

# EC series

## -The Optimum Controller for a Heat Source System that Consists of Centrifugal Chillers-



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*For energy saving of a heat source system, sophisticating the system control matters, along with improving the efficiency of a heat source. Due to the complexity of advanced system control that makes use of the performance features of a centrifugal chiller, however, challenges lie in actually deploying it. As such, in 2010, Mitsubishi Heavy Industries, Ltd. (MHI) developed and commercialized the heat source total control system "EC series," which comprehensively easily controls a heat source system. For this product, we developed advanced system control with a plain control algorithm using findings through research with a university, thereby enabling EC series to make significant energy savings. Field verification conducted in 2012 indicates that the system achieved 23%-more energy saving compared with an existing cutting-edge system. Valued for its technical advancement and achievements, EC series was awarded the "Minister's Prize, the Ministry of Economy, Trade and Industry" for electricity conservation in the product and business model category, in the "FY2013 Grand Prize for Excellence in Energy Efficiency and Conservation" contest.*

### 1. Introduction

A centrifugal chiller is a piece of high-capacity heat source equipment mainly supplying chilled water. It has been deployed in large-scale heat source systems such as in factories or for district heating and cooling, not just in air conditioning systems in large buildings. Since 2003, when we started marketing an inverter-equipped centrifugal chiller, centrifugal chillers have continued to enhance performance and they have now been deployed in air conditioning systems in smaller buildings and small and medium-scale factories. A heat source system consists of a main piece of equipment, namely the centrifugal chiller, and auxiliary equipment such as a pump and a cooling tower. The improved performance of a centrifugal chiller resulted in an increased share of power by the auxiliary equipment in the total electric power consumption of the heat source system. Therefore, optimization of the entire system, including auxiliary equipment, has increasingly been needed. Considering such needs from customers, EC series was developed as the optimized system controller.

This paper presents the technical features of total heat source system optimizing controller EC series and about field verification.

### 2. Development background

Energy consumption from heat source systems including a centrifugal chiller counts for about one third of total consumption for commercial use and therefore improvement of efficiency is expected. MHI has pursued development and efficiency improvement of the centrifugal chiller (an inverter-equipped type in particular), which is a piece of large volume equipment, and our latest

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GART-I series achieved COP 25.3<sup>\*1</sup> as the best scores at partial load and IPLV 9.29<sup>\*2</sup>.

Achievement of higher performance of standalone heat source equipment appeared to be nearing its limit, but there was room for further energy saving through optimization of management measures for the entire heat source system. For example, it is expected that a 19.9% saving of energy is made if an inverter is equipped with a centrifugal chiller in an office building and a 24.3% saving is made by optimizing management of the number of chillers through a system control.<sup>1</sup> However, it requires technical knowledge and expertise to devise an optimized operational plan that considers the performance features of an inverter-equipped centrifugal chiller and to execute the planned operation. Therefore, a method that does not require customers with professional skills that a chiller manufacturer would have was expected.

Next, a heat source system is designed to cover the maximum load during the summer. Therefore, most of the time the system operates (i.e., intermediate periods such as spring, autumn, night-time in summer) falls into the partial load area that is beyond the specification points of a chiller. In addition, even during the winter, there is a cooling load in factory processes or for the purpose of local heat supply and it is known that the operation times tend to be longer at low cooling water temperature. "The proposition expected by our customers" involves a possible solution for such a wide array of problems through optimized system control.

As such, we reached the belief that a heat source system operational support tool for high-efficient operation should be developed, while the enhancement of heat source equipment is also necessary.

\*1: COP: Coefficient of Performance. The greater the number, the higher the energy saving performance is.

\*2: IPLV: Integrated Part Load Value. Based on calculation criterion of JIS B 8621 (2011)

### 3. Technical features

Since 2007, when there were no established methods for heat source system control that fully exerts the capabilities of an inverter-equipped centrifugal chiller, MHI, together with a university laboratory, has researched heat source system control through simulation. That resulted in the conclusion that significant energy saving is possible with just a plain and versatile control algorithm. The findings and achievements were incorporated into a real controller, thus, the heat source system total control system "EC series," which comprehensively easily controls a heat source system, was produced. MHI put it on the market in 2010. This chapter explains the technical features with which the EC series is equipped.

#### 3.1 Plain control algorithm to significantly save energy

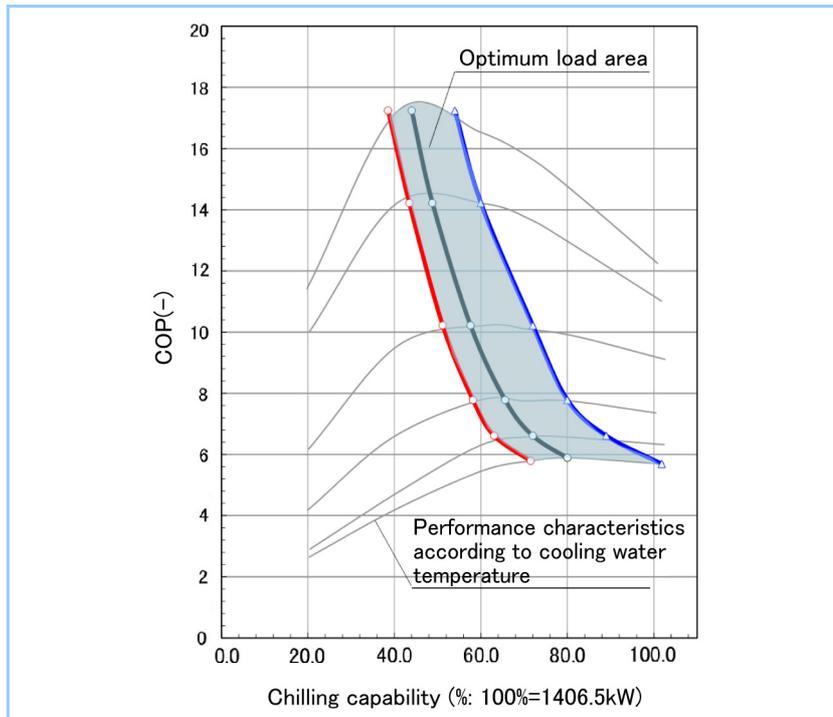
##### (1) Multiple chiller control for optimum load

Multiple chiller control to maintain high COP is effective in energy saving for a heat source system. An inverter-equipped centrifugal chiller has the feature that the load area where high COP is realized (hereafter "optimum load area") is varied depending on cooling water temperature. The performance properties of an inverter-equipped centrifugal chiller can be represented according to the mechanical engineering principle for a general centrifugal compressor. Based on this, the optimum load area under the current operation conditions was derived (**Figure 1**). As a result, it was confirmed through simulation that electric power consumption can be reduced by controlling the number of units based on computed results.<sup>(1)</sup>

##### (2) Control for auxiliary equipment

(Variable flow control of chilled/cooling water and cooling tower control)

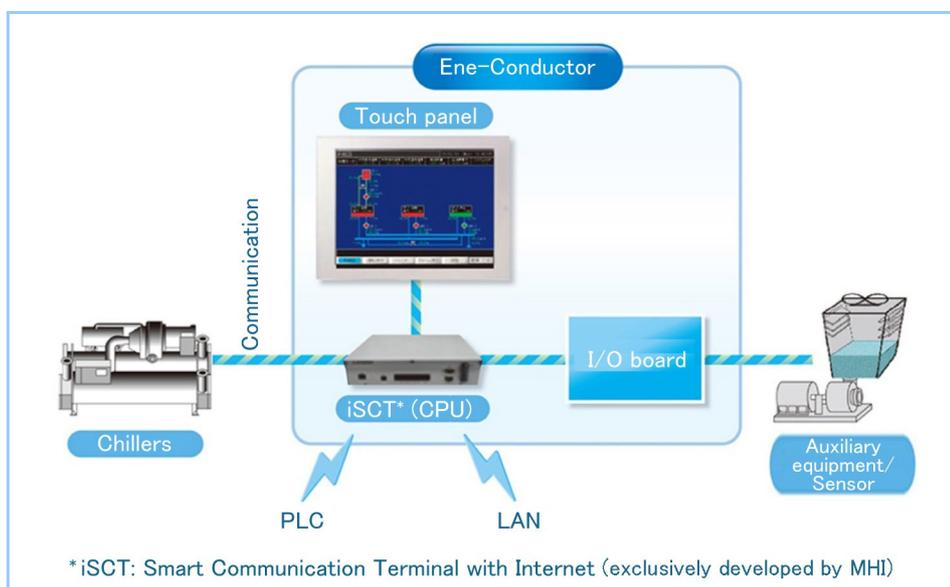
Control design for auxiliary equipment in a heat source system tends to be complex. This is because operations of auxiliary equipment control affect the energy consumption of the other equipment. We prepared an environment, where the annual air-conditioning loads at places like retail facilities or office buildings can be simulated, to consider the control method. After that, we combined a variety of heat source systems assumed from facts and data of each building with various patterns of control methods for auxiliary equipment to understand the relation with the electric power consumption of a system for each case. This led to the finding that control for auxiliary equipment can be optimized with a plain algorithm using parameters that is obtainable under operation such as load value and chilled or cooling water temperature.<sup>2</sup>



**Figure 1 Optimum load areas of inverter-equipped centrifugal chiller**

### 3.2 Communications interface added

The EC series is equipped with a communications interface as standard. Thanks to the interface, it is easily connectable to auxiliary equipment and peripherals such as a centrifugal chiller, programmable logic controller (PLC) and LAN interface (**Figure 2**). The communication function is fully utilized, in particular, to communicate with MHI's centrifugal chiller. Data obtained through communication with sensors can be used to get temperature and flow data that are necessary in system control. This eliminates the necessity of sensors on the facility side that it otherwise should have and leads to a reduction of construction costs. Besides, specific parameters only necessary for chillers such as the optimum load area, which is different in each model, are computed by the control unit on the chiller side, whereas EC series uses the results to control auxiliary equipment or to calculate the best number of units under operation. Through this, complicated work needed to create the program for a complex characteristic curve for chillers is eliminated, which otherwise must be done if the system for optimum control is configured in the design of the facility. Furthermore, the capability to communicate with upstream equipment such as PLC and LAN make monitoring from remote places easy.



**Figure 2 EC series' hardware configuration**

### 3.3 Standardization of embedded control program

In the case of programming for heat source system control in general, the program designer writes codes for each case from the connection diagram for the facility onsite. However, EC series is run by one standard control program. Control functions to be installed were narrowed down to key functions and were incorporated in a versatile program. They include functions necessary for stable system operation (cooling water bypass valve control and chilled water bypass valve control) as well as the ones mentioned in section 3.1 (multiple chiller control, variable flow control of chilled/cooling water and cooling tower control). Parameters such as the necessity of a controlling function, choice of model and the number of chillers are automatically configured based on the preset parameters and communications with the chiller so as to accord with the customer's system configuration.

Verification with a real unit has a limitation as many configuration patterns of heat source systems are possible. To address this, we created a verification system using PRANET<sup>3</sup>, a proven simulation code that was used in dynamic characterization for our power plants and other facilities, and created an environment where a number of patterns of heat source systems are configured and represented as a physical model on a computer. Using this system, verification of the combination with the control logic was performed.

The standardization of the control program obtained the following results:

- (1) Transition from on-site integral-style programming to mass-produced-type programming, which resulted in enhancement of product quality and reliability, as well as in cost saving for control design.
- (2) Saving of verification time for trial operation by pre-verification in our company, which cut operating costs onsite.

### 3.4 High value-added functions featured

The avoidance of performance degradation of a centrifugal chiller is also important in efficiently operating a heat source system. This product can always calculate executable COP that a centrifugal chiller originally has (hereafter "target COP") and enables comparison with actually measured COP. We expect that our customers will improve their chiller operation and early detection of abnormalities by comparing the COP values. In fact, in the trial operation phase, approximately 30% of cases of performance degradation due to inadequate parameter tuning for a chiller were detected early and improved<sup>4</sup> (Figure 3).

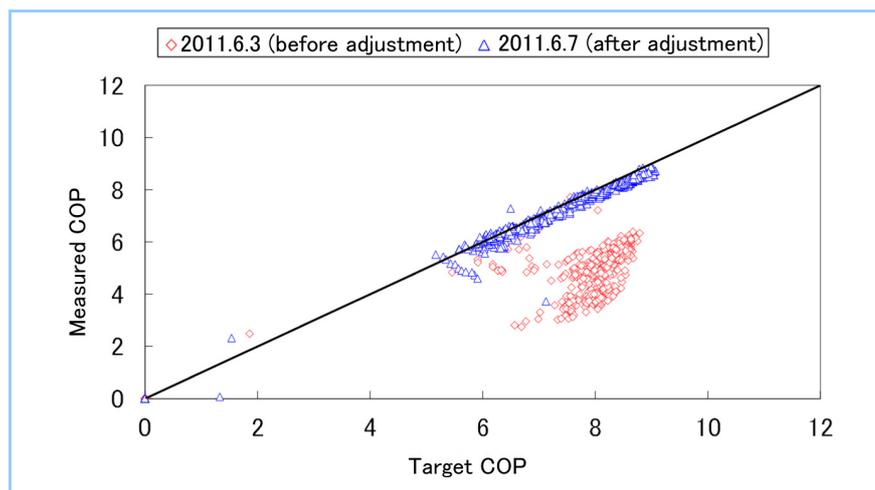


Figure 3 Performance degradation detection of target/measured COP

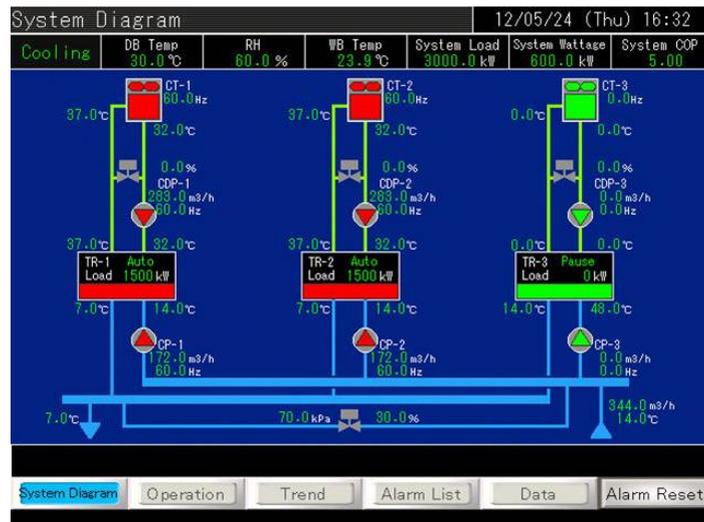
## 4. Product specifications

The appearance of EC series is not particularly different to that of a general controlling board. For a user interface, a 10.4-inch touch panel is employed. The screen layout was ergonomically designed by our design department, with consideration given to the operability and ease for viewing by an operator (Figures 4, 5).

The lineup is two models: EC-3 which is controllable for up to three centrifugal chillers and EC-6 for up to six, which is equivalent to a large-scale system (**Table 1**).



**Figure 4** Appearance of EC series EC-3



**Figure 5** EC series systematic diagram on screen

**Table 1** Specifications of EC series

Item		Model: EC-3	Model: EC-6
Target facility		Heat source facilities composed of centrifugal chillers and air-cooled heat pumps manufactured by MHI	
Number of chillers to control		1 to 3 units	1 to 6 units
Controlling functions		Six functions for optimum control in heat source systems (1) Multiple chiller control (2) Variable flow control of cooling water (3) Variable flow control of chilled water (4) Cooling tower control (5) Cooling water bypass valve control (6) Chilled water bypass valve control	
Outer dimension	Width	700 mm	800 mm
	Height	1300 mm	1800 mm
	Depth	350 mm	500 mm
Weight		Appx. 240 kg	Appx. 130 kg
Power source specification		Single phase 100V-125V, 50Hz/60Hz common use (Optional: Single phase 200V class)	
Installation method		Wall hung	Standing

## 5. Field verification

Performance verifications by third parties (including a university) have been conducted since fiscal 2012 at the Sony Corporation Sendai Technology Center, which introduced EC series after facility renovations.<sup>5</sup> The heat source system to undergo the field verification is one with two units of an inverter-equipped centrifugal chiller of 500USRt (1USRt=3.516kW) and all the auxiliary equipment is equipped with an inverter (**Figure 6**).

In fiscal 2012, appraisal of verification data indicated a high efficiency of annual average system COP 7.7<sup>\*3</sup>. In fiscal 2004, it had also recorded a good result of annual average system COP 5.9<sup>6</sup> with a cutting-edge heat source system before the renovations, but this represents a further 23% energy saving. The performance gaps are particularly evident in the winter season, during which thermal load becomes low as outside air temperatures go down. This indicates the advantage of control at low thermal load by EC series (**Figure 7**).

\*3: This figure represents the COP of the entire heat source system; not of a chiller alone but including auxiliary equipment.

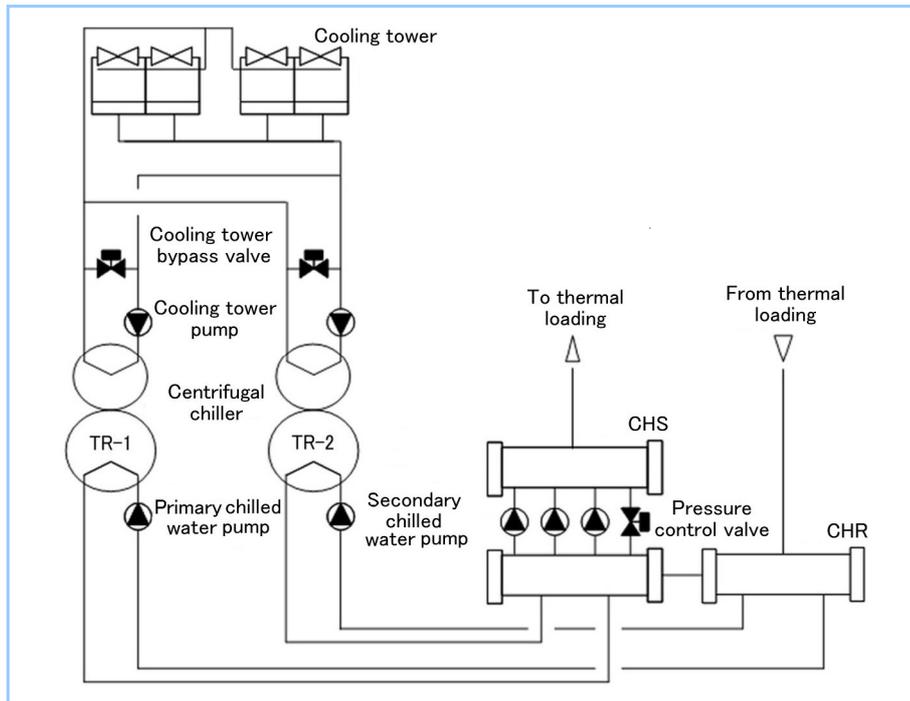


Figure 6 Systematic diagram of heat source system at Sony Corporation Sendai Technology Center

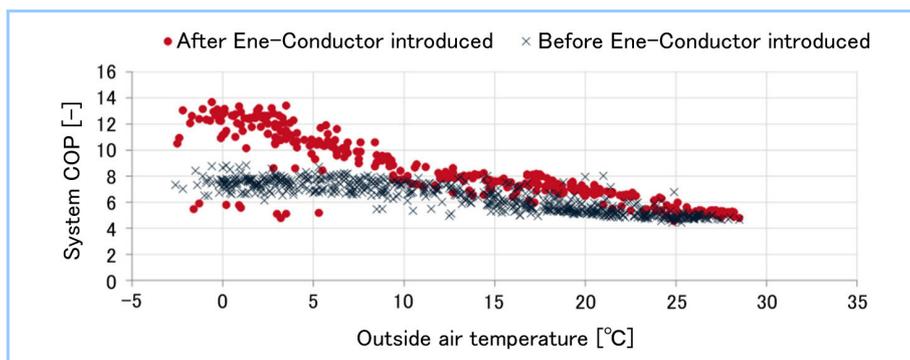


Figure 7 Heat source system's COP at pre- and post-deployment of EC series

## 6. Conclusions

EC series, an energy saving tool, facilitates optimization of a heat source system that had presented customers with technical hurdles that were difficult to overcome. The technologies and achievements introduced in this paper were highly valued and EC series was awarded the "Minister's Prize, the Ministry of Economy, Trade and Industry" for electricity conservation in the product and business model category, in the "FY2013 Grand Prize for Excellence in Energy Efficiency and Conservation" contest sponsored by the Energy Conservation Center, Japan (ECCJ). At present, (as of the end of March 2014) this product is used by a wide range of customers: factories for semiconductors, beverages, chemicals and other areas for industrial-use purposes and hotels, retail facilities, hospitals and other facilities for commercial-use purposes.

With a system prepared to support customers who strive to address and manage their energy saving issues, MHI not only helps customers with optimization when they introduce the system but also provides a service through which they can view the measured data of a heat source system on the Internet through our remote monitoring system, which we have been offering since before the development of EC series, and understand the operation status.

This product at the present stage is a controlling program that allows for application to our limited series of lineups, which are heat source systems comprised of the GART, AART and ETI series centrifugal chillers and the Voxcel series air-cooled heat pumps. In the future, we will continue with our efforts to make it applicable to systems that include other company's centrifugal chillers and adsorption chillers, and we intend to evolve EC series into a versatile, customer-friendly product.

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## References

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