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Integrating Chillers and Building Automation Systems

By Richard Robertson and Rob Moult

Richard Robertson is Vice President - Southeast Asia for McQuay International and Rob Moult is Director - Southeast Asia for Johnson Controls.

Chiller manufacturers have been providing chillers equipped with sophisticated, microprocessor-based control panels for many years. These advanced controls have helped the industry achieve record energy efficiencies (COP) and have dramatically increased he level of instrumentation available to monitor, maintain and have dramatically increased the level of instrumentation available to monitor, maintain and service chiller system. In some cases, these control panels have also created the opportunity for the chiller to share most of this information with the Building Automation System (BAS).

This article will attempt to describe the type of information that can be shared between chillers and the BAS and the benefits to the building manager if this integrated capability is fully implemented.

McQuay Centrifugal Chiller with Control Panel (Inset)

What can be Integrated

There are two types of information available at a chiller control panel that can be shared with a BAS.

- Monitoring information such as temperature, pressure, status, alarms, etc.
- Control information such as start/stop and set-point adjustments.

As an industry example, **Table 1** lists the information available to a Johnson Controls BAS from a McQuay centrifugal chiller. The table gives an indication of the amount and type of information available. The actual information available for a specific project will depend on the brand of BAS, the type and brand of the chiller, the options installed with the chiller, and the communication interface between the chiller and the BAS.

Table 1: Information Available to Building Automation System from Chiller

Generally, any information that can be displayed at the chiller control panel can be monitored by the BAS and a limited subset of the information that can be controlled by the chiller control panel can be controlled by the BAS. BAS control is typically limited to remote start/stop, resetting the leaving chilled water set-point and resetting the demand (amp) limit signal. The chiller control panel will not allow the BAS to override safety controls or cause unsafe operating conditions.

How the Chiller and BAS are integrated

The Chiller manufacturer and the BAS manufacturer must work as partners to achieve a successful integration.

The chiller manufacturer provides a high-level connection point into their chillers (typically EIA-232 or EIA-485). The chiller company releases all of he message formats to the BAS company (their "protocol") and participates in joint testing, certification and documentation with the BAS company.

The BAS company has the responsibility of providing a high-level connection point into the BAS and developing the software necessary to convert the messages from the BAS and vice versa.

In brief, to make an integration work, the chiller manufacturer releases information and cooperated during testing while the BAS manufacturer undertakes the software development. To avoid confusion, it is best for the consultant or end-user to ask the chiller manufacturer for the list of BAS that they have already integrated with and it is best to ask the BAS manufacturer for the list of chiller makes and models that they have already integrated with. It is also important to ask what information is exchanged through this integration. If there is a proven, off-the-shelf, integration already in place for the selected chiller and BAS, then the work at site is simplified and future technical support is assured.

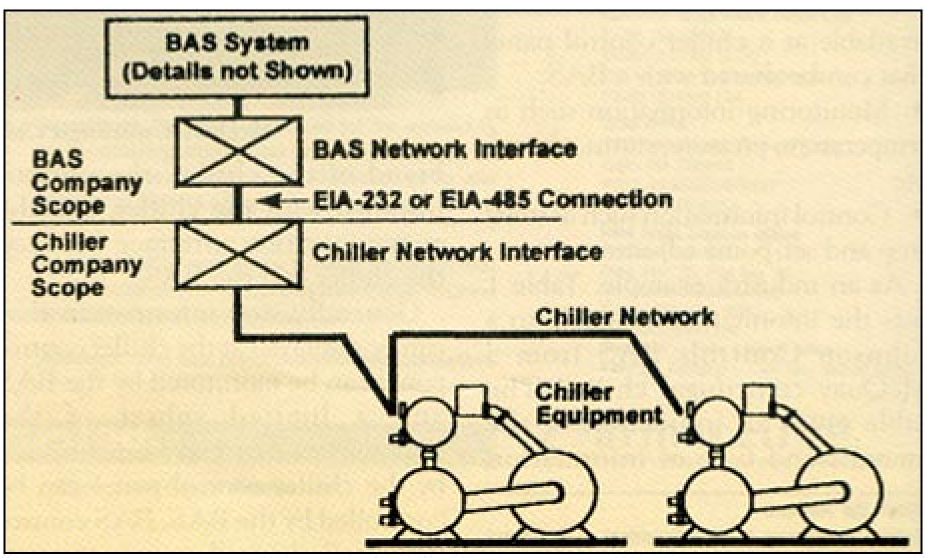

Figure 1 : Chiller Connection to BAS

As shown in **Figure 1**, the components necessary to integrate a Chiller and a BAS are as follows:

- **Chiller Network** - provided by the chiller manufacturer - interconnects the chiller system.

- **Chiller Network Interface** - provided by the chiller manufacturer - provides addressing and converts messages on the chiller network to an EIA-232 or EIA-485 format.
- **BAS Network Interface** - provided by the BAS manufacturer -converts messages from the chiller network interface to a format compatible with BAS.

In the past few years, two standard protocols have emerged, ASHRAE's BAC net and Echelon's Lon Works. These protocols hold the promise of greater connectivity between chillers and BAS. At some point in the future, application of these protocols may allow the elimination of the Chiller Network Interface, the BAS Network Interface, or both. But since the implementation of these protocols is still in its infancy, it is best not to get caught up in the jargon and instead, determine exactly what has been accomplished and proven on current projects.

Why Integrate the Chiller to the Bas

There are a number of justifications for integrating the chillers with the BAS, including:

- Reduced installation cost
- Enhanced energy management
- Application of BAS management features
- Building operator training
- "Single set" user interface

Reduced Installation Cost

Integrating the BAS with the chiller plant through a high-level communication interface can substantially reduce installation costs. This takes full advantage of all the sensors and system control accessories that are supplied with the chillers, preinstalled and tested at the factory, and eliminate wasteful duplication of components and wiring. For example, some chiller control panels include the chiller control panels include the digital outputs necessary to start and stop the lead and lag chilled water and condenser water pumps in the sequence required for the safe operation of the chiller system. When this integral capability of the chiller is used, the BAS can monitor the status of the pumps through the communication interface without duplicating any digital outputs, relays or wiring costs.

The same principal applies to the chiller's factory installed water temperature sensors. There is no need for the BAS to duplicate these sensors when all the data can be shared through the communication interface. This logical sharing of sensors also eliminates troublesome control conflicts that can arise if data is input from two slightly different sensors reading the same temperature point.

Enhanced Energy Management

To minimize energy and demand costs, it is important to have both energy efficient chillers and an appropriate chiller plant control strategy. An energy required to deliver a given leaving chilled water temperature. The chiller plant control strategy will determine the leaving chilled water temperature that meets the current building requirements while minimizing energy consumption.

Table 2 shows a comparison of various types of chillers. The COP rating is a rough indication of the chillers at nominal ARI conditions. To get a more accurate picture, the part load characteristics of the chiller should also be considered. The third column gives an approximate indication of how much the energy consumed by the chiller will change as the leaving chilled water temperature is reset by one degree Celsius. For example, a centrifugal chiller operating at 1040 kWt may consume 173.3 kW of power if the leaving chilled water temperature is 6°C. Consumption will reduce by 3.5% to 167.2 kW if the leaving chilled water temperature is reset to 7°C while holding all other conditions constant.

Table 2: Nominal Chiller Ratings

Chiller Type	COP	ΔCOP/°C
Centrifugal	6.00	3.5%
Screw	5.70	5.5%
Reciprocating	4.00	2.5%
Absorption	0.95	2.5%

Using the BAS to reset the leaving chilled water temperature can be a significant source of energy savings. In the past, the leaving chilled water was reset based on the time of day or outside air temperature. Today, with the advent of direct digital control, it is possible to reset the leaving chilled water to just satisfy the particular part of the building requiring the most cooling. This is done by scanning the valve positions on the air handling units. **Figure 2** shows an algorithm used by the BAS to determine the optimal leaving chilled water set-point. This algorithm will maximize energy savings and ensure that the building loads are always satisfied. Am alert operator can monitor which of the AHUs is consistently calling for the most cooling and can save even more energy by fine tuning the water balancing.

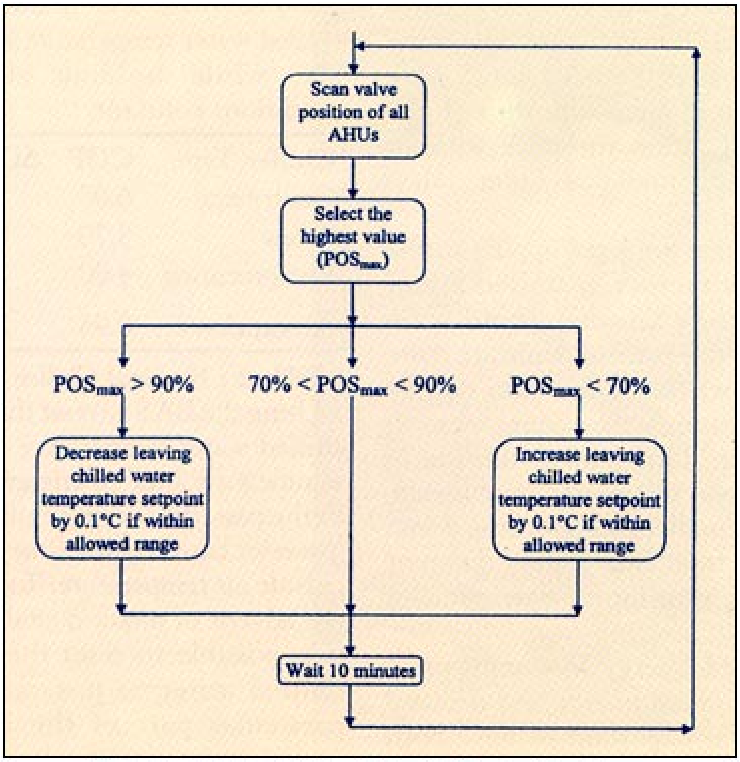

Figure 2 : Chilled Water Setpoint Reset Algorithm

A second energy management strategy commonly applied to chiller plants is chiller sequencing. There are a number of popular chiller sequencing algorithms which determine the most energy efficient combination of chillers to be operated based upon:

- Chilled water return header temperature.
- Plant load [flow x (chilled water return header temperature -chilled water supply header temperature)]
- A combination of chilled water return header temperature and plant load.
- Chiller amperage as a percentage of rated load amps (RLA).

Implementing a chiller sequencing algorithm for the first three methods requires the addition of sensors (flow and/or header temperatures) which are not internal to the chiller. The last method of chiller sequencing can be achieved without additional sensors.

As the single largest energy-consuming piece of equipment in the building, it is useful to include the chiller in the building-wide energy demand limiting strategy. The BAS has a predictive algorithm that anticipates when future demand will exceed the target, maximum demand.

Some utility companies invoice users according to their peak demand that is often based on the average kW consumption over a 15-minute interval. To reduce demand charges, the BAS calculated the average consumption over the past 10 minutes and uses this average to predict the future level of billed demand. If the BAS anticipates that the future demand will exceed a predetermined target, then BAS will take corrective action that may include:

- Sending a signal to one or more chillers to temporarily reset the amp limit.
- Shedding loads (turning off equipment) for a short period.

Since the building power and other loads are connected to the BAS, the BAS is in a position to implement a building-wide demand limiting strategy. The effectiveness of this demand limiting strategy is enhanced by high level communication with the chillers.

Applying BAS Management Features.

The following BAS management features can be applied to information available from the chiller when the chiller control system is integrated with the BAS:

• **Alarm Reporting** - A BAS works using a principle of "management by exception". The BAS continuously compares readings with "normal" any conditions and reports any exceptions. Exception reporting can take one or more of the following forms:

- Displaying a message at one or more operator workstations
- Printing a message at one or more printers.
- Storing a record of the event in one or more files residing on one or more operator workstations.
- Alerting the operator using various paging methods including off-site paging.

When interfaced with the chiller, the alarm management features of the BAS can alert the operator to any problems, or even potential problems, with the chiller system. For example, the BAS can indicate the possibility of a slow refrigerant leak by detecting a gradual increase in the liquid sub-cooling temperature. Or the BAS might alert the operator to the possibility of a blocked water strainer on the oil cooler if the oil temperature is trending upward.

• **Historical Data** - One of the main functions of the BAS is to provide historical data to assist the operator in troubleshooting mechanical system problems and for record keeping purposes. Many BAS allow historical data to be graphed and stored in a format that is compatible with popular business software such as spreadsheets and databases. When the chiller is integrated with the BAS, the historical data recording and management features of the BAS can be applied to any of the information originating from the chiller.

• **Maintenance Management** - To prolong the life of major equipment a preventive maintenance program is used which defines and schedules maintenance tasks. Some tasks may be scheduled based simply on the run-time of the equipment. The BAS can record the actual run-time of the Chiller and integrate this information into the building-wide preventive maintenance program. Other tasks can be more effectively scheduled based on detecting changes in operating conditions rather than simple run-time. For example, the BAS can track the condenser tube cleaning is required.

• **Dynamic Graphics** - To assist the operator to better understand the information presented, the BAS allows data to be presented in dynamic graphics. Dynamic graphics consist of a static background screen with real-time information or links to other graphics superimposed. Background screens are typically created using one of three methods:

- Scanning photographs or images (could be used for the exterior view of a building).
- Importing CAD drawings (could be used for floor plans of a building).
- Using a drawing tool and symbol library (to create a schematic of an AHU for example)

Using dynamic graphics a detailed diagram of the refrigeration cycle and other chiller functions can be drawn and actual field values can be superimposed. These values can include all of the pressure, temperature and other variables available from the chiller control panel. Dynamic graphics such as these are extremely useful in helping the operator understand in helping the operator understand the operation of the chiller system.

• **Schedule** - BAS are used to control building equipment based on a time schedule to save energy. Because of holidays, overtime, and variable temperature conditions, time schedules need to be constantly adjusted to accommodate the actual needs of the building. The operating schedule of the chiller is tied to the operating schedule of the air handling units. A BAS can provide a single point of entry for all time schedules to ensure that they chiller allows the BAS to send a master start/stop command to the chiller while still allowing the chiller to dictate the proper sequence for controlling is associated pumps and cooling its associated pumps and cooling towers.

Building Operator Training

An effective building operator can deliver a superior level of service and initiate innovative energy saving programs. To do this, the operator requires a good knowledge of the BAS, the chiller and the building systems.

Over the past ten years, BAS have become more and more user friendly but the buildings that they are installed in have become more and more complex. Today the average building operator has little trouble using the BAS to display information and issue simple commands. Though the building operator may know how to use the BAS, he may not understand the air conditioning or electrical systems in the building.

Of the building systems, the air conditioning system is:

- the most complex
- the most dynamic
- the largest energy consumer
- the most common sources of occupant complaints.

The chiller is at the heart of the air conditioning system. It is the most complex piece of equipment and consumes the most energy. For all these reasons, it is important that a building operator understand the functioning of the chiller. Using BAS features such as dynamic graphics and historical trends, drain upon a complete set of data supplied from the chiller via a high level interface, the building operator can become much more familiar with refrigeration cycle and the overall operation of the chiller plant. The learning process is further enhanced because the PC display located in the operator's office is much more conclusive to this type of discussion and instruction than standing in a noisy and hot mechanical room.

"Single Seat" User Interface

Some brands of chillers are able to offer a direct PC-based interface to their chiller. These PC-based interfaces have features similar to a BAS, except that they are usually limited to monitoring only the chiller plant. This is a useful and cost-effective capability when the building is not equipped with a system-wide BAS. However, if a PC-based interface is used for the chiller, in addition to a BAS, then the operator faces the following challenges:

• **Duplicated costs** - Some of the software functions and wiring of a PC-based chiller interface might be duplicated by the BAS. Also, the PC itself is probably duplicated.

• **Energy Management** - Energy management strategies which require access to building-wide information such as chilled water reset and demand limiting cannot be implemented as effectively if the BAS is not integrated with the chiller.

• **Operator Effectiveness** -Operator effectiveness is reduced when both a BAS and a direct-to-chiller PC interface are used because the management features (alarm reporting, historical data, maintenance management, dynamic graphics, scheduling and management reports) will be different on each system. This would require the operator to learn and adjust to two different ways of accomplishing similar tasks.

Conclusion

Today's chillers offer a wealth of information which, when fully integrated with the BAS, can offer significant benefits to building managers. These include enhanced energy savings, alarm reporting, maintenance scheduling, breakdown analysis, enhanced operator training, and reduced installation costs. These benefits are not limited only to new installations. Many existing chiller installations can be interfaced to BAS with compatible microprocessor control panels.

Whether evaluating a new or existing chiller installation, it is important to determine which brands of BAS have already been integrated with the chiller. Similarly, it is important when evaluating a BAS to determine which brands and models of chillers have already been integrated with the BAS. This information should be considered even if there is no plan to integrate the chiller and the BAS initially because the requirement may arise at a later date. Standard protocols such as BACnet and Lon Works are emerging as a major step toward connectivity, but the true measure of connectivity for any BAS and chiller system today is the list of existing, proven integrations which have already been accomplished.