonstration, education and information dissemination. DDC Online and NBCIP are publicly available resources that commissioning providers, building owners, facility managers and others can draw upon to make informed decisions about building controls based on credible information. By integrating quality building control products and proven control strategies early in the design process, the number of control problems that must be addressed during functional performance testing can be reduced.

The paper begins with an overview of DDC Online. This is followed by an overview of NBCIP and descriptions of several projects. The projects described include product testing of duct-mounted relative humidity transmitters, a case study of the control problems and opportunities in a large federal office building, an application guideline on return fan control strategies, and a best-practice guideline on supply fan control strategies. The paper concludes with a brief summary of how DDC Online and NBCIP can benefit commissioning providers.

DDC Online

DDC Online is a valuable resource for professionals involved with the specification of direct digital control (DDC) systems. Specifying DDC systems is a time-consuming task, particularly
when it involves comparing product lines of different manufacturers. Manufacturers of DDC systems naturally strive to differentiate their products from those of their competitors. Product capabilities and the terminology used to describe these capabilities are two of the ways this is done. DDC Online strips away the artificial differences (the terminology) to help specifying engineers and commissioning providers see the functional differences (product capabilities) between product lines of different manufacturers. Figure A shows the generic architecture diagram used to present the product lines of each manufacturer listed on DDC Online. The labels on the right side of Figure A correspond to eight distinct layers of the architecture that delineate the capabilities of the product line. For each manufacturer, the layers are populated with appropriate devices and/or communication information. A quick screening of the architecture diagram of various product lines can identify those lines with an appropriate level of sophistication for the application of interest. Clicking on a controller such as the primary controller PCU 1 in Figure A allows users to drill down and view more detailed information about that particular controller. Templates are used to present this information so that the same

![Figure A: Generic architecture diagram showing the eight layers used to classify controller and communication capabilities on DDC Online [1].](image)
information can be readily located for a comparable primary controller from another manufacturer. Product information is based on technical specifications provided in the manufacturer literature.

DDC Online also presents introductory material on DDC systems that aids in the understanding of the product descriptions. Topics range from the elements of a control loop to types of control responses and various types of network topologies. There are also descriptions of various control devices, explanations of the different approaches for programming control logic, and an overview of communication issues. Another section of DDC Online describes a wide range of input and output devices and the terminology (e.g., accuracy, repeatability, hysteresis) used to characterize the performance of these devices. Further details of DDC Online content are available in reference [3].

The National Building Controls Information Program

Overview

The second resource for commissioning providers described in this paper is the National Building Controls Information Program (NBCIP). NBCIP was established to facilitate the adoption of energy efficient building control products and strategies through testing, demonstration, education and information dissemination. Whereas DDC Online provides manufacturer reported information, NBCIP provides credible independent controls information based on research, testing, and sound engineering practice. The program consists of four primary activity areas:

- **Product Testing** – Projects in this area involve independent testing of comparable control devices from different manufacturers. The first product testing project involves evaluating the performance of duct-mounted relative humidity transmitters and is described in the following section.
- **Best-Practice Control Strategies** – Projects in this area involve comparative testing of alternative control strategies/algorithms to determine the preferred strategy based on energy efficiency and other criteria such as cost, ease of implementation, and robustness of the strategy.
- **Application Guidelines** – Projects in this area offer guidance concerning the proper application of control system strategies and devices.
- **Building Operation Tutorials** – Projects in this area offer guidance on “how” typical installation, operation and maintenance tasks are performed.

Reports stemming from NBCIP are made publicly available after they have been peer reviewed. Expertise from outside the program is being drawn upon to help identify projects, advise on the scope of these projects, review project reports and, in some cases, carry out the projects. Commissioning providers are some of the key individuals who have offered guidance and review on NBCIP projects.
While NBCIP draws upon a broad range of expertise to develop and shape project ideas, project selection is made by the organizations that sponsor the program. To protect the credibility of the program, product manufacturers cannot be sponsors.

Summaries of two ongoing NBCIP projects and two planned projects follow.

**Ongoing NBCIP Projects**

### Product Testing of Duct-Mounted Relative Humidity Transmitters

Relative humidity transmitters are notoriously problematic and erroneous readings can lead to significant energy waste and poor comfort conditions. Duct-mounted relative humidity transmitters having a manufacturer-stated accuracy of \( \pm 3\% \) are being evaluated in the first NBCIP product testing project.

Product testing projects are conducted using a process designed to ensure the credibility of the testing results. This process begins with a literature search to identify a standard method of test appropriate for the device of interest. In the case of the humidity transmitters, no such standard was identified, so a method of test was developed and external peer reviews obtained to ensure its suitability. The method of test describes the setup of the testing apparatus and instrumentation, procurement of devices to be tested, procedure for conducting the testing, and data analysis procedures. The draft report of the testing results undergoes external peer review before being made public.

Duct-mounted relative humidity transmitters from six manufacturers are undergoing a battery of tests to determine their accuracy, stability, response time and performance under extreme conditions. In the first phase of testing, a humidity generator with an accuracy of \( \pm 0.5\% \) RH was used to create known temperature and relative humidity conditions in which the transmitters could be tested. A comparison of the accuracy of relative humidity transmitters from two manufacturers is shown in Figure B for a range of temperatures and relative humidities [4]. The plots in Figure B are obtained by averaging the results from three identical transmitters from each manufacturer. According to the manufacturer’s stated accuracy, all the points on the curve corresponding to 77°F should fall within the gray box. The relative humidity transmitter in Figure B1 satisfies this criterion, whereas the transmitter in Figure B2 does not. In addition, the accuracy of the transmitter in Figure B1 is for the most part insensitive to both relative humidity and temperature, while the transmitter in Figure B2 is sensitive to both. Manufacturer names are suppressed here but are available in the NBCIP report that details the results of the accuracy, repeatability, hysteresis and linearity testing [4].

The results in Figure B were obtained under controlled conditions. Figure C provides a one-day comparison of readings obtained from six test transmitters (one from each of the six manufacturers) installed side-by-side in the outdoor air duct of an air-handling unit (AHU). These data were collected as the transmitters undergo an ageing test designed to assess the stability of the sensors over a one-year period. The readings from an in-situ reference transmitter having a manufacturer-stated accuracy of \( \pm 1\% \) are also shown in Figure C. The difference
Figure B: Comparison of the accuracy of ±3% relative humidity transmitters from two manufacturers tested by NBCIP [4].

between the minimum and maximum values from the transmitters under test ranges from 9 to 18% RH. This is one and a half to three times the maximum expected difference of 6% RH based on the manufacturers’ stated accuracy. Eliminating the transmitter reading that is consistently lowest reduces this difference to 5 to 12% RH. The data were collected less than one month after the transmitters were installed in the duct. The temperature ranged from 53 to 73ºF on this day.

Figure C: One-day comparison of readings from relative humidity transmitters installed in an air-handling unit outdoor air duct.
Testing results such as those in Figures B and C are useful to commissioning providers in several ways. First, the results can help commissioning providers identify one or more transmitters from those tested that they would recommend given the anticipated operating conditions and accuracy requirements of a particular application. Second, the results can support the recommendations of the commissioning provider for a higher grade of transmitter, particularly for critical applications such as humidity control in a museum. Also, for other applications where the investment in a higher grade device is not justified, the commissioning provider may choose to alter a control strategy to avoid the use of a relative humidity transmitter.

Testing of the relative humidity transmitters is ongoing. Future testing will measure response time, an important characteristic for control applications, as well as the capability of the transmitters to withstand extreme conditions such as cycling between high and low relative humidity conditions and exposure to saturated conditions.

**Case Study of Control Problems and Opportunities**

NBCIP has conducted several scoping activities to help understand the link between control systems and inefficient energy use in buildings. The scoping activities included a review of published case studies citing building control problems [5] and roundtable discussions with recognized controls experts aimed at gaining insight about the nature of control problems experienced in the field [6,7]. These activities produced a classification scheme consisting of twelve categories for grouping various types of building control-related problems. The experts agreed with the published case study findings that identified software programming problems, which includes any problem arising from incorrect or inappropriate control logic and parameters that produce output to control HVAC equipment, as the most pervasive problem with building controls. The NBCIP case study described here was undertaken to see first-hand the extent and nature of control problems in buildings and to document the energy savings from correcting control problems and capturing opportunities where the control can be improved.

The building under study is a large federal office building in the Pacific Northwest that is less than ten years old and is equipped with a modern DDC system. NBCIP is conducting the case study with a commissioning provider who is re-commissioning the building. NBCIP is tracking the work and characterizing findings of the commissioning provider in an effort to understand the root causes of control problems identified in the building. The aim is to identify ways in which control systems, and the understanding of these systems by their users, can be improved.

Numerous problems and opportunities linked to the control system and having significant implications for energy and maintenance costs, equipment life, and comfort have been identified. The distinction between problems and opportunities is subtle, but important. Problems refer to situations where, for whatever reason, the control system is not doing what it was intended to do. An example of a control problem is a reset strategy that is not functioning properly. The root cause may be a flawed design, flawed programming logic, failed sensor, or any of a number of other possibilities. An opportunity, on the other hand, refers to situations where the control system is performing as intended, but improvements are possible. Examples of opportunities would be implementing an optimal start strategy where one did not exist, and turning off equipment that is...
running unnecessarily. Some examples of control problems and opportunities from the case study building are highlighted below:

- **Problems:** (1) Unstable operation of the primary and secondary chilled water systems, including the AHU chilled water valves and the centrifugal chillers. Figure D shows the discharge air temperature of the four cooling AHUs for a day with particularly unstable control. The discharge air temperature of individual AHUs varies from 7ºF peak-to-peak for the most stable temperature, to 12ºF peak-to-peak for the least stable. On this same day, the lead chiller (450-ton centrifugal) cycled on and off 15 times in a 12-hour period. (2) The hot deck discharge air temperature set point is higher than the heating water set point, which causes the heating water valves to go to the full open position and the pumps to run at excessively high speeds. The differential pressure set point in the heating water loop is also set higher than necessary and is contributing to the excessive pump speeds. (3) Outdoor air damper for one AHU overridden to 30% open, requiring chiller operation at temperatures where cooling with outdoor air should satisfy the discharge air temperature set point. (4) The scaling parameters for the relative humidity transmitters for one AHU are incorrect and result in readings that are erroneous. These readings are used in the economizer control strategy and for the chilled water reset control.

![Figure D: Discharge air temperatures of four cooling AHUs demonstrating unstable control.](image)

- **Opportunities:** (1) Dedicated outdoor air fans are introducing more outdoor air than necessary based on building occupancy. One of the ideas proposed for providing the required outdoor airflow rate is to shut off two of the dedicated outdoor air fans and allow two others to continue to operate as they do now. (2) Turn off the remaining two dedicated outdoor air fans during economizer operation. (3) The chilled water reset strategy resets
the chilled water supply temperature to its lowest value whenever the lowest return air relative humidity of the four cooling AHUs falls below 50% RH. By increasing this criterion to 60% RH, comfort can be maintained and the chilled water supply temperature can be raised for a significant number of operating hours.

A review of the preliminary findings from the commissioning provider indicates that problems outnumber opportunities by about a two-to-one margin. Some of the issues are unrelated to the building control system (e.g., problems with onboard equipment controls, such as a chiller controller) and therefore were not classified as a problem or opportunity. The preliminary findings are also consistent with previous NBCIP scoping activities [5,6,7] that indicated software programming problems are the most prevalent type of problem. Some of the problems and opportunities have likely existed for some time, perhaps since the building was built. The problems have likely gone unnoticed by the building operators, or in cases where a problem was identified, “work-around” solutions were devised that sacrificed energy to keep the equipment operating and occupants comfortable. Part of the solution to this type of situation is education and training, but even the most highly trained building operators need tools to help them do their work. The case study emphasized the diagnostic limitations of one of their most important tools, the DDC system. Commissioning providers are also impacted by the limitations of the DDC system. Some of these limitations are highlighted below:

- **DDC systems often lack the capability to trend sufficient data to understand how individual systems are operating and how systems are interacting.** The limitation generally stems from inadequate communication capabilities, which limits sampling rates for data collection and/or the number of pieces of data that can be transferred in a given period of time (bandwidth), and inadequate memory, which limits the amount of data that can be stored in a controller before it must be uploaded to another storage medium such as the operator workstation hard disk. Communication limitations are often exacerbated by poorly designed network topologies that result in data bottlenecks [8, 9, 10].

When specifying a DDC system, the capability of the system should be clearly defined in terms of the sampling rate and the number of points that must be collected within the sampling period. Reference [11] identifies data points for chilled water systems and variable-air-volume systems that should be monitored using the DDC system. For routine monitoring, the system may be expected to trend and archive in excess of 1000 points at 10 to 15 minute intervals; however, it may also be expected to collect certain data points more frequently to monitor, for instance, the stability of the discharge air temperature. When troubleshooting, fewer points need to be trended and archived simultaneously, but a sampling rate of 1 to 2 minutes is a necessity. This is adequate to identify most unstable control loops as well as the main operating characteristics of a system; however, it may not be adequate to resolve certain sequences of events. For instance, in the case study building, it appears by looking at the data that a primary pump is turning on unnecessarily and is triggering a sequence of events that leads to very unstable operation of the chillers as well as the primary and secondary pumps and the AHU chilled water valves. There is no doubt that the operation becomes unstable, but with data collected at 2-minute intervals, it is very difficult to determine if there is some other event that is causing the
primary pump to start. To capture the triggering event, it is necessary to be able to trend a smaller number of points at 5 to 10 second intervals. Unfortunately, a substantial percentage of installed DDC systems do not have this capability.

- **DDC systems generally have a significant amount of custom control logic that can be difficult to access and comprehend.** Custom control logic is prone to errors and can be time consuming to interpret. Controls technicians from the same branch office have been known to have different “preferred” control sequences and frequently have difficulty understanding the sequences programmed by another technician. Although a certain amount of customization is necessary, every effort should be made to develop standard control sequences that can be modified to address requirements of a specific building. This sentiment has been expressed by controls experts [6,7] and is being addressed by Technical Committee 1.4 Control Theory and Application of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, which is working to develop “reference” sequences for common systems.

Another barrier associated with accessing and understanding control logic is the programming interface. Programming interfaces of some DDC systems are prohibitively complex, to the point where considerable training and frequent use are necessary to maintain some level of proficiency. It can even be a challenge to get a legible printout of the control logic. Graphical programming is becoming prevalent in modern DDC systems and well-designed graphical interfaces can make programming control logic and interpretation of that logic significantly easier; however, there is a great deal of difference in the user-friendliness of graphical programming interfaces. A complicating factor is that DDC systems from a single manufacturer often require multiple software tools for programming/configuration of controllers.

- **The format of trend files can make it difficult/tedious to use trend data in third-party software.** DDC systems come equipped with software that enables trend data to be viewed using an “internal” graphics tool. Getting the data out of the system and into a format that “external” tools can read can be very challenging. Ideally, a column formatted ASCII file could be produced that contains user-selected time synchronized data. Some DDC systems support this functionality, while others produce file structures and/or data formats that require additional processing and conversion that is anything but trivial.

In spite of these limitations, commissioning providers still have to get the job done. And so it is with the case study building. The re-commissioning effort there is ongoing. As the root cause of each problem is determined, the problem will be classified into one of the twelve categories identified by the NBCIP scoping activities [5,6,7]. In addition, post-commissioning monitoring is planned to assess the impact of the control system changes on energy consumption.

**Planned NBCIP Projects**

The rapid incorporation of variable frequency drives to control the airflow in variable-air-volume systems has resulted in a plethora of fan speed control strategies. Two projects addressing fan
speed control strategies for variable-air-volume systems are under development by NBCIP. The first is an application guideline for return fan speed control strategies. Return fan speed control affects the pressure within a variable-air-volume system and the building zones it serves, the intake of outdoor air, the occurrence of reverse flow of outdoor air through the exhaust damper, and ultimately the system energy consumption and building indoor air quality. Several different return fan control strategies, such as speed tracking control, airflow volume tracking control, and differential pressure control, are currently used. The choice of an appropriate return fan control strategy depends on several factors including cost, outdoor air strategy, building pressurization requirements, and required sensors or instrumentation.

In spite of the information available on individual return fan control strategies, comprehensive guidelines that identify and compare the costs, advantages, disadvantages, practical implementation issues, and suitable applications of return fan control strategies are lacking. As part of this project, NBCIP is developing an application guideline that aims to:

- describe existing return fan speed control strategies, emphasizing key design and implementation issues; and
- provide guidelines to design engineers on the selection of the most appropriate strategy for a given application, implementers on the best approaches to ensure a given strategy meets the design intent, and building operators on how to ensure a given strategy operates as intended.

The second project addressing fans is the development of a best-practice supply fan speed control strategy. The supply fan operating speed is typically controlled using a static pressure control loop in which the fan is controlled to maintain a constant static pressure set point at a specific location in the duct where static pressure is sensed. The static pressure set point is based on the static pressure required to provide the design airflow under peak cooling load conditions; however, systems often operate at part-load conditions. DDC systems provide the opportunity to implement fan control strategies aimed at reducing fan energy consumption by either dynamically changing the static pressure set point to reflect actual load conditions or by controlling the fan speed directly based on VAV box damper position. Although the opportunity to reduce fan energy exists, very little information is available that documents the algorithms, tuning parameters, tuning approaches, performance and energy savings of alternative fan control strategies. The aim of this NBCIP project is to increase the awareness and understanding of energy efficient supply fan control strategies through rigorous testing against the traditional fixed static pressure control strategy.

**Summary**

Commissioning providers are routinely called upon to diagnose control problems. NBCIP and DDC-Online are resources that commissioning providers and others can draw upon to increase their expertise and make informed decisions about building controls based on credible information. By integrating quality building control products and proven control strategies early in the design process, the number of control problems that must be addressed during functional performance testing can be reduced.
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