Energy Saving Control System for Freezing-Refrigerating Warehouse

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ABSTRACT

Freezing-refrigerating warehouses, which are designed for storing and sorting products in food distribution processes, are being required to be more energy efficient due to increasing electricity costs. Fuji Electric has developed an energy saving control system for centrally controlled freezing-refrigerating warehouses that optimizes the operation of the freezing-refrigerating equipment (refrigeration unit, unit cooler) inside warehouses while also making it possible to carry out efficient operation control. It has been confirmed that yearly power consumption in warehouses can be reduced by 12.3% through the adoption of enhancements such as optimized control for the unit cooler and pressure control for the low-pressure side of the refrigerator unit utilizing a unique algorithm for responding to load conditions inside the warehouse.

1. Introduction

In recent years, freezing-refrigerating warehouses have been increasingly required to contribute to energy saving and facilitate energy visualization in accordance with the provisions of the "Act on the Rational Use of Energy" (Energy Saving Act). Furthermore, warehouse operators have been increasingly requiring centrally controlled systems that come equipped with a temperature management system for ensuring the level of food safety demanded by consumers, as well as energy saving functions to support suppression of operation costs in equipment.

In order to meet these market needs, Fuji Electric has developed an energy saving control system for freezing-refrigerating warehouses based on the "ECOMAX Controller," which is an industry-proven controller designed for stores.

2. Development Background

Freezing-refrigerating warehouses are utilized for storing frozen and refrigerated food products, as well as in the sorting work required in shipping. In most cases, they can continue to be used and operated for many years even after a 20-year amortization period, thus providing them with a reputation for having a substantial life cycle and extremely long investment payback period (see Fig. 1).

However, in recent years, freezing-refrigerating warehouses that are larger in size and more integrated have been increasingly penetrating the market in order to improve the efficiency of distribution networks.

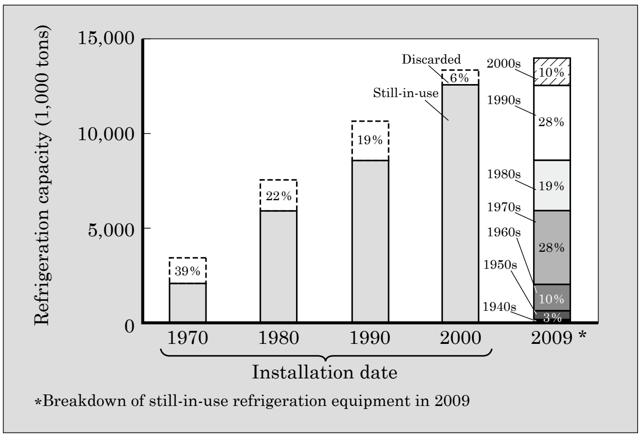

Fig.1 Breakdown of installation dates for freezing-refrigerating warehouse equipment

In addition, there has been an increasing number of facility upgrades for freezing-refrigerating warehouses to facilitate compliance with regulations for preventing global warming, including switching from fluorocarbon refrigerants to more environmentally friendly refrigerants .

Moreover, the rise in electricity rates has gradually increased the financial burden of operators, and as a result, there has been a greater demand for energy saving solutions.

In order to improve energy saving, freezing-refrigerating warehouses need to be equipped with the latest equipment and energy measuring equipment, and thus require a somewhat sizable investment. However, in consideration of the fact that operators need to suppress investment costs as much as possible, we have pursued the development of a control system that contributes to energy savings and increased efficiency in energy visualization, while not requiring a hefty investment.

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3. Development Goals and Challenges

Since system complexity is directly related to increased costs, we place high importance on adopting a relatively simple configuration for the freezing-refrigerating warehouse. Therefore, we need a simple system to implement energy savings without requiring many sensing rather than a supervisory control and data acquisition (SCADA) system.

In developing the system, we formulated the system requirements to enable comprehensive management and energy saving control of the freezing-refrigerating warehouse as follows:

(1) It can be introduced easily in a low-cost under various layouts and operating conditions. To achieve this, the function of visualizing energy saving effect, power consumption and other monitoring data should be developed for Fuji Electric's facility equipment management controller for warehouses.

(2) It can monitor temperatures and operating status inside each warehouse in real time, and its system settings can be changed easily depending on the operation.

(3) It can energy saving control according to the operating conditions of equipment installed in the warehouse

(4) It has demand control functions, such as power consumption management and peak-cut operations.

4. System Overview and Features

Figure 2 shows the configuration of the system. The "ECOMAX Controller" is the main component of the system. It collects operation data from each piece of equipment and provides simple functions for carrying out control based on the data. There are many different types of layouts inside of warehouses to accommodate application needs, and the system facilitates efficient operation by enabling operation and operation management of all pieces of equipment from the office.

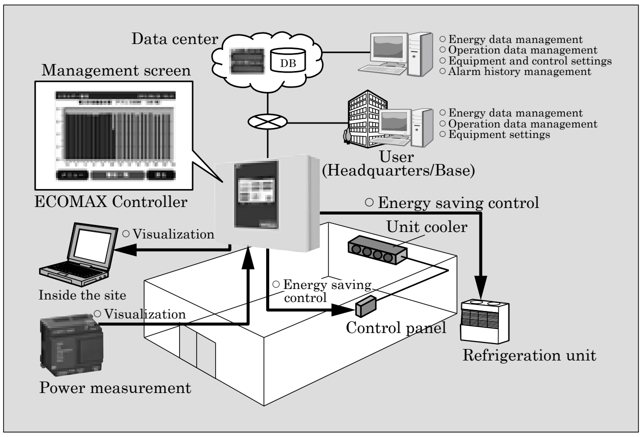

Fig.2 System configuration

(1) Status management and settings

The controller is mounted with a built-in color touchscreen that is highly visible and easy to use. In addition, users can connect to the Internet to perform remote management and setting configuration.

(2) Energy saving control

In order to improve operation efficiency in the refrigeration unit and unit cooler, which are the main components of freezing-refrigerating equipment, the system performs pressure control of the low-pressure side of the refrigerator unit, optimized control of the unit cooler, and load leveling control, thus enabling it to achieve yearly energy savings of 12.3% compared with conventional systems that do not implement control.

(3) Energy management control

The system makes it possible to display graphs to view the operation data and power consumption of equipment. Furthermore, it is possible to configure target values (maximum power) with allowance rates for cumulative power consumption in 30-minute intervals in order to suppress the maximum demand of power. In addition, demand control makes it possible to determine the likelihood of exceeding target values based on power usage estimations, and the unit enables power suppression control and automatic restoration control, while also preventing excessive suppression control of power.

5. Management Functions

The system broadly divides its functions into 2 types, which include energy management functions and status management functions for the freezing-refrigerating equipment. The functions include local management in which controller changes the settings according to changes in operating conditions, and center monitoring that provides information history via data server and correlation analysis between temperature transitions and energy.

(a) Status management functions
- ○ Internal temperature management
- ○ Operating status monitoring
- ○ Cooling management (temperature-controlled shift schedule)
- ○ Defrosting management (defrosting schedule)

(b) Energy management functions
- ○ Energy monitoring

(c) Data collection

(d) Alarm monitoring

Figure 3 shows an overview of the controller management screen configuration.

(1) Local management

As a means of local management, it is possible to adjust the settings for the temperature inside the warehouse and configure a schedule for performing defrosting operations for the unit cooler from the control-

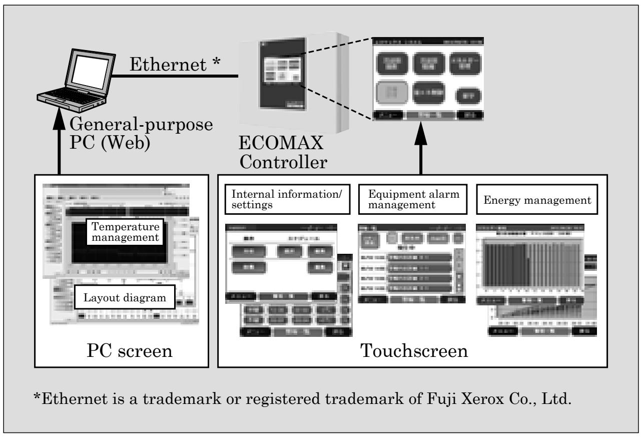

Fig.3 Overview of the controller management screen configuration

ler-mounted touchscreen all at once. Furthermore, the unit has other features such as a function for raising an alarm when equipment or temperature abnormality is detected based on temperature information in the warehouse. When an alarm is raised, immediately the display is switched to the operation information monitoring screen for the relevant piece of equipment, and notification is made via an alarm buzzer or email.

The unit can also provide visualization of energy usage covering a period of up to 2 days, providing equipment administrators with an improved day-to-day management awareness as they make comparisons with the previous day.

(2) Center Monitoring

This system comes with built-in web server functions to enable users to manage detailed information from remotely located computers.

Furthermore, data regarding the operating conditions of facility equipment and the usage conditions of energy stored by the system's controller can be acquired via network communication. Users can easily implement centralized management of multiple sites from remote locations such as the company headquarters or other offices, while even performing comparative analysis between locations based on energy indicators1.

6. Control Functions

This system comes equipped with operating control functions for the refrigeration unit and unit cooler, which are the main components of the freezing-refrigerating equipment. Acquiring operation information for the unit cooler from the controlgear, the controller sends control orders to the refrigeration unit. Control functions include an energy saving control function and a demand control function.

Furthermore, we are currently developing load fluctuation control for implementing energy savings and maintaining a stable temperature inside warehouses to respond to sudden cooling load changes that occur when opening and closing doors during loading and shipping of products. We plan to release this function during FY2016.

6.1 Energy saving control functions

Energy saving control is conducted in combination with the following control functions.

(1) Pressure control function for the low-pressure side of the refrigerator unit

Pressure control for the low-pressure side of the refrigeration unit is capable of achieving energy savings by controlling the output (low-pressure side) of the refrigeration unit in response to heat loads inside the warehouse in order to harmonize heat loads with output.

Specifically, the operating conditions (electromagnetic valve on-off information) of the unit cooler installed in the warehouse are reported to the controller, which then performs calculations based on the operating conditions in order to control the refrigeration unit so that it operates at the minimum required refrigeration capacity. By doing this, it is possible to determine the total required refrigeration capacity (demand) and perform operation while maintaining an appropriate refrigeration capacity (supply) by controlling the pressure of the refrigeration unit, thus contributing to the suppression of excessive power consumption.

A basic overview of the algorithm is given in the block diagram of Fig. 4. Determination regarding the operating conditions of the unit cooler is made based on the electromagnetic valve on-off information (electromagnetic valve operation information) for controlling the flow of refrigerant used in cooling the heat exchanger in the unit cooler. When the electromagnetic valve on (cooling on) time is longer than the maximum setting value, it is determined that "the load of the unit cooler is above the refrigeration capacity," and when the electromagnetic valve off (cooling off) time is longer than the minimum setting value, it is determined that "the load of the unit cooler is below the refrigeration capacity." When it is between these 2 setting values, it is determined that "the load of the unit cooler and the

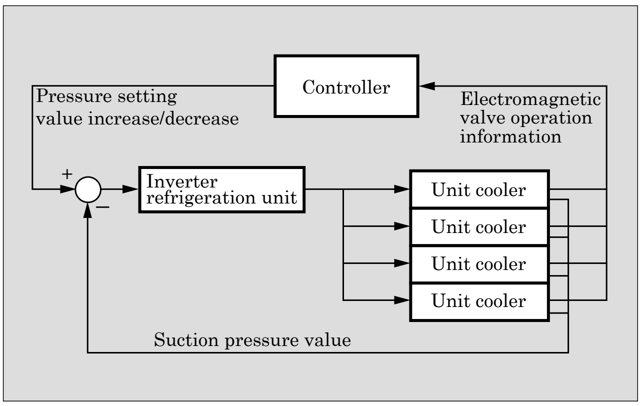

Fig.4 Basic block diagram of pressure control algorithm for the low-pressure side of the refrigeration unit

refrigeration capacity are nearly balanced.”

With regard to the refrigeration unit for inverter control, frequency control is conducted to ensure that the suction pressure value of the refrigerant is equivalent to the pressure setting value. When the pressure setting value is raised, the refrigeration capacity and power consumption drop, but when it is lowered, the refrigeration capacity and power consumption increase. As a result, when it is determined that even one of the multiple unit cooler loads suffers from insufficient refrigeration capacity, the pressure setting value is lowered to increase refrigeration capacity. On the other hand, when it is determined that the refrigeration capacity for all of the unit coolers is too high, the pressure setting value is lowered to decrease the refrigeration capacity. Finally, when it is determined that the refrigeration capacity is neither too high nor too low, control of the pressure setting value is implemented appropriately.

The utilization of the above algorithm achieves energy savings and ensures that the refrigeration capacity for multiple unit coolers is always optimally maintained.

(2) Unit cooler optimal control functions

Unit cooler optimal control contributes to energy savings by optimally controlling the activity of the unit cooler based on the cooling state.

Wasteful cooling operations can be suppressed by adjusting higher (setback) the setting temperature during time periods when the cooling load is low. Automatic operation can also be performed by configuring a weekly schedule to set time periods for performing the setback operation or periods when there are significant temperature changes.

Furthermore, energy loss related to unit cooler fan operations can be reduced by optimizing the operation of the fan when cooling loads are low.

(3) Load leveling control functions

In typical freezing-refrigerating warehouses, a single warehouse is equipped with multiple unit coolers and one temperature sensor. Based on the measured temperature, thermo operation (electromagnetic valve on-off control) is performed to maintain the target temperature.

This type of configuration faces the following challenges:

(a) Since all of the unit coolers implement thermo operation with the same behavior, it is difficult to maintain a balanced temperature inside the warehouse when there is diversity in cooling loads.
(b) Stable cooling cannot be performed when there is large fluctuation in refrigeration unit loads.
(c) During the winter when loads are relatively low, frequent starting/stopping operations by the electromagnetic valve on-off on the refrigeration unit generates wasteful startup power.

Load leveling control counters these challenges by utilizing a temperature sensor installed in each unit cooler, as shown in Fig. 5, to calculate the appropriate cooling load as required for each unit cooler, while also correcting the electromagnetic valve on-off timing of each unit cooler to enable thermo operation at a constant refrigeration unit load. As a result, the refrigeration unit can be operated with stability and high efficiency.

Moreover, stable operation for the refrigeration unit is also effective in suppressing unnecessary starting and stopping.

By combining load leveling control with the above mentioned pressure control for the low-pressure side of the refrigeration unit, it is possible to stabilize both the refrigeration unit side and the cooling load side to achieve a high energy saving effect.

6.2 Demand control functions

Demand control functions provide monitoring and controlling the power consumption of equipment to ensure that power consumption for the entire monitored warehouse does not exceed its target value. The demand control in this system has the following features with regard to its control method.:

(1) A method for determining if the target power value has been exceeded

In conventional demand control systems, the function for determining whether power consumption would exceed the target power value made predictions simply based on power consumption data per 30-minute interval. However, the current system makes determination of excessive power consumption by means of an upper-limit power value with an allowance rate for power consumption in 30-minute intervals. As a result, this method of determination prevents excessive suppression control when there are sharp increases or decreases in power consumption due to variation in

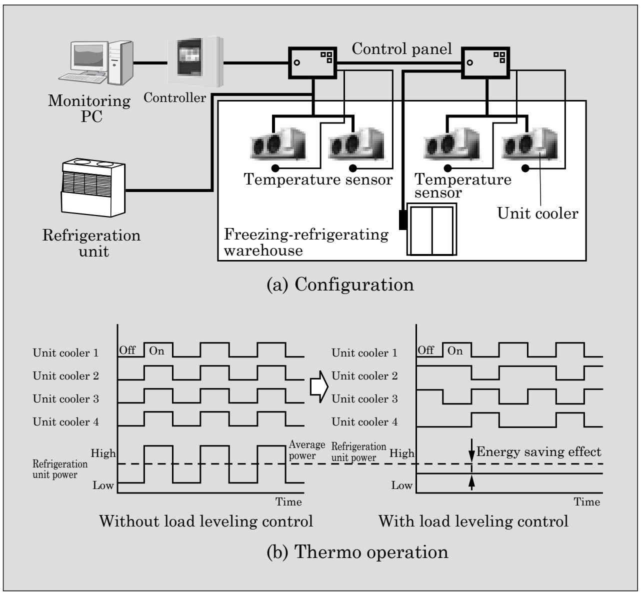

Fig.5 Configuration for load leveling control

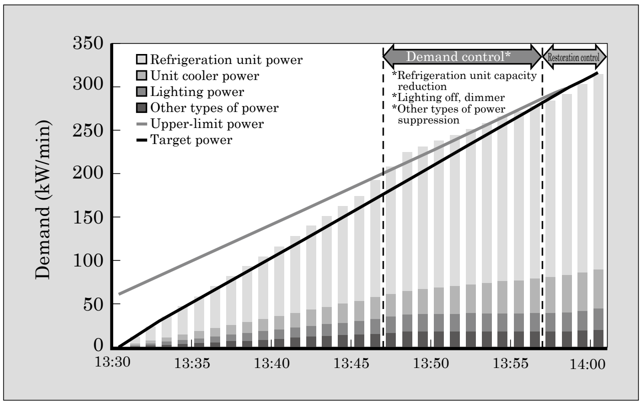

Fig.6 Demand control

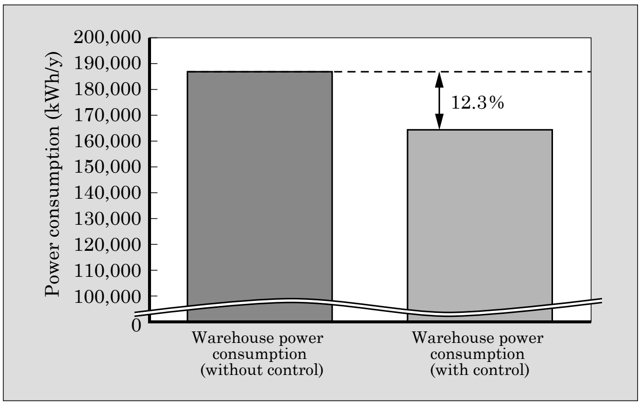

Fig.7 Energy saving verification and evaluation results

measurement values or sudden temporary changes in power consumption.

(2) A method for implementing consumption suppression control and restoration control

As shown in Fig. 6, when it is likely that power consumption will exceed the target power value based on a determination of exceeding the target value, the applicable equipment is sequentially controlled so as to decrease the power consumption in accordance with the previously established control object table in the 30-minute interval range, and thus perform suppression control of the power consumption.

Conventionally, restoration in typical demand control systems was often done manually. In this system, when an appropriate allowance is secured with the power consumption dropping below the target power value, control is implemented to restore the equipment sequentially to the states they were in before the excessive consumption occurred. The control object table, therefore, consists of data such as the identity of the applicable equipment, priority order, controllable range, and state before and after the control. By implementing the restoration automatically, this demand control system is not only applicable to power consumption peak-cut operations during the summer, but also makes it possible to implement operation as an energy saving entity by purposely setting target power value low.

7. Verification and Evaluation

We verified the energy saving control performance during the summer and winter in Fuji Electric's experiment-use freezing-refrigerating warehouse environment. The results verified that the system enables yearly energy savings of 12.3% (see Fig. 7). The amount of power consumption in Fig. 7 represents the combined effect of the pressure control for the low-pressure side of the refrigeration unit, optimal control of the unit cooler fan, and load leveling control.

8. Postscript

Along with the increasing number of upgrade projects for freezing-refrigerating warehouses, there has been a consistent need for energy savings and streamlining of work processes. In addition, the energy sector has been seeing a greater number of subsidized projects and joint development projects. Fuji Electric will continue its efforts to spread energy technology to Japanese and global markets by further developing energy saving functions and strengthening management and control features.

References

(1) Kido, T.; Kanzaki, K. The "ECOMAX Controller" Realizes EMS for Use in Stores. FUJI ELECTRIC REVIEW. 2013, vol.59, no.3, p.181-185.

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