Minimizing Energy Consumption by Improving the Automatic Control Management Approach to Building Automation Systems

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Keywords
energy conservation, visualization of control results, building automation systems, savic-net FX

Conventionally, the user interface of building automation systems (hereafter BA systems) has included state monitoring, setting of automatic control, and history management functions separately, with the coordination of these functions left up to the user. Moreover, the results of automatic control often have not been easy to distinguish. We have recently developed a system which makes it possible to promote the energy efficiency of a BA system (through the cycle of setting automatic control → visualization of control results → planning for improvement → setting of automatic control for greater energy efficiency) by adding a function that gives a bird's-eye view of history data related to automatic control (visualization of control results), and a display function for raising the awareness of building tenants regarding potential energy-saving measures.

1. Introduction

In order to qualify as a "top level company" as defined by Tokyo Metropolitan Government ordinance, and to deal with constraints on the supply and demand of electricity, a company must have a BA system that specifies an energy consumption target and is capable of achieving it. Conventionally, energy management functions have often been provided by adding a building management system (hereafter BMS) to an existing BA system, which however was done mainly for large buildings. Demand for a BA system that provides simple energy management at a low cost without adding a BMS has been growing.

To reduce energy consumption in a tenant building or the like, other than upgrading equipment, a building manager is limited to actions such as turning off the air conditioning and adjusting the heating or cooling setpoint for public spaces, without much opportunity for improvement. Since tenants occupy most of the building, it is essential to gain their cooperation in order to save energy. For that reason a BA system with a display function is desirable for raising tenants' awareness regarding potential energy-conservation measures.

2. System configuration

The system configuration of savic-net™ FX is shown in figure 1. Three optional functions (explained below) have been added to the System Management Server (SMS), Data Storage Server (DSS), and System Core Server (SCS, used for integrated control), which make up the central monitoring system.

The SMS, DSS, and SCS have display, management, and control functions respectively. As an exception to this functional distribution, a setpoint scheduling control function is installed on the SMS to enable setting independently of the controller.

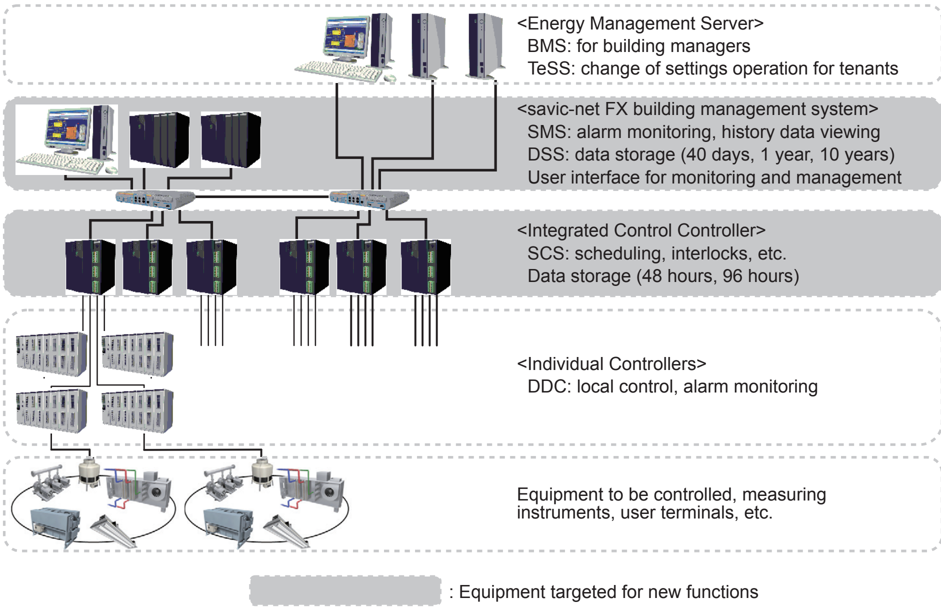


Figure 1. System Configuration

3. Overview of enhanced functions

The following three functions have been improved.

- Energy consumption curtailment function
- History data (actual results) display function
- Energy-conservation support function

The energy consumption curtailment function promotes energy conservation by adding a temperature setpoint control function, a feature not found among the existing BA system control functions.

The history data display function helps to make the results of control easily recognizable by providing a bird's-eye view of history data, allowing users to check if the control functions are working correctly and to make adjustments to the control function settings.

Since there are limited opportunities for the building manager alone to save energy, the energy-conservation support function promotes the involvement of occupants in furthering energy conservation. Details of the enhanced functions are described below.

4. Enhancement of the energy consumption curtailment function

<Conventional>

The following approaches can be used to reduce the energy used by an HVAC system.

(1) Optimized control for AHU etc. equipment
(2) Shortened operation time
(3) Adjustment of cooling/heating setpoint

Optimized control of AHU etc. equipment (1) is implemented by individual controllers. Shortened operation time (2) is implemented by the SCS using optimized control of starting/stopping, duty cycling, etc. Regarding (3), tenants are often entrusted to adjust temperature setpoints manually. In this case, there will be divergence between the temperature desired by the tenants, who want a comfortable environment, and that desired by the building manager, who wants to save energy. Nevertheless, moderation in the setting of temperature on the part of many tenants is possible.

<Enhanced>

The conventional approach to (3), adjustment of the cooling/heating setpoint, has been improved. The following control functions related to temperature setting have been added.

- Scheduled setpoint control
- Conditional setpoint control
- Interlock setpoint control

These functions enable moderation of the temperature setpoint without entrusting it to tenants.

4.1 Scheduled Setpoint Control

The setpoint can be automatically changed according to period, day of the week, and time. The temperature setpoint can be changed according to the season, or the room temperature at a specified time every day can be preset.

This function has 2 setpoint controls (cooling and heating are controlled separately). In addition, in a situation where this function would normally change the setpoint, but the change would cause the estimated energy consumption to increase, a period of time during which a change will not be made can be specified (increased energy use prevention).

Furthermore, the following features are provided.

- A time period when the tenant-set setpoint cannot be changed can be specified.
- Commands can be output a maximum of 24 times per day (at a minimum interval of 5 minutes)
- The year can be split into a maximum of 12 periods
- Records on setpoint changes (from xx °C to yy °C) can be saved and checked.

4.2 Conditional Setpoint Control

This function allows the setpoint to be automatically changed according to predefined conditions, such as the starting or stopping of devices, or a small/large relationship between measurement input points or setting input points. For example, in summer, if energy consumption is about to exceed the limit, the temperature setting will be raised to 28 °C, or 3 °C will be added to the present setting of 26 °C.

By specifying an appropriate setpoint in advance, taking into consideration the pattern of operation, operation sequence, response to alarms, etc., it is possible to moderate the temperature setpoint in order to save energy, and to take coherent action in the case of urgent incidents. Also, the moderated setpoint can be reset to the controlled setpoint by a "restore" operation. Refer to 4.4.

Be sure that this function cannot be used if the setting input point is controlled by a third party controller, since the "restore" operation is controlled by the SCS.

4.3 Interlock Setpoint Control

Input from measurement points or setting points can be output to other setting points, either with the same value as the input data or with a predefined amount of deviation (within upper and lower limits). In order to eliminating mixing loss in winter, this function enables, for example, lowering or raising the temperature setpoint for a perimeter zone by 1 °C or more compared to an interior zone.

4.4 Integrated setpoint control

What would happen if the three functions described in 4.1–4.3 all requested a setpoint change, and to three different values? To handle setpoint change requests from multiple sources, a situation that did not require consideration previously, a prioritization system has been defined. A degree of priority (ranking) has been assigned to each control function, and the setpoint requested by the control function with the highest priority is used as the new setpoint. The recently added functions have a priority of 3 or 4. Priorities 1 and 2 are reserved in case high-priority functions are implemented in the future.

Fig. 2 shows an example of the priority system. In summer, if the energy consumption is about to exceed the limit, conditional setpoint control will raise the temperature setpoint from 25 to 27 °C. A higher priority is given to conditional setpoint control. On the SCS, the priority 3 setpoint of 27 °C and priority 4 setpoint of 25 °C are stored. After time elapses with the more moderate setpoint, if the scheduled setpoint control requests a change to 26 °C, the setpoint priorities stored on SCS will be 27 °C at priority 3 and 26 °C at priority 4. The temperature setpoint will remain at 27 °C. When energy use drops below the the target and the moderated condition is reset (when the conditional setpoint control retracts its request), the priority 3 setpoint stored on the SCS will be deleted, and 26 °C (priority 4) will become the new temperature setpoint.

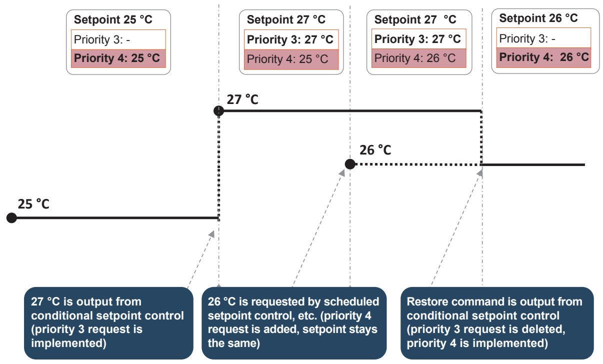


Figure 2. Handling of Requests from Multiple Setpoint Controls

5. Enhancement of the history data display function

<Conventional>

The change history data from measurement points and setting points is generally displayed by a line graph, which is called a "trend" in the present BS system. The change history of totalizing points (e.g., for electricity) is displayed by a bar graph showing trend or by the data sheet function (daily/monthly/yearly report). The ON/OFF records for equipment are displayed by a line graph showing trend or by a list (on the "alarm dashboard") as a time series. These display methods are effective in showing records for measurement points, setting points, totalizing points, and equipment ON/OFF incidents individually, but there is some difficulty in grasping multiple graphs that are displayed together. Also, information from 20 or 30 sources cannot be displayed at one time.

<Enhanced>

A new "color data grid" function has been developed so that the change history from multiple measurement points, setting points, and totalizing points, as well as equipment ON/OFF records (excluding alarm points), can be displayed in a table containing data sampled every minute for 24 hours, with table cells color-coded to indicate threshold values.

Thus temperature distribution over time can be shown simply and graphically using change records from measurement points and setting points. Fig. 3 shows an example of the color data grid. The temperature distribution for a heat storage tank can be displayed by sequentially representing, starting from the top row of the grid, the data from a measurement point located at the top of a tank. Compared to the conventional line graphs, the color data grid allows the temperature distribution of the heat storage tank to be grasped immediately.

Equipment ON/OFF history can be displayed visually as a time chart. Fig. 4 shows an example of the color data grid. If the control functions have been set to average the load, it is possible to check at a glance if the target devices were sequentially started or stopped.

Using this function, the past settings of control functions can be reviewed, or unintended device operations can be isolated.

Conventional: Trend graph display

Enhanced: Color data grid display

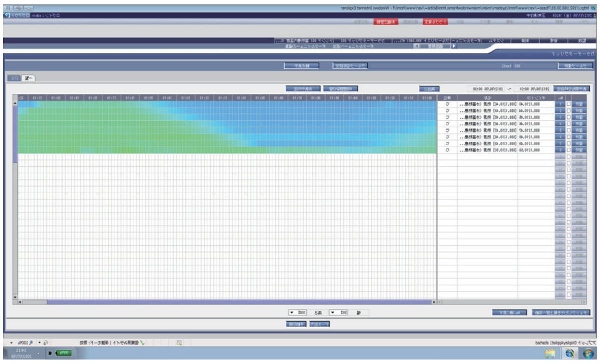


Figure 3. Comparison of Temperature Distribution Displays for Heat Storage Tank

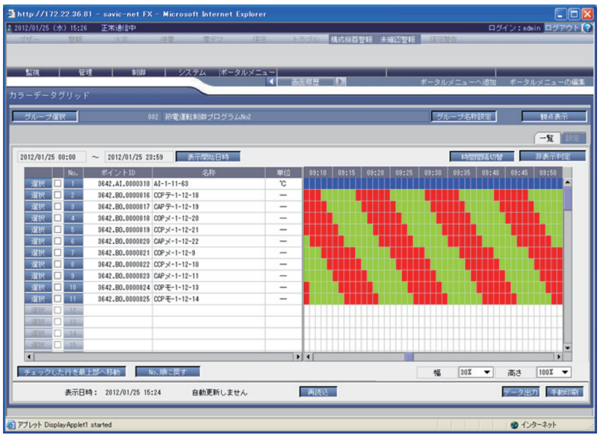


Figure 4. ON/OFF Status of Equipment

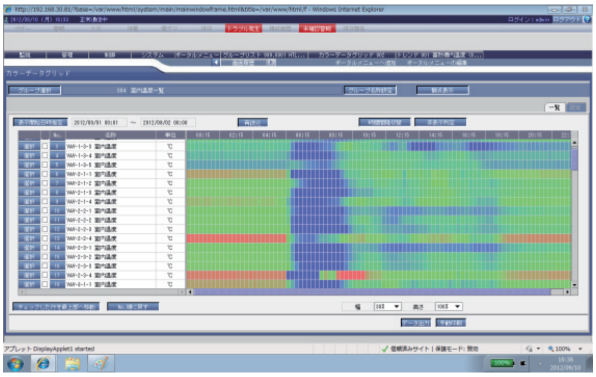
For the change history of measurement points and setting points, if out of the 24 hours only the time period when a particular device was operating needs to be checked, a filter allows the color-coded display of that time period, with other times not displayed. Fig. 5 shows an example of the filtering display. To check room temperatures where a VAV system is used, the time slots when the VAV units were OFF can be filtered out, enabling immediate identification of locations where the temperature did not reach the target.

In addition, by clicking the time bar, the time charts can be sorted in ascending or descending order by value (e.g., temperature) at the clicked time. If there are multiple locations with abnormal values on the time charts, they can be displayed in descending order by temperature so that action can be taken according to priority.

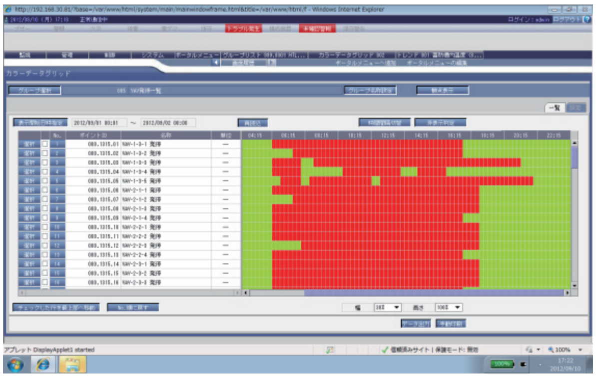
Furthermore, the following features are provided.

- A maximum of 100 points can be displayed for one group.
- 24 hours of data sampled every minute can be displayed in intervals of 1, 5, 10, 15, 30, or 60 minutes.
- The starting time for displaying the 24 hours of 1 minute data can be set freely.
- Each cell can be classified by color or intensity gradation depending on its value and threshold.
- Zoom in or out is supported for the horizontal (time) axis and vertical (target point) axis.

Room temperature distribution



VAV ON/OFF status



Results of filtering

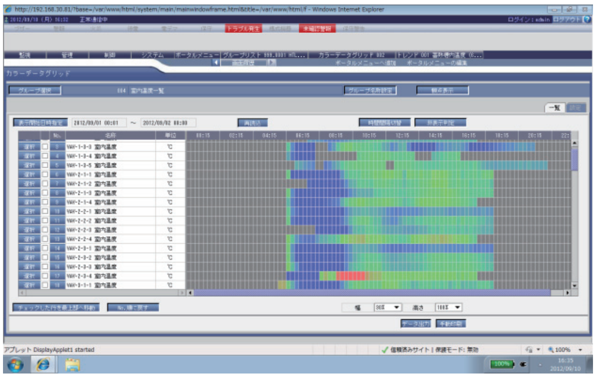


Figure 5. Example of Display with Filtering

6. Energy-conservation support function

<Conventional>

The central monitoring station of the BA system has only an alarm monitoring function, control setting function, and history data management function, but lacks a notification function for visitors or occupants. Building managers are required by ever stricter energy-efficiency regulations to conserve energy, but achieving energy conservation targets is difficult without tenants' cooperation.

<Enhanced>

We have developed a new function for displaying information to visitors or tenants. This function enables the display of various types of information on a monitor installed in a public area (such as the entrance hall) of a building. The function can be used to encourage energy-saving activities of tenants. Also, energy-saving measures taken by the building management can be made known to visitors, and energy-saving activities inside and outside the building can be publicized.

The BA system's conventional graphic displays can show present data. They have recently been enhanced to show past data (data at a specified time) and the results of calculations also. Since these graphic displays can be created at the site, they can be tailored to the circumstances of visitors or tenants. Also, as shown in figure 6, the upper part of a normal monitoring screen contains various buttons for showing alarm information ("indicators"), the latest alarm history ("new alarms"), menus, etc. The graphic display is shown at the bottom of the screen. In response to a request to show only the graphics screen to visitors or tenants, full-screen display of the graphics screen is now possible (figure 7).

Figure 6. Conventional Monitoring Screen

Figure 7. Full Screen Display

Furthermore, the following features are provided.

- The results of arithmetic operations, comparisons, and logical operations can be displayed.
- The results of unit conversion can be displayed.
- Graphics can be created at various resolutions for use with high-resolution displays.
- The display can be switched automatically at specified intervals (min. 10 s).

Figures 8 and 9 show examples of these features. The result of totaling the data on electricity use stored at multiple totalizing points can be displayed as bar graphs by the day of the week (also with comparison of the previous week), by day, by month, or by year.

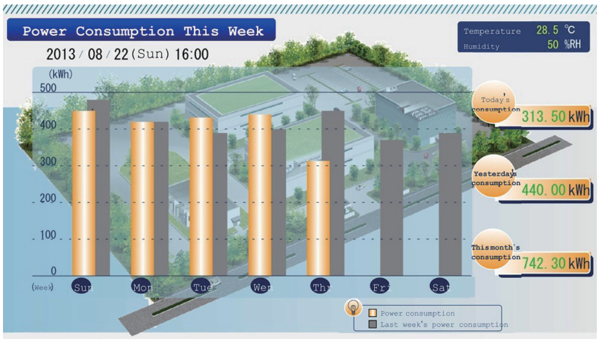


Figure 8. Screen for Visitors (Comparison by Day of Week)

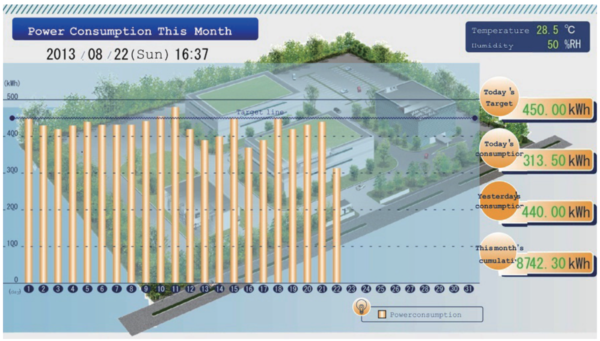


Figure 9. Screen for Visitors (Comparison by Day)

As shown in figures 10 and 11, the amount of electricity consumed can be shown in terms of the equivalent number of average households, quantity of CO_2 emissions, or amount of money.

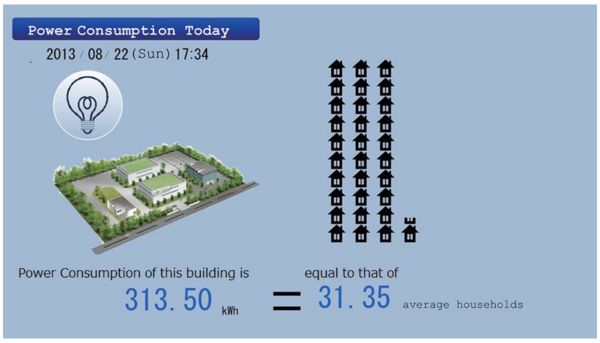


Figure 10 Screen for Visitors (with Conversion 1)

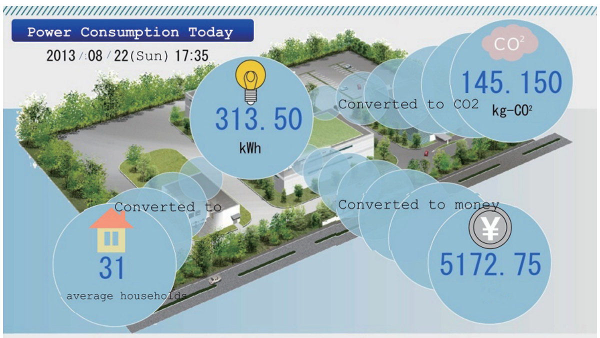


Figure 11 Screen for Visitors (with Conversion 2)

7. Conclusion

In the past a common approach to energy conservation has been “saving as much as possible without affecting comfort” (comfort > conservation), but against the background of Japan’s now-tight electricity supply this is changing to “salvaging as much comfort as possible within the given amount of energy” (conservation > comfort).

The newly developed functions, namely the three types of setpoint control, the color data grid, and the graphic screen for visitors and tenants, can be used in a variety of ways to raise consciousness about appropriate adjustment of the temperature setpoint for any kind of HVAC facilities. For example, when the present energy consumption in a building is less than the limit, the setting of temperature can be left to the tenants, but when energy consumption approaches the limit, it can be managed by the central monitoring station and the SCS.

In such a case, if visitors and tenants are notified by a public display screen that energy consumption is approaching the limit, they may agree to help save energy even if there are minor sacrifices in comfort.

Also, since in the past functions for visualizing the results of control action were insufficient, it was not possible to check if control functions were working properly in order to adjust the settings. Using the recently developed functions, the history data can be reviewed to find improperly adjusted settings, or to learn whether adjusting the settings of control functions is likely to result in improvement. Therefore, it is possible to work through an energy-conservation cycle such as: setting of automatic control → visualizing of control results → planning for improvement → adjusting of automatic control settings.

We plan to improve the visualization of control results (for easily recognizing the situation when an alarm occurs, etc.) and to develop new functions to further energy conservation.

References

(1) Daiki Nishira, “Latest Setpoint Control and Viewing Function of Stored Data for Energy-Saving Control and Management on BA System,” Instrumentation Technology, Vol. 32, No. 3, pp. 42–46 (January 2013).

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