AIRCUITY®

OptiNet™ Applications

A Review of the Unique Requirements for a Facility Monitoring System

White Paper Series

A Review of the Unique Requirements for a Facility Monitoring System

Overview

The surging cost of energy in recent years, coupled with the rapid growth and interest in building more sustainable and healthier buildings, has dramatically increased the interest in building and retrofitting facilities to be more energy efficient while also enhancing a facility's indoor environmental quality (IEQ). These facilities sometimes referred to as green buildings or "high performance" buildings use increased amounts of controls and environmental sensors to achieve the aforementioned benefits. Unfortunately, oftentimes desired levels of energy efficiency and indoor environmental quality are not achieved. One of the major reasons this shortfall occurs is that the quality, accuracy, and quantity of indoor environmental sensors that are typically used are not sufficient to successfully and cost effectively implement many of the energy efficiency approaches that are tried. Even more often, information about the quality of the indoor environment is not sensed at all due to the cost of doing so, leading to situations where systems do not properly control, resulting in complaints, and subsequent disabling of the control approaches, and finally the loss of the anticipated energy savings. The above problem is most acute and significant in its impact on building operation with respect to the control of the building HVAC (Heating, Ventilating, and Air Conditioning) systems and often with respect to the use and control of outside air.

Requirements for a Facility-wide Sensing System

To successfully and cost effectively enable energy savings applications such as demand controlled ventilation and differential enthalpy economizer control, a multi-parameter, multiple location, facility monitoring system should be deployed and at least meet the following four requirements:

Facility Monitoring System Requirements:

1. Low first equipment and installation cost per parameter for many locations
2. High reliability, with low calibration and maintenance costs
3. Sense a broad range of indoor environmental parameters & air contaminants
4. High absolute sensing accuracy and very high differential sensing accuracy

The latter differential sensing accuracy refers to sensing the difference in an air parameter such as carbon dioxide between outside levels and inside levels. The accurate measurement of this difference is important to saving significant energy in buildings by accurately controlling the amount of outdoor air into a building.

Traditional Approaches to Sensing Air Parameters in a Facility

Traditionally, indoor air parameters such as temperature, humidity, carbon dioxide and other parameters have traditionally been sensed by field wiring individual air parameter sensors into a building control or automation system. This works fine for a simple, inexpensive and reliable sensor such as: a temperature sensor. However, building monitoring requirements for indoor air parameters have increased so that many locations need to be monitored for other parameters such as: relative humidity, dewpoint temperature, carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOCs), odors, fine particles, etc., the number of sensors can be overwhelming. Some of the problems with using multiple individual sensors are summarized below:

Problems with Traditional Sensor Approaches

High First Cost

- Many sensors required for multiple parameter, multiple location sensing
  - *First cost to sense many parameters quickly becomes prohibitive*
  - *Commercial grade sensors often used, causing poor accuracy & reliability*

High cost of installation & integration

- A single hard wired Building Automation System CO_2 or RH point can range from: $1,000 to $1,500/pt.

High Operating Costs

- Accuracy required often beyond sensor limits
  - *Poor performance results = Lost energy savings*
- High maintenance cost
  - *Every sensor needs periodic calibration (1x - 3x/yr)*

Poor Differential Sensing Accuracy

- Use of two sensors doubles normal sensor
  - *Each location requires its own sensor*
- Signal differences can be small relative to individual location signals
  - *Signal errors are further magnified by trying to measure a small difference*

The use of individual sensors wired into a building control system can be prohibitively expensive when even a few parameters are to be sensed. Beyond temperature sensing even relative humidity and carbon dioxide sensing can be quite expensive due to the high cost of wiring, installation and integration of each sensor into a building management system. Often times, poor commercial grade sensors are used with poor accuracy and reliability that waste energy or cause environmental complaints due to drifting performance and reliability problems. Even with the use of lower grade sensors, the cost of installation can raise the installed cost of a relative humidity or carbon dioxide sensor into a range of $1,000 to $1,500 per point.

An equally serious problem with the use of individual sensors is that the calibration and maintenance cost of using this large number of sensors is quite expensive and difficult to manage. Environmental sensors other than temperature need to be calibrated one to three times a year based on the type of sensor, if accurate information is desired. Unfortunately, overworked maintenance staffs often do not have time to calibrate even a few sensors, let alone hundreds of them. Accessing, un-mounting, and calibrating the sensor with a minimum span and offset calibration using test gases (or the use of salts for a relative humidity (RH) or dewpoint temperature sensor), plus remounting the sensor can take from one to two hours or more per sensor based on the type and location of the sensor. Factory calibration, although more accurate, is very difficult with installed systems which can not be taken out of service for a week or two to have the sensors calibrated, particularly with the number of sensors involved.

Lastly, individual sensor approaches suffer from very poor differential measurement accuracy. Differential sensing is a core requirement of many energy saving ventilation control applications such as outside air control and differential enthalpy control of an air handler's air conditioning system (as is described in the next section). For example, good quality CO_2 sensors have an accuracy of about ± 75 PPM. To make a differential measurement of indoor CO_2 measurements vs. outdoor measurements, requires two sensors using this approach. Thus the differential measurement can have an error that is double the previous numbers or ± 150 PPM, which could be the case if the two sensor are at opposite ends of their error ranges. For proper building operation, a typical CO_2 setpoint above outside levels will be 375 PPM to take into account the sensor tolerances. With the above mentioned errors, the actual CO_2 could then be off by ± 40%! In terms of outside air volume this translates into a potential for almost doubling the outside air flowing into a building. In a climate such as Chicago, this could increase energy costs by $0.10 to as high as $0.40 per square foot per year.

Distributed Packaged Sensor System Solutions

Packaged sensing systems have tried to provide a more economic solution compared to traditional sensing of multiple parameters as expressed previously. Rather than field mount and wire many individual sensors, these systems use wall mounted, multiple sensor, monitoring units that contain one to many sensors, and are wired as one device. This reduces installation costs particularly when more than a couple sensors are desired. However, on a per sensed parameter basis, the first cost can be up to 50% more than a distributed sensing system noted further on, even though the sensors used are inexpensive, commercial grade sensors. As an example, the carbon monoxide sensor relies on a metal oxide sensing element often found in detectors used in residential applications. Although good for go/no-go detection of high levels of carbon monoxide, they drift substantially over time, have limited sensitivity to low, but still health affecting levels, and can be affected by other gases. Basic performance accuracies for a carbon dioxide sensor used in these systems are ± 100 PPM vs. the ± 75 PPM mentioned earlier.

Distributed packaged sensing systems also suffer from the same problems mentioned previously regarding calibration expense and the inability to provide accurate differential sensing. As such, these systems are challenged at implementing the many energy reducing ventilation control approaches such as demand controlled ventilation. Regarding calibration expense, when the cost to field calibrate and replace the sensor elements is included in a 5 year life cycle cost, these systems become prohibitively expensive. Lastly, the downside to having a prepackaged sensor unit is the difficulty of adding any additional sensors in the future since these systems are often not configured hardware wise, or via software for any additional sensors. Furthermore, the sensors and packaging of these systems often times do not offer outdoor air and duct mounted sensing, adding yet another obstacle to ventilation control applications.

Shared Sensor System Solutions

To significantly reduce the number of sensors and the calibration requirements needed to accurately sense multiple parameters at multiple locations, a shared sensor approach can be used. The basic concept involves moving air samples from a room or location back to a centralized or shared sensor that sequentially monitors air samples from many areas. This concept is not new and has been used for over 20 years for sensing carbon monoxide in garages, for refrigerants in a penthouse, or even for particles over short distances (less than 100 feet) in clean rooms. These single sensor systems all use the same structure, namely an octopus like system using dedicated, home run tubing connections between the sensed location and the air monitoring unit. The monitoring unit contains both the sensor(s) and solenoid valves to switch the air samples into the sensor(s) from the many sampling tubes. These completely centralized systems have all sensors and controls in one box and, as such, are not modular in their application in terms of the cost of switching solenoids and controls.

A shared sensor system based on a home run or octopus structure avoids many of the problems mentioned earlier regarding individual sensor systems. In addition to many fewer sensors and lower calibration expenses, these types of systems can inherently provide true differential sensing capability. In a shared sensor approach the centralized, remote sensor can sense the outdoor conditions, and then within a few minutes also measure the indoor conditions. By then subtracting these two signals, a differential signal is produced where almost all of the sensor's error is canceled out creating a very accurate differential signal.

One of the more significant concerns with this type of system is the massive amount of tubing that must be installed in the building to bring all the individual samples of air back on their own dedicated tube. This increases installation costs significantly, while also reducing the future expandability of the system. In fact, unless extra unused tubing is pulled throughout the building during building construction or fit-out, a pneumatic tube that is potentially hundreds of feet long must be retrofitted into the building for every added location that is to be sensed. Therefore, although the number of sensors has been reduced substantially, significant overhead in terms of system hardware, and installation is needed for this type of system in addition to the sensors themselves.

A second disadvantage with this system is the limited number of sensed parameters that can be sensed. The problem with this type of system is that the polyethylene pneumatic tubing commonly used by these systems can not transport many air parameters beyond the gases mentioned. Any VOCs or odors, and many gases will be absorbed into or desorbed out of the tubing which would significantly affect the accuracy of successively sampled readings from a given location. Since these tubes are sitting with no airflow through them for more than 90% of the time, VOCs and other gases can linger in the walls for hours and even days until they finally flush out, significantly affecting any readings for those locations. Particle performance is also very poor for any significant distance due to the high particle losses in the tubing as a result of electrostatic and gravity losses. Even a simple parameter such as temperature can not be sensed since the temperature of the sampled air changes very rapidly as it moves through the tubing and within a few meters is the same temperature as the tubing walls. As a result, although dewpoint temperature or the amount of water vapor in the air is sensed, it cannot provide a measurement of relative humidity, another common parameter of significant interest from a controls standpoint since room temperature is also needed for measuring this parameter.

A third major issue with these systems is a concern over its inherent integrity and the reliability and accuracy of the sensed information from the system. Due to potentially long tubing runs scattered throughout the building, it is not unlikely that some of this tubing could be damaged during installation as well as during the life of the system due to work done in cable trays, or in the ceiling spaces where this tubing is located. Although this problem can and does happen with any cabling or tubing running through a building, these systems traditionally have no means to detect that the tubing has been damaged or cut, resulting in air samples being drawn from another area or riser space instead of the intended locations.

A New Solution: Multiplexed Sensing with OptiNet™

Shared sensing systems solve many of the problems involved with using many discrete sensors in buildings to sense multiple parameters at many locations. Unfortunately, the shared sensor systems introduce many new problems specific to their sensing approach that have limited the commercial acceptance of those systems.

The OptiNet system from Aircuity provides a solution to the three major problems of shared sensor systems while still retaining the advantages of this approach. To provide a solution to the first issue of having many long dedicated tubes throughout the facility, OptiNet uses a networked air sampling architecture. A common, hollow backbone cable known as OptiNet Structured Cable, and Air Data Routers situated along the backbone, switch air packets from the sensed locations using solenoid valves that are located in the routers onto the backbone and then back to a Sensor Suite. By using a common backbone cable that contains an air transport conduit, the large amount of parallel run tubing used in the home run or octopus approaches is substantially eliminated, reducing the amount of cable required by OptiNet. Additionally, the system is very modular and easy to expand since a new router can be spliced into a section of the backbone cable to pick up additional points. The backbone cable can be extended to a new area to be sensed, similar to how a building control network bus can be easily expanded, or new controllers added to the system at little extra cost. Additionally, by combining all the wires required by the system such as low voltage power, data communications, and signal wires into the same structured cable containing the air sample conduit, installation costs are further reduced.

To further reduce calibration costs beyond just the reduced number of sensors needed by a shared sensor system, OptiNet has placed its sensor elements into removable rack mounted cards that can be swapped out of the Sensor Suite in minutes. As a result, a "Netflix™" type of service is offered where on a periodic basis such as twice a year, a calibrated set of sensor element cards is shipped to the local OptiNet representative or customer. The customer or representative then pulls out the existing sensor cards and replaces them with the recently received freshly calibrated cards. The old cards are then sent back to the factory for cleaning, calibration and shipment to another customer. In this way, as with Netflix's DVDs, a pool of sensor cards rotates through many different customers. Since a sensor card can be rapidly and very accurately calibrated at the factory using special test fixtures, this service provides a very cost effective solution to calibration. In fact, if problems with calibration are detected remotely through the web interface, new sensors can be shipped to the customer before the customer might even know the sensor has a problem.

To solve the limited sensing capabilities of shared sensor systems, OptiNet's nanotechnology based MicroDuct™ air sample conduit uses a mixture of carbon nanotubes and a fluoropolymer resin to line the inside walls of the MicroDuct. This creates an inert, flexible, and electrically conductive layer that allows an almost unlimited number of air parameters including VOCs and particles to be sensed accurately.

Another parameter that shared sensor systems cannot sense is temperature. OptiNet solves this problem uniquely since the OptiNet Structured Cable that contains the sample conduit also contains a data communications cable and signal wires. These additional wires are used to connect to a wall mounted temperature sensor located at the sensed location that also contains a screened inlet and port to the MicroDuct conduit. If for some reason another parameter was desired to be sensed locally as well, the appropriate sensor could also be located in the room sensor enclosure giving the system significant flexibility due to its hybrid local and shared sensor sensing capabilities.

Finally, OptiNet solves the third major problem of shared sensor systems relating to sensed data integrity through several features. Firstly, OptiNet locates the solenoid switching valves near the sensed locations instead of near the sensor. As a result, all the solenoid valves can be closed periodically and the entire backbone tube can be vacuum pressure checked for any flow leaks. Additionally, the OptiNet Structured Cable contains multiple conductors that due to the sensing of temperature and the network communications cable, any break or cut in the cable that might affect the MicroDuct would also sever these wires creating a fault condition that would be sensed. The pressure drop from the sensed location back to the sensor suite is also monitored so that any blockages or crimping of the cable can also be detected.

Regarding the integrity and reliability of the sensors themselves, a shared sensor system has the increased vulnerability of having a failure of a sensor affect not just one room but many rooms. On the other hand, whereas it is difficult to detect sensor drift in any given local sensor used in a many sensor approach with building control systems, OptiNet provides a capability to significantly increase a sensor's reliability. This is because when many locations are sensed with a single sensor, errors or drift in a sensor can be easily detected by comparing the results from multiple rooms and even an outdoor location. Where one room might exhibit an unusual change in signal, it is highly unlikely for all areas to see the same error. Additionally, since outdoor levels have fairly well defined characteristics, unusual sensed outdoor values, particularly if they persist over time are clear clues to sensor problems. This calibration and error checking can also be monitored remotely via the web for automated analysis and notification of problems further enhancing reliability. Lastly, OptiNet is able to use higher grade and higher quality sensors cost effectively, further enhancing the integrity of the system's data.

Summary

By addressing the drawbacks inherent in using discreet individual sensors, packaged sensing systems, as well as shared sensing approaches, OptiNet's cost effective multiplexed sensing system, effectively draws upon the positive aspects of all three approaches, to meet the unique requirements for a Facility Monitoring System. The system addresses industry acknowledged deficiencies inherent in conventional sensing approaches used to control building ventilation. As expressed, these approaches either lack the required accuracy for reliable control, or are not cost-effective due to their prohibitively high first cost and high maintenance costs. OptiNet delivers on the long-sought promise of buildings designed for both energy efficiency and environmental quality. The result is reliable, cost-effective ventilation control that reduces energy costs without sacrificing occupant comfort, health or productivity.

About Aircuity

Aircuity is the leading manufacturer of integrated sensing and control solutions that cost-effectively reduce building energy and operating expenses while simultaneously improving indoor environmental quality. Aircuity's goal is to optimize building ventilation for energy efficient performance without sacrificing occupant comfort, health, or productivity.

The company's systems are suitable for a broad range of commercial building applications where energy efficiency and enhanced indoor environmental quality are important, including offices, laboratories, hospitals, educational institutions, museums, convention centers, and sports arenas.

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