Chapter 20

Facility Operations and Development Unit

20.1 Members

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20.2 Overview of Research Activities

Our facilities possess multiple features not found at other supercomputer sites. These features include an expansive and pillar-free computer room, a power supply system that consists of a co-generation system (CGS) and a high-speed current-limiting circuit breaker without uninterruptible power supply (UPS), distribution boards installed not on the computer-room walls but under a raised floor, extremely quiet and high-efficiency air conditioners, and a water-cooling system for the CPUs featuring precise temperature control.

To ensure stable operation of the K Computer and its peripherals, the facility operations and development unit (FODU) of the operations and computer technologies division, RIKEN R-CCS, is responsible for the operation and enhancement of the facilities. Furthermore, FODU conducts research on the advanced management and operations of the R-CCS facilities.

One of the most serious problems is the rapid and substantial increase in the electricity prices since 2011. Therefore, we are investigating the most suitable driving conditions to allow the R-CCS facilities to achieve effective cost reductions.

Another problem is the increased power consumption by R-CCS. The use of electricity by R-CCS is strictly limited by a contract between R-CCS and the local electric supply company. However, in the early stage of operation, the facility's power consumption exceeded the contract limit. This is important because the company requires us to accept an increase in the upper/lower power limit, which amounts to an increase in the electricity cost. To prevent this, we have investigated methods to control the power consumption of the K Computer using emergency job stopping together with the system operations and development unit and the application tuning development team of the operations and computer technologies division, RIKEN R-CCS.

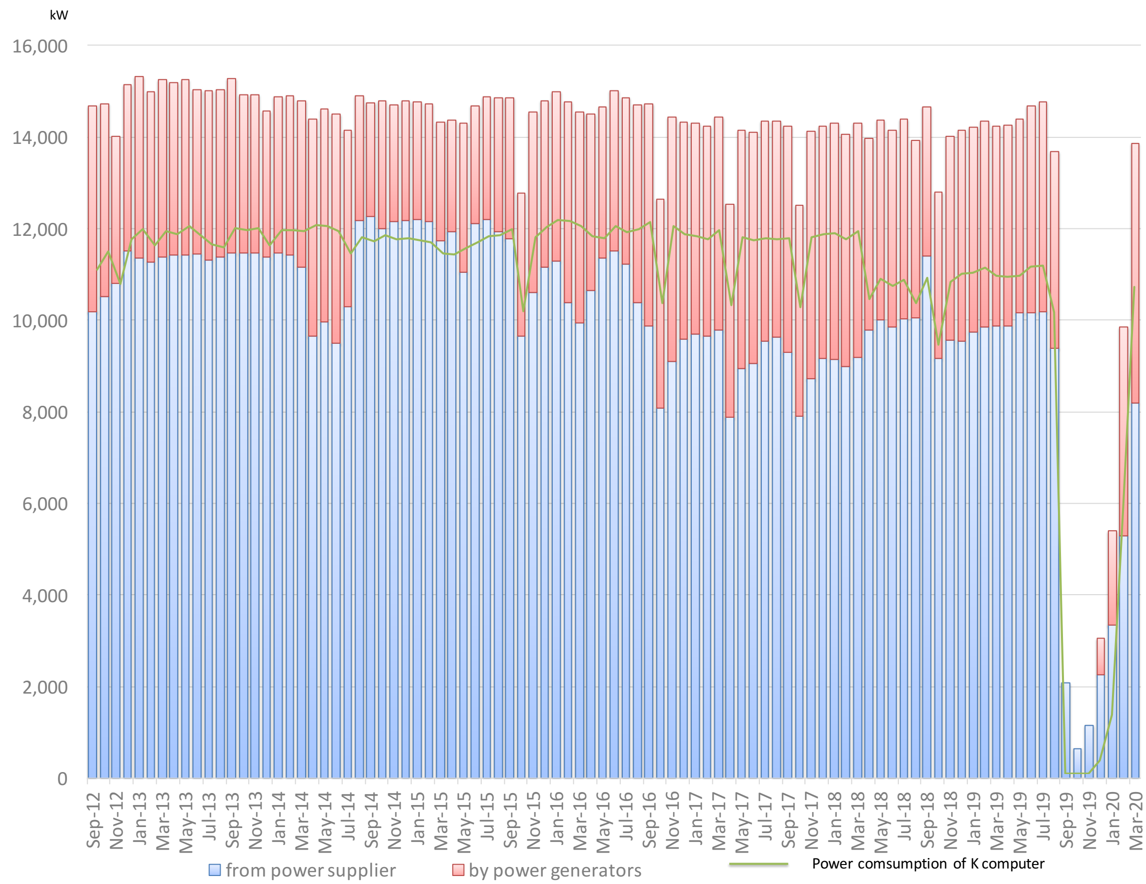

Figure 20.1: Monthly power supply and K computer power consumption.

20.3 Research Results and Achievements

20.3.1 Optimum operation of electric power

Figure 20.1 shows the monthly total power supply and power consumption of the K computer and the supercomputer Fugaku from September 2012 to March 2020. The power supply consists of commercial power purchased from a supply company and power generated by CGS.

The R-CCS power consumption is nearly synchronized with that of the K Computer. The power consumption of R-CCS is nearly 14,000 kW on average, and the power consumption of the K Computer accounts for approximately 80% (11,000 kW) of the total consumption of R-CCS.

As shown in Figure 20.1, the electric power supply of R-CCS consists of commercial and CGS power. There are two CGS systems at R-CCS, and they are used in turn for two weeks at a time. Therefore, at least one CGS is always in use. Commercial electric power is contractually set at approximately 12,500 kW, and the power consumption was approximately 11,000 kW (annual average), which corresponds to approximately a 90% load factor.

To minimize the cost, we try to optimize the ratio of the commercial and CGS electricity.

To investigate the optimized conditions that minimize the sum of the electricity and gas cost, we determined the costs of several ratios of commercial electricity to CGS electricity. We also constructed a model to describe the energy flow of the electric power supply and the cooling system. Then, we performed computer simulations using the model and the actual operating data. In the near future, we intend to identify the cost-optimized conditions that contribute to reducing costs.

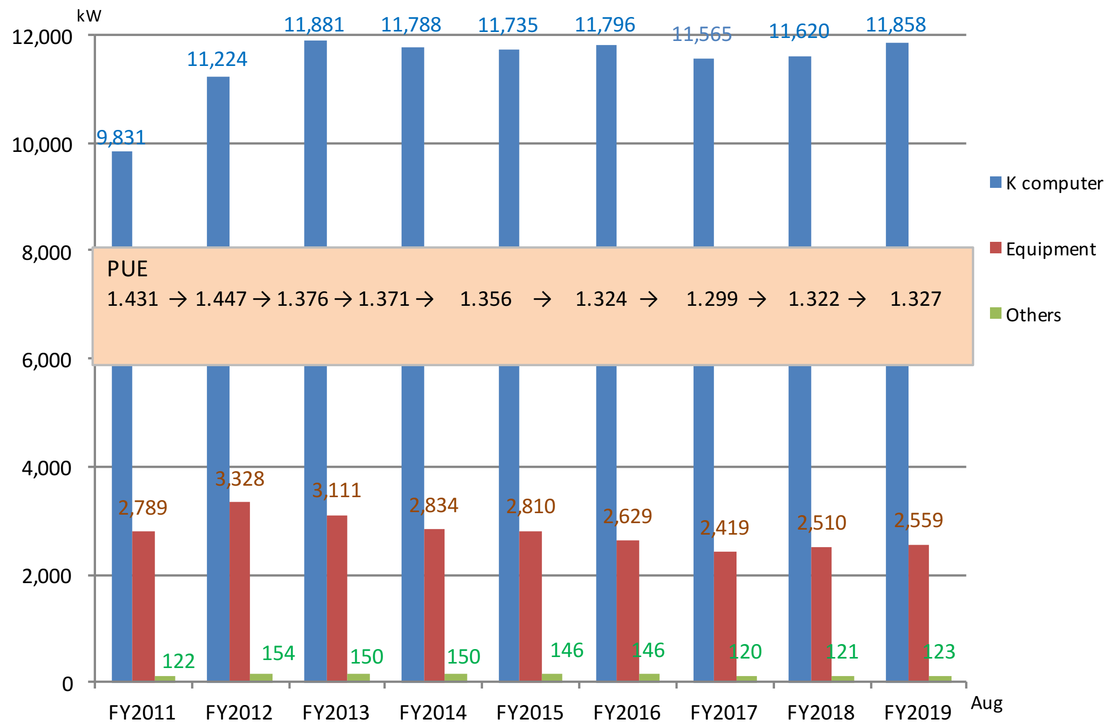

Figure 20.2: Trend in the annual average electric power consumption.

20.3.2 Improvements to the power usage effectiveness (PUE)

We have continued to work on improvements for the effective use of electricity. PUE is a well-known indicator of the effectiveness of electricity use.

To improve the PUE, we have attempted to optimize the operation of the cooling equipment (e.g., chillers and air-handlers) since FY2013.

Figure 20.2 indicates the change in the annual average power consumption of the K Computer (including the peripheral devices) and the cooling equipment. Since FY2013, the power consumption of the K Computer has been nearly flat at approximately 11,800 kW; however, the power consumption of the equipment decreased gradually from FY2013 to FY2017. Accordingly, the PUE of R-CCS improved to 1.322 in FY2018 from 1.447 in FY2012, contributing to the reduction in the electricity cost.

In FY2013, we reduced the electricity cost of the air conditioners by reducing the number of working air conditioners. The total cooling performance was maintained by lowering the air temperature. We achieved a reduction in the power consumption of 217 kW.

In FY2014, we focused on the fault-tolerance feature of the air-conditioning equipment. Each air conditioner has two motors for fault tolerance. We found that if one of the two motors could be stopped, the airflow could be maintained at approximately 60

In FY2016, we worked on improving the efficiency of the cooling tower. As a result, we achieved a reduction of 181 kW in the power consumption.

In FY2017, we focused on optimizing the operation control of the refrigerator using a heat storage tank. This reduced the power consumption by 210 kW.

In FY2018, we carried out the overhaul of a cooling tower and a large number of pumps. However, we were not able to operate CGS by the effective output because the electric equipment disorder caused by the typhoon occurred. Therefore, we were not able to improve PUE of FY2018 from last year.

20.3.3 Facility Expansion Work

This work was carried out between January 2019 and March 2020. We have greatly enhanced the power supply and cooling capacity for the Fugaku installation. Specifically, we doubled the number of 6000V/200V transformers, and tripled the cooling capacity per rack. In addition, the necessary chillers were added.

Since the work was to be carried out in parallel with the operation of the K computer until the end of August 2019, we had to be very careful not to affect our operation. In addition, a strict schedule was implemented to remove all the K computers by the end of September and to complete the under-floor facility work so that Fugaku could be installed in December.

20.4 Schedule and Future Plan

We will continue to improve the advanced management and operation of the R-CCS facilities and contribute to the user service of the K computer and Fugaku. We will work on reducing costs by investigating and applying the most suitable driving conditions to all the electric power supply and cooling equipment. Further, we will improve the electric power and cooling control of the entire R-CCS facility with the system operations and development unit to minimize the electric power consumption.

20.5 Publications

20.5.1 Conference Papers

[1] Motohiko Matsuda, Hiroya Matsuba, Jorji Nonaka, Keiji Yamamoto, Hiroshi Shibata, Toshiyuki Tsukamoto, "Modeling the Existing Cooling System to Learn its Behavior for Post-K Supercomputer at RIKEN R-CCS", In proceedings of Energy Efficient HPC State of the Practice Workshop, 2019

20.5.2 Posters

[2] Fumiyoshi Shoji, Jorji Nonaka, Motohiko Matsuda, Hiroya Matsuba, Keiji Yamamoto, Yasumitsu Maejima, Toshiyuki Tsukamoto, "CPU Water Cooling Temperature Effects on the Performance and Energy Consumption", ISC 2019 HPC in Aisa Poster, Frankfurt, Germany, 2019.
[3] Jorji Nonaka, Keiji Yamamoto, Akiyoshi Kuroda, Toshiyuki Tsukamoto, Kazuki Koiso, Naohisa Sakamoto, "View from the Facility Operations Side on the Water/Air Cooling System of the K Computer", SC'19 Research Poster, Denver, USA, 2019.
[4] Jorji Nonaka, Toshiyuki Tsukamoto, Motohiko Matsuda, Keiji Yamamoto, Akiyoshi Kuroda, Atsuya Uno, Naohisa Sakamoto, "A Brief Analysis of the K Computer by using the HPC Facility's Water Cooling Subsystem", 2nd R-CCS International Symposium, Kobe, Japan, 2020.
[5] Motohiko Matsuda, Hiroshi Shibata, Jorji Nonaka, Toshiyuki Tsukamoto, Keiji Yamamoto, Hajime Naemura, "R-CCS Facility Simulation Modeling for Assisting Operation Planning and Decision Making", 2nd R-CCS International Symposium, Kobe, Japan, 2020

20.5.3 Oral Talks

[6] Hiroshi Shibata, Hajime Naemura, Fumio Tsuda, Toshiyuki Tsukamoto, "Operations of Thermal Storage Tank for K Computer", Proceedings of the 53th Japanese Joint Conference on Air-conditioning and Refrigeneration(Tokyo). (In Japanese)
[7] Motohiko Matsuda, Hiroya Matsuba, Jorji Nonaka, Keiji Yamamoto, Hiroshi Shibata, Toshiyuki Tsukamoto, "Modeling the Existing Cooling System to Learn its Behavior for Post-K Supercomputer at RIKEN R-CCS", Energy Efficient HPC State of the Practice Workshop (EE HPC SOP 2019) held in conjunction with ICPP 2019, Kyoto, Japan, 2019.