DEVELOPMENT AND CASE STUDY ON TOTAL OPTIMAL CONTROL SYSTEM FOR HEAT SOURCES

Itaru, MURASAWA, Technical Research Institute, TONETS Corporation, Chiba-pref., Japan
Hideki, YASUKOHCHI, Technical Headquarter, TONETS Corporation, Tokyo, Japan

Abstract: In order to improve system quality and several heat sources should be flexible. Total Optimal Control System for heat sources can give a good solution to situation.Based on measured data, i.e. make the maximum use of heat balance. The "TOCS" is considered for an additional construction plan and set up in a large scale semiconductor production factory The following excellent results were obtained during operation. The annual system COP based on secondary energy equivalent was 8.0 and the amount of CO_2 emission per thermal unit was 14.8 kg-CO_2/GJ/year.

Key Words: Controller for Heat Sources, Energy Conservation, Generalization, Reliability, Combined Efficiency

1 INTRODUCTION

We have established a "total optimal control system for heat sources (hereinafter referred to as "TOCS")(**Fig.1**)" which is a high quality general-purpose system that will flexibly handle diversified heat source systems and will establish heat source systems in accordance with requests from our customers. We will introduce an example of high efficiency operation results where a yearly COP of a cooling heat source system (converted into the secondary source) was 8.0 and the amount of CO_2 emission per thermal unit was 14.8kg-CO_2/GJ/year, which we have obtained by introducing the "TOCS" to a large-scale semi conductor production plant.

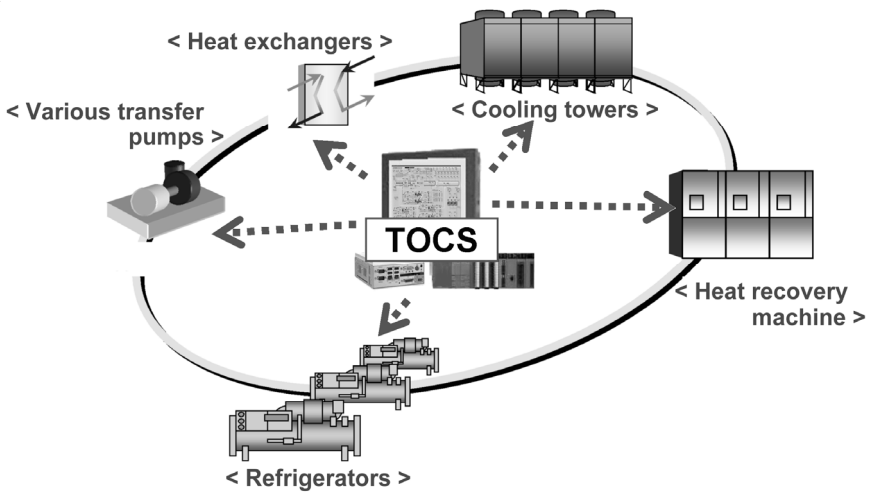


Fig.1 Schematic of TOCS

2 Necessity of "TOCS"

To reduce the energy consumption from the heat source systems, it is important to improve the system efficiency during the partial loading operation, which is much longer than the maximum peak. To improve system efficiency during the partial loading operation, it is

necessary to understand the heat loading variations due to calculations of the seasonal heat loading, which is 8,760 hours a year, as well as calculations of only the peak loading. It is necessary to design and operate heat source systems, which can operate optimally even during the partial loading. The "TOCS" which controls the heat source system is effective in optimally operating the optimally designed heat source system. The three reasons why the "TOCS" is effective are described below.

The first reason is that equipment with excellent partial loading characteristics can be effectively used. The current heat source equipment has been said to operate the most effectively with a loading rate of 100%. Hence, the operation of the heat source equipment with a loading rate of 100%, by using heat source systems, is the most effective, as it does not decrease the operation efficiency of the heat source equipment during the partial loading. Around the year of 2000, "Equipment with excellent energy saving during partial loading: inverter turbo refrigerator" was promoted for its effective use; therefore, the common wisdom changed that heat source equipment operates at prime efficiency with a loading rate of 100% and the design concepts for heat source energy saving also changed (**Fig.2**).What is important is to constantly deliver excellent heat source equipment, regardless of changes to the air status, as well as hot and cold water loading; and to maximize the efficiency of whole heat sources, including pumps and fans. The "TOCS" which can control heat source systems is extremely effective.

The second reason is that heat recovery can be used in a balance between cooling and heating. In buildings where cooling and heating occur simultaneously, heating discharged outside at a cooling tower can be effectively used by using heat recovery equipment where cooling and heating can be simultaneously generated. This heat recovery system is expected to operate maintaining highly efficient heat recovery, but maximally maintaining efficient heat recovery, in accordance with changing loading, has been the issue of the heat recovery system. As the heat recovery equipment needs to be operated while a balance between cooling loading and heating loading is checked, the heat recovery equipment is difficult to be automated and has been manually operated. The obtained heat recovery effectiveness is limited as the manual operation allows for a wide margin for safety. The "TOCS" is effective to obtain the amount of heat of cooling and heating and to automatically continue a stable and maximized operation of heat recovery.

The last reason is that natural energy can be effectively used. The inverter turbo refrigerator features a high efficiency during the partial loading operation with a temperature decrease of the cooling water. Under air status where cooling water can be directly produced in a cooling tower (hereinafter referred to as "free cooling at the cooling tower") without operating a

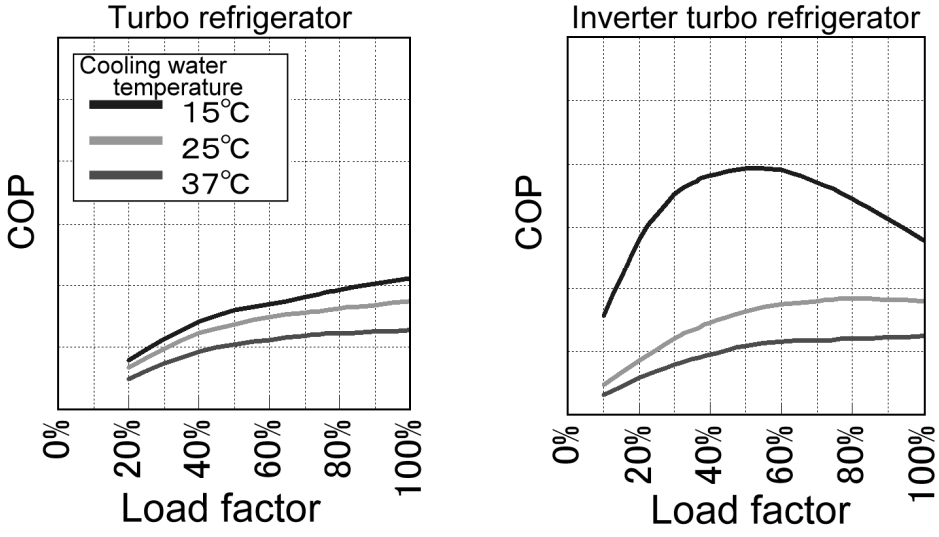


Fig.2 Equipment with excellent partial loading characteristics

refrigerator, free cooling at the cooling tower can operate with greater energy saving than the inverter turbo refrigerator can, depending on the conditions of the temperatures of the water delivery. Free cooling at the cooling tower is usually operated manually. As cooling capabilities change greatly depending on air conditions, and the temperatures of the cooling water also change depending on loading conditions, manual setting of free cooling at the cooling tower allows for a wide margin for safety. Hence, the operation period is shorter and expected effectiveness is not obtained in most cases. For the effective operation of free cooling at the cooling tower, the "TOCS" is effective because it can set flow rates and temperatures of free cooling at the cooling tower in accordance with air and loading conditions.

3 Function and System Designs of the "TOCS"

Uniquely developed simulation software is used to design the functions and systems of the "TOCS". This simulation software enables a calculation with "TOCS" control methods, equipment characteristics (heat source equipment, cooling tower, heat exchange device and air conditioning coils etc.) and equipment specifications. When new control logic is added to the "TOCS", the simulation software constructs control calculation algorithms, and confirms that the calculation is approved and how much the amount of energy saving effect is expected. As developed control logics are sequentially modularized, contents which are once tested can be re-used and can be used for the comparison of several systems. The calculation accuracy is maintained by checking with operation accumulation data obtained in buildings where the software is actually used. As normally used spreadsheet software is used, designers are trained in operating the software and it is easily introduced. Major items to be discussed in simulation software are; the number of heat source equipment with different characteristics to be installed, improvement of system efficient during the partial loading, low temperatures of cooling water and efficiency with collective cooling towers, capacities of cooling towers and of pumps, validity of exhaust heat recovery, and use of nature energy.
One of the important functions of the "TOCS" is "optimal operation continuity". Installing a number of sensors and control devices is necessary to control the heat source system, causing a high risk of failure. To secure energy saving and credibility, redundant designs in accordance with specifications of buildings are necessary. Major redundancy items to be discussed include equipment backups, control device and sensor backups, control device fail safes, operation checks for refrigeration units when the sensor detects any abnormalities, measures taken against instant voltage decrease and for recovery from blackouts.

4 Development and Generalization of the "TOCS"

As the heat source system varies according to each building and requests from customers also vary, specifications of each heat source control system vary in accordance with each building. Even if the heat source system varies according to each building, there are many patterns which are common in each control of equipment. Controls of heat source can be combinations of patterns, or, combinations of modules. The "TOCS" which can save energy in cooling and heating sources including pumps and cooling towers by the combinations of modules flexibly apply to diverse heat source systems by creating modules in units which can be combined. By such modularization, the "TOCS" can apply its high credibility and high efficient operation control to many types of heat source systems.
To increase reliability of software as well as for laborsaving of tests, the "TOCS" was constructed by the use of the TSC21 naming code (**Fig.3**), as well as modularization of control functions and the loop structure was made mostly for the program control structures. The TSC21 naming code shows naming convention to encode measurement point names and is regulated by the TSC21 Association of Japan. The TSC21 Association of Japan supplies mechanisms of BEMS constructions, determines and promotes specifications of TSC21 technology to contribute to energy solutions. The TSC21 technology includes PROG, COM

and naming, and the TSC21 naming code is used in the "TOCS". Advantages of measurement point names being encoded, are that ambiguities due to Japanese names are removed, and several buildings could be evaluated in a cross-sectoral manner. When the contents of the control calculation, such as which calculation is performed with which of the measurement points, and how the calculation results are output, are incorrectly explained to the software houses during joint discussion, control functions will not work correctly. The TSC21 naming code is very effective to clearly express the phrases which may be confusing, such as whether "temperatures to cooling water" means the exit of the cooling tower or the exit of the refrigeration unit, and to correctly indicate the measured values, set values, measurement equipment answers of the set value, as well as control output and output answers. Adoption of the TSC21 naming code enable the checking of calculation formulas in programs in a program source, and the use of loop structures brings high efficiency and high credibility to the data processing methods. These methods reduce programming glitches.
The TSC21 naming code has been adopted in SHASE-M0008-2005 "Measurement of Energy Performance on Facility System manual". Naming conventions are applied to measurement points to be used to evaluate energy performance for each air condition heat source system.
Documents related to the TSC21 naming code can be freely downloaded from the following address: http://www.serl.co.jp/tsc21/

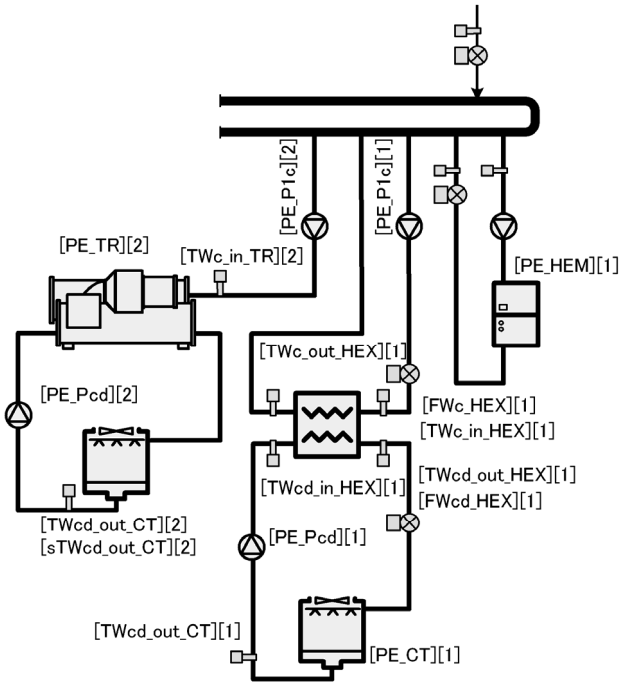


Fig.3 Example of TSC21 naming code

5 "TOCS" Introduction Example

The request from the customer for a heat source facility, where our developed "TOCS" is introduced, were that yearly COP of the system based on refrigeration production heat amounts should be 5.0 or higher, controls of the heat source facility should be a dual structure, and backup controls should be enabled when any failures occurs while the stable heat source supply, energy saving properties, environmental, and maintenance properties are taken into consideration.
As the basic policy of the customer's company is "aiming at being an earth friendly plant", we set a goal to establish heat source systems which would realize "the highest possible efficiency" and "a continual stable supply". The optimal system design and introduction of the "TOCS" were necessary to obtain the maximum efficiency of energy saving. For the optimal

system design and determining specifications of "TOCS", the customer, operators, designers and the manufacturer cooperated with each other to discuss details and had intense meetings on the results of the discussion.

A committee by a third party group was created to continuously verify performance of the heat source system during the operation phase, after the trial operation and the heat source system was adjusted. Members of the committee shared and analyzed the operation accumulation data by using a Web monitoring system (**Fig.4**) through the Internet.

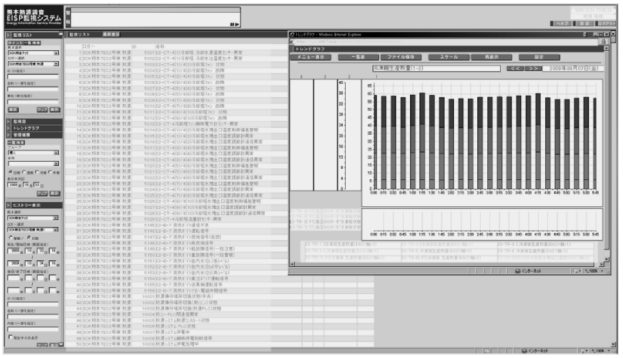


Fig.4 Web monitoring system

Fig.5 shows the COP of the cooling heat source system of each month. The highest COP of the system in winter where cooling water temperatures could be low temperatures is the monthly COP of the system in January, 2007, which is 15.95. Even in summer, the COP of the cooling heat source system exceeds 6.0, which indicates a high efficiency operation. **Fig.5** shows the COP until June, 2009. When the yearly COP of the cooling heat source system from November, 2008 to October, 2009 was calculated in another analysis, the COP was the highest figure, 8.0.

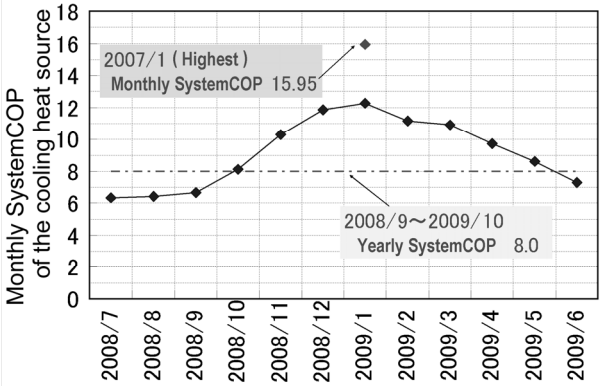


Fig.5 Monthly SystemCOP of the cooling heat source

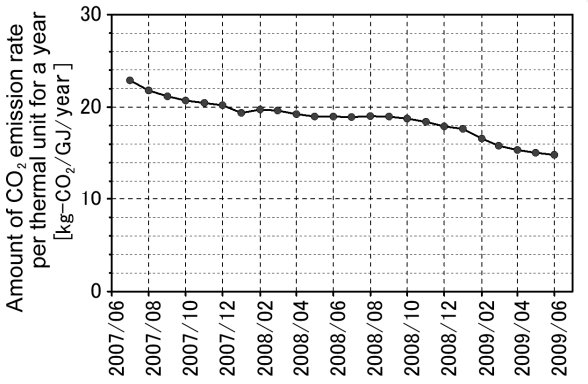


Fig.6 Amount of CO_2 emission rate per thermal unit for a year

Fig.6 shows the amount of CO_2 emission per thermal unit. The amount of CO_2 emission per thermal unit has decreased year after year and this decrease indicates that the efficiency of heat sources has improved. This index would be useful for a cross-sectional evaluation of several buildings as the one where cooling and heating is combined. The amount of CO_2 emission per thermal unit from July, 2008 to June, 2009 was 14.8 kg-CO_2/GJ/year. The CO_2 conversion factors are 0.378 kg-CO_2/kWh for electricity and 2.365 kg-CO_2/Nm^3 for gas(13A)

6 Conclusion

A variety of measures such as improvement of the partial loading and exhaust heat recovery was taken for energy saving in the introduced "TOCS". The "TOCS" provided very highly efficient operational results as a trial control system, controlled by the "heat source controller" that the yearly COP of the cooling heat source system was 8.0 (converted into the second energy) and the amount of CO_2 emission per thermal unit was 14.8 kg-CO_2/GJ/year.

From the viewpoint of performance verification, energy control and measures for energy saving through analyses of the heat source systems established by the optimal design in advance would bring more energy saving, showing that a continuous optimal system operation would be important.

Finally, we have received valuable advice and an enormous amount of cooperation from many people for development and construction of the "TOCS". We greatly appreciate the advice and the cooperation that we received.

7 Reference

The Japan Heat Service Utilities Association 2008. Heat Service Utilities Handbook

New Heat Storage System Operation Control Subcommittee 2005. SHASE R-1002-2005

Akashi, Fukuzaki, Sumiyoshi, Miyata, Kuwahara, Ueda, Murasawa 2008. "Performance Evaluation of Heat Source System with High Efficiency Technology. (Part1) Performance Evaluation based on Actual Measurement", Proceeding of SHASE Annual Meeting, pp.1623-1626.