Selecting and Specifying Building Automation System Sensors

Considerations for upgrading sensor performance

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Building automation systems (BAS) are extensive and sophisticated systems empowered to monitor and control millions of dollars worth of equipment spread over dozens, perhaps hundreds, of buildings. With all of the different types of BAS available, one common thread ties the systems together—you can only control what you can measure. To affect measurement, the BAS primary input device is the humble sensor.

A wide variety of sensors are produced for the analog measurement of common HVAC system controlled variables—temperature, humidity, pressure, flow, power, and air quality to name a few. These sensors are available from BAS-equipment manufacturers as well as several companies specializing in the production of HVAC sensors. Other manufacturers build precision instrument grade sensors and meters that can be used in HVAC applications.

Achieving the expected BAS operational performance, energy efficiency, and reliability requires attention to the design, selection, and specification of the sensors. It also requires an understanding of how the sensor interfaces with the HVAC systems and the BAS.

Basic HVAC system sensor selection criteria are:

- Accuracy and uncertainty.
- Application and function.
- Reliability and quality.
- First cost and life-cycle costs.

While many exotic types of sensors may be available, this discussion is limited to the sensors practical for building HVAC systems.

ACCURACY AND UNCERTAINTY

How important is the deviation between the measured value and the true value? Accuracy is defined as the capability of an instrument to indicate the true value of the measured variable. Usually, inaccuracy is of greater concern. Inaccuracy is the deviation from the true value due to all causes of error, including non-linearity, hysteresis, repeatability, drift, resolution, noise, and temperature effect, among others.

It also is important to realize that the measurement process in direct-digital-control systems typically involves a sensor, transducer, signal conditioning, analog-to-digital conversion, and software processing to produce a final digital value for the measured input variable. Errors may be introduced at any part of this measurement process. Evaluation of sensor to digital value inaccuracy may require an uncertainty analysis to estimate the measurement errors and determine how the errors propagate. A discussion of measurement errors and uncertainty analysis was featured in the October 2000 issue of this magazine.

Meter type	Typical accuracy	Turndown rangeability	Low-flow cutoff
Orifice differential pressure	+/- 4 % of reading	3:1	1.0 fps
Venturi differential pressure	+/- 3 % of reading	4:1	0.5 fps
Turbine impeller	+/- 1 % of full scale	30:1	0.5 fps
Turbine propeller	+/- 2 % of reading	75:1	0.1 fps
Vortex shedding	+/- 1 % of reading	20:1	0.3 fps
Magnetohydrodynamic	+/- 5 % of reading	100:1	0.04 fps

Notes: Typical HVAC-type liquid-meter values are noted. Actual values vary from meter to meter and manufacturer to manufacturer

TABLE 1. Various types of liquid flow meters with the typical accuracy and turndown rates normally applied to HVAC systems.

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APPLICATION AND FUNCTION

Is the sensor used for general indication, system control, critical monitoring, or performance verification? Standard HVAC grade sensors normally are adequate for general indication and relative control, for example, sensing water temperature to determine if heating water is available, coil entering-air conditions or maintaining room temperature relative to occupant comfort.

Applications requiring absolute control or critical monitoring often dictate a sensor upgrade to achieve an improved level of control. Consider the absolute control application of maintaining supply air temperature at 55 F in an air-handling system with terminal reheating capability. A total measurement error of up to 2 F is not uncommon with conventional non-commissioned HVAC BAS systems using single point temperature measurement. The measured and controlled value of 55-F supply air maintains a true supply-air temperature of 53 F. A significant energy penalty results from the additional 2 F of terminal reheat energy required any time the system is operating at minimum air-flow volume. A further loss of system efficiency occurs from operating the system at unnecessarily low temperatures. This energy penalty is transparent to the building operator, who is under the impression that his sensors and transducers have been factory calibrated. An offset of 2 F in the other direction results in excess air flow and possible loss of comfort due to the elevated true supply-air temperature.

For absolute control applications, consider upgrading the temperature sensor to a device with higher accuracy, minimal drift, and multiple sensing points. Critical monitoring and control applications such as maintaining a health and safety laboratory pressure requirement of negative 0.05-in.WG, also justify an upgrade to a precision sensor with greater stability.

It is increasingly common for the BAS to measure the chilled water, heating water, and electrical energy consumption of a building or tenant space to verify energy performance or sub-metering of utility costs. This "cash register" application warrants a meter with a higher system accuracy over the entire operating range. The electric meter should be specified to meet ANSI standards for metering. Measuring chilled and heating water energy consumption requires accurate and reliable temperature measurement as well as flow measurement. The critical factor for both air and water-flow measurement is the actual accuracy over the expected flow range and the "turndown" of the meter. If large variations in flow are anticipated, a meter with a higher turndown provides better readings at low flow rates. Table 1 lists various types of liquid flow meters with the typical accuracy and turndown rates normally applied to HVAC systems.

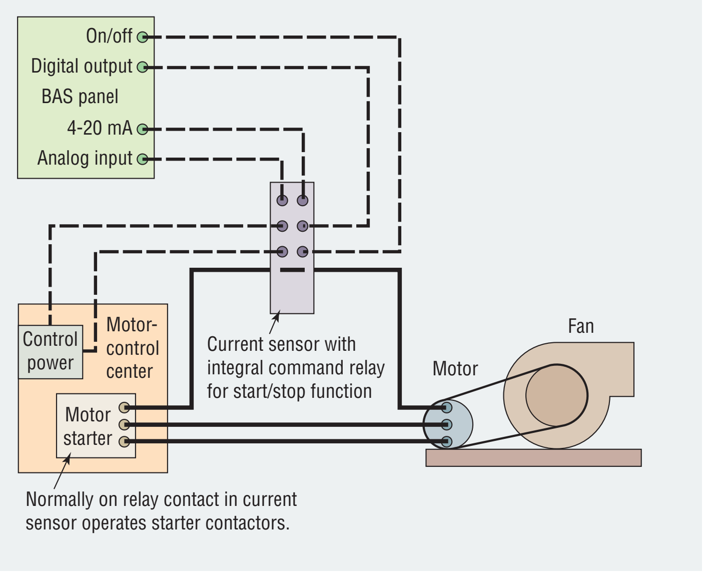

FIGURE 1. Current sensors with integrated command relay for start/stop applications.

RELIABILITY AND QUALITY

Will the sensor continue to fall within the specified limits for accuracy and precision considering the realistic commissioning, operating environment and ongoing calibration and maintenance efforts the sensor will receive over its useful life? Frequently, sensors are designed to fail because they are not suited to the environment in which they operate. Consideration must be given to moisture, vibration, temperature extremes, condensation, vandalism, and other aggressive environments. Special enclosures may be necessary for cleanrooms, prisons, operating rooms, washdown areas, etc. The reliability of the sensor is enhanced by specifying completely encapsulated circuitry, sealant filled connectors, and Teflon-jacketed lead wires. Transmitters hardened against electromagnetic interference eliminate inaccuracies due to electrical noise from variable frequency drives, motors, machinery, and broadcast signals.

Accessibility and ease of service plays a role. Routine calibration and maintenance may be hampered by a remote or inaccessible sensor location. In these cases, an upgrade to a more rugged and higher-quality sensor may be justified on a maintenance cost basis. The need for operational reliability may warrant the use of a redundant or backup sensor. Some temperature-sensors are available with dual temperature sensing elements calibrated and matched within a specified tolerance. The dual-element feature allows a simple reference calibration or a quick changeover during an emergency.

The best high-accuracy precision-grade sensor becomes unreliable after an extended period without necessary calibration and maintenance. Accuracy and quality should not be confused when selecting sensors requiring a high level of reliability.

FIRST COSTS AND LIFE-CYCLE COSTS

The cost characteristics of sensors range from commodity products priced at a few dollars each to precision instruments costing several thousand dollars per point. The incremental cost of upgrading a sensor often is justified on a life-cycle-cost basis with consideration for energy, reliability, and maintenance costs over the expected service life of the sensor.

It is worth noting that sensor installation and setup costs are a significant part of the total installed cost of a typical building automation system. Although the upgrade sensor itself costs more, the installation costs are generally the same and, in some cases, less than the installation costs of an inexpensive commodity sensor. Purchasing sensors from an independent source may also be more cost effective than through the BAS equipment supplier.

The total cost per point may often be reduced by specifying integrated or combination type sensors and meters. Some examples include:

- Combination temperature and humidity sensors for room, duct, and outside air applications.
- Integrated electronic air-flow and temperature-measuring stations.
- Integrated water flow and temperature measuring stations for energy metering.
- Current sensors with an integrated command relay for start/stop applications (Figure 1).

These sensors reduce the number of installed components and wiring costs and also save space and installation time.

CONCLUSION

Selecting and specifying the proper sensor requires reconciling accuracy, application, reliability, and costs. Upgrading the sensor is the first step in reducing system inaccuracies and improving the reliability of the system. A life-cycle-cost approach is valuable when considering the relative merits of various sensors. Sensor technology continuously advances. The future will hold an increasing number of smart sensors capable of providing a highly accurate digital signal directly to the BAS control network.