Sensor types, accuracy and the proper procedures for point-to-point checkouts.

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Modern Building Automation Systems (BAS) have become sophisticated management and control systems that operate critical building services systems. However, the most advanced BAS cannot operate without accurate sensors - you can only control what you can measure.

With the wide selection of sensors available these days this paper will provide an overview of:

- the various types of sensors
- the applications they are best suited for
- accuracy
- calibration and BAS accuracy

The paper details HVAC applications and particularly temperature measurements.

The paper will focus on the need for Point-To-Point (PTP) checkouts and the correct procedures for carrying them out. Incomplete or inaccurate commissioning of the BAS can severely compromise its effectiveness and may result in building Owners incurring additional expense and occupant dissatisfaction. Proper Point-To-Point (PTP) testing verifies readings from sensors in the field all the way back to the operator's station and confirms correct mapping of points on the Graphical User Interface (GUI). An accurate record of all testing must be maintained and deficiencies noted and retested once they have been rectified.

TYPES OF SENSORS

The basic types of temperature sensors are Resistance Temperature Detectors (RTD), Thermally sensitive resistors (thermistors) and Thermocouples.

Resistance Temperature Detectors

RTD's measure temperature via the change in resistance of a fine wrapped wire or thin-film element. They are well suited for both HVAC applications and hand-held instruments and provide accurate readings for a very wide temperature range. RTD's offer the most linear signal of any electronic temperature sensor. RTD's often require a transducer with a voltage or current output for connection to the Building Automation System (BAS). The most common RTD's are Platinum RTD's, which are sometimes referred to as Platinum Resistance Thermometers (PRTs).

Thermistors

Thermistors relate the resistance of a small metal oxide semi-conductor to temperature. They are also well suited for HVAC applications and hand-held instruments and provide accurate readings however, they have a more limited temperature range than RTD's.

Thermocouples

Thermocouples measure a voltage change between two wires of dissimilar metals and relate this to temperature. These are used in most hand-held instruments and in high temperature applications. Thermocouples are inexpensive and durable however they are not as accurate as RTD's and Thermistors.

Calibration

Sensor accuracy is typically listed in the manufacturer's technical literature. However, this often does not account for the transducer and the wire used to connect the sensor. Wire length can affect the readings for RTD's. The longer the wire to the sensor, the higher the signal resistance and therefore this will affect the reading. Therefore field calibration of temperature sensors to ensure accurate temperature readings is often necessary. A small variation in the reported temperatures versus the actual conditions can result in large amounts of wasted energy and therefore costly utility bills. The author's experience shows that proper calibration of sensors and actuators could alone save 1-2% on the energy used in a facility.

COMMISSIONING

Even the best designed BAS will fail to operate as intended if the system is not commissioned properly. The full commissioning process as defined in ASHRAE Guideline 0-2005, *The Commissioning Process*, details a complete process of verifying that the owner's requirements and design teams intent have been met. The full process starts from early in the design phase and continues for the life of the

project (through the Occupancy and Operations Phase). Therefore commissioning is not just a new building activity; there are ongoing PTP and commissioning requirements. This paper will primarily focus on the PTP testing procedures and BAS functional tests. Final commissioning cannot occur until a complete PTP checkout has been completed. PTP testing is a critical prerequisite for functional testing of building systems.

The author's experience in the Middle East has been that the commissioning exercise was typically left to the contractors. And while there are many professional contractors in the region who carry out the necessary testing there are several disadvantages to this:

1. The individual contractors only test the components they have installed and therefore no testing of the components as an integrated system is done.
2. Due to the fast paced development in the region over the past few years it has been the author's experience that many systems are not thoroughly commissioned and clients accept systems that do not perform as required. This generally results in increased building operating costs, inefficient buildings and tenant dissatisfaction.
3. Systems are often commissioned during the final stages of the project by the Test And Balance (TAB) contractor's personnel who may lack the details of the sequences of operations required by the BMS to ensure that the system functions as intended.
4. Commissioning documentation is typically not given the attention it requires resulting in the Owner not being provided with complete as-builts and Operations Manuals so that they can properly manage the facility.

More recently there has been a positive trend towards appointing third party independent commissioning firms to manage the commissioning process and provide a documented record to ensure that the Owner's requirements are met and that the building operates as intended by the design team.

Additionally, the common misconception that retaining third party independent commissioning agents adds cost to the project is now slowly being dismissed. The commissioning process is a quality-based method that is intended to reduce the cost of delivering construction projects while increasing Owner and end user satisfaction.

Point-To-Point (PTP) Testing

A crucial part of the commissioning process is the Point-To-Point testing of the field devices. Complete PTP testing verifies readings from sensors in the field all the way back to the operator's station and confirms correct mapping of points on the Graphical User Interface (GUI). A minimum of two commissioning agents is required for PTP testing; one to inspect the field installations while the other confirms readings on the GUI.

PTP testing starts with ensuring that the end device installed is in fact what was specified. For example, in the case of a temperature sensor, the tester must verify that the correct type of sensor has been installed. This includes verifying the accuracy, wiring configuration, temperature range and transducer (if applicable).

The next step is to verify that the end device has been installed correctly and in accordance with the manufacturer's requirements. This includes examination of the device's mounting, wiring and installation location. The installation location of a sensor may greatly influence the accuracy of the readings. The end device and wires should be clearly field labelled and the wiring terminations at the BAS control panel should also be appropriately labelled. Additionally a complete wiring diagram of the BAS control panel should be provided within the panel enclosure.

The tester should then verify that the end device is communicating properly with the control panel, the operator's workstation and is mapped correctly on the Graphical User Interface (GUI). This procedure varies based on the type of point and end device.

Sensors

For sensors a typical inspection will include verifying the device's accuracy using an accurate hand-held

instrument reading taken as close as possible to the sensing element. However, this alone does not guarantee that the sensor is mapped correctly, as it may be a coincidence that another sensor on the system is reading the same value. The tester needs to confirm that the sensor being investigated is the actual one being monitored on the GUI. This can be done by varying the sensor's reading and confirming the change on the GUI; the simplest way of achieving this is disconnecting the sensor in the field.

Actuators

Actuator inspections involve verifying the actuator's fail safe or 'normal' position and then stroking the actuator through a full cycle and ensuring that the end device fully opens and closes. It is also necessary to confirm that there is no flow when the actuator closes the end device. For example, in the case of a valve a differential pressure sensor across the coil could be used to verify that the valve is not leaking.

Controlled Digital Outputs

The verification of the Digital Outputs is triggered from the GUI. The tester should issue a command to the BMS to turn On/Off a particular piece of equipment and the field tester should confirm that the correct equipment is Started/Stopped. The time for the command to be sent and the equipment started should also be noted and compared to the specified times.

Digital Inputs

Most digital inputs are status signals and are typically verified in conjunction with the Digital Outputs.

Functional Testing

The PTP testing is considered part of the Pre-Functional Testing procedures. The next step in the commissioning process is to carry out coordinated Functional Tests on the systems. The Functional Tests cannot be carried out until PTP testing has been completed and documented. During the Functional Testing phase all coordinated sequences of operations are tested. These tests are typically carried out for, at minimum, each unique system to verify that the operation of the system matches the design sequence of operations. These tests may include several different contractors/suppliers to ensure that the integrated system operates as intended. All modes of operation (Start-up, Shut down, Emergency, etc) are inspected during these tests. Additionally alarm limits, trends, overrides and other system configurations are witnessed during this phase.

Test Equipment

Calibration of sensors is necessary to ensure that they are reading accurately and therefore the automation system is controlling correctly. During field calibration the Commissioning Agent uses accurate hand-held instruments to take readings near the sensor being checked and compare results with the BMS. Differences can then be adjusted to ensure that the BMS is controlling based on accurate readings. The hand-held instruments used by the Commissioning Agent must be selected with an overall accuracy that is suitable for the application. Additionally if multiple sets of instruments are being used it is imperative that one master test instrument is used to calibrate all instruments from.

PTP DOCUMENTATION

A critical part of the commissioning process in general is the documentation of the test findings and results. During the design phases the Commissioning Agent should provide Pre-Functional and Functional Test plans that are to be used to document the Commissioning Process. These should include PTP test sheets for the documentation of the testing (and example of a typical PTP test sheet is provided in Table 1). This documentation is to be clearly organized and provided to the Operators when the facility is handed over and serves as an integral part of the Operations and Systems manuals.

CONCLUSIONS

In conclusion, the commissioning process is an essential part of any project and professional independent commissioning agents should be considered part of the standard project team. Retaining a commissioning agent early on in the design phase so that they can provide specification input as recommended by ASHRAE is beneficial.

PTP testing has many important benefits some of which are:

1. PTP testing aids in meeting project construction deadlines. The commissioning agent manages the process of PTP testing

during the construction phase. This not only reduces delays by catching problems early on but also can identify systems that are deficient early so that they get the necessary attention. This provides early identification and resolution of issues that may delay the project.

2. Provides Owners with a high level of comfort that the systems they are accepting meet their requirements and the design team's intent.
3. Reduces labour and material costs due to correcting defects that are discovered after handover. These defects are typically found as a result of tenant complaints.

REFERENCES

ASHRAE Guideline 0-2005. *The Commissioning Process*

ASHRAE Guideline 1-200X. *The HVAC&R Commissioning Process (Technical Requirements)*