Chapter 19

Facility Operations and Development Team

19.1 Members

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19.2 Research Activities

The K computer 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 team (FODT) of the operations and computer technologies division, RIKEN AICS, is responsible for the operation and enhancement of the facilities. Furthermore, FODT conducts research on the advanced management and operations of the AICS 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 AICS facilities to achieve effective cost reductions.

Another problem is the increased power consumption by AICS. The use of electricity by AICS is strictly limited by a contract between AICS 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 team and the application tuning development team of the operations and computer technologies division, RIKEN AICS.

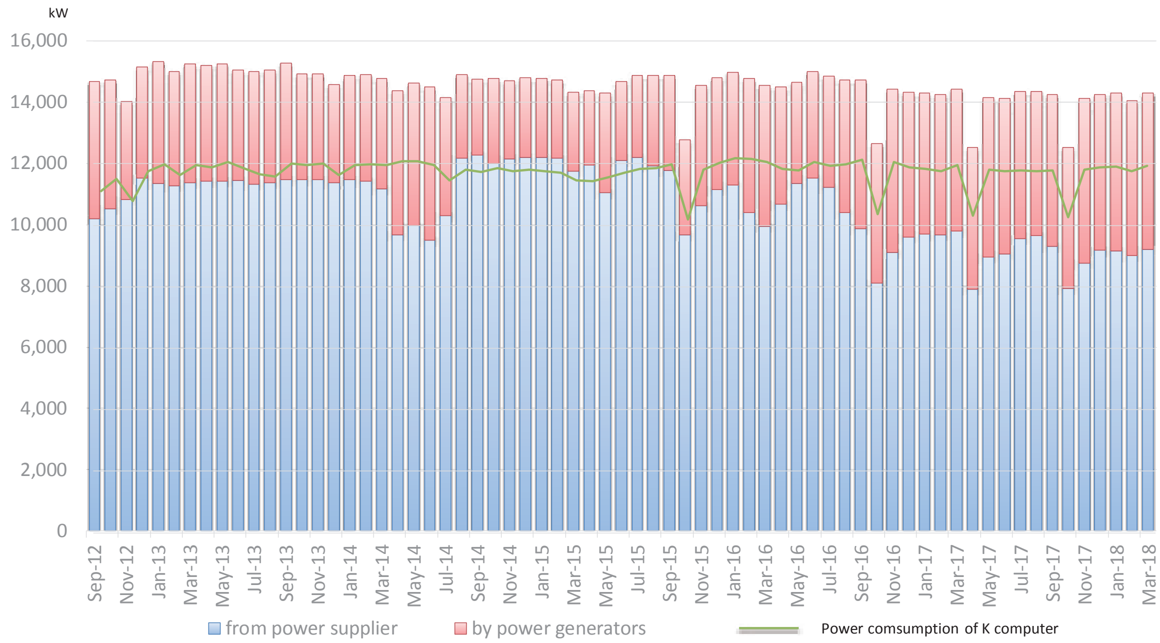

Figure 19.1: Monthly power supply and K computer power consumption.

19.3 Research Results and Achievements

19.3.1 Optimum operation of electric power

Figure 19.1 shows the monthly total power supply and power consumption of the K computer from September 2012 to March 2018. The power supply consists of commercial power purchased from a supply company and power generated by CGS.

The AICS power consumption is nearly synchronized with that of the K computer. The power consumption of AICS is nearly 15,000 kW on average, and the power consumption of the K computer accounts for approximately 80% (12,000 kW) of the total consumption of AICS.

As shown in Figure 19.1, the electric power supply of AICS consists of commercial and CGS power. There are two CGS systems at AICS, 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 12,000 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.

19.3.2 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 19.2 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 AICS improved to 1.299 in FY2017 from 1.447 in FY2012, contributing to the reduction in the electricity cost.

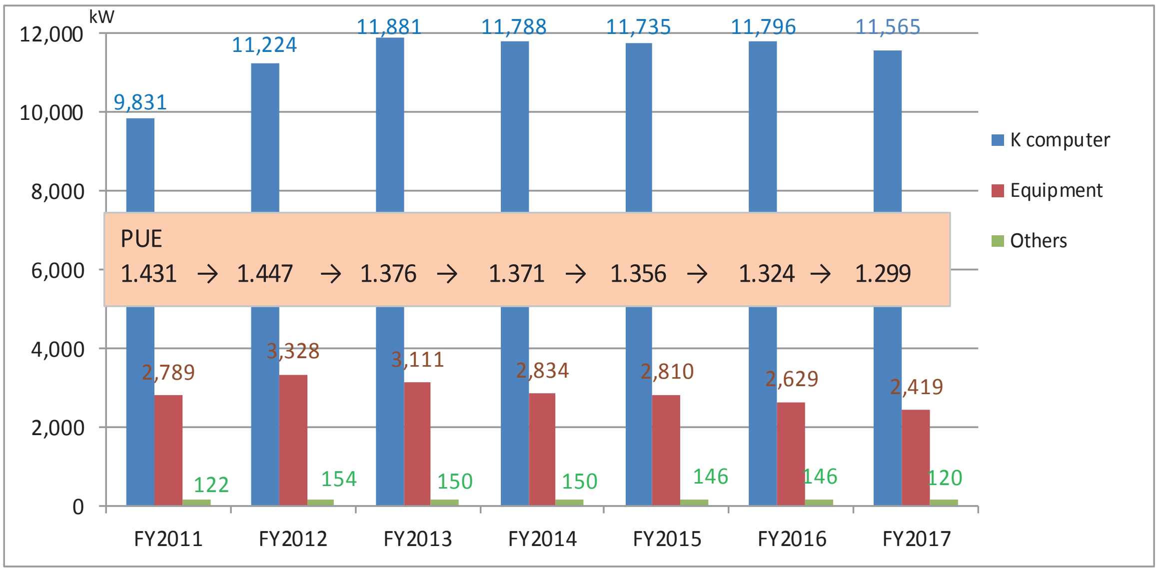

Figure 19.2: Trend in the annual average electric power consumption.

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%. Therefore, we reduced the power consumption by a further 277 kW in FY2014 and by 24 kW in FY2015.

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.

19.4 Schedule and Future Plan

We will continue to improve the advanced management and operation of the AICS facilities and contribute to the user service of the K computer. 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 control of the entire AICS facility with the system operations and development team to prevent overshooting of the contracted power demand.

19.5 Publication, Presentation, and Deliverables

19.5.1 Journal Papers

[1] Keiji Yamamoto, Atsuya Uno, Katsufumi Sugeta, Toshiyuki Tsukamoto, Fumiyoshi Shoji, "スーパーコンピュータ「京」の運用状況," IPSJ Magazine Vo.55 No.8 pp.786-793, 2014. (In Japanese)

[2] Keiji Yamamoto, Atsuya Uno, Hitoshi Murai, Toshiyuki Tsukamoto, Fumiyoshi Shoji, Shuji Matsui, Ryuichi Sekizawa, Fumichika Sueyasu, Hiroshi Uchiyama, Mitsuo Okamoto, Nobuo Ohgushi, Katsutoshi Takashina, Daisuke Wakabayashi, Yuki Taguchi, and Mitsuo Yokokawa. "The K computer operations: Experiences and statistics." In Proceedings of the International Conference on Computational Science, ICCS 2014, Cairns, Queensland, Australia, 10-12 June, 2014, pages 576-585, 2014.

[3] Fumiyoshi Shoji, Shuji Matsui, Mitsuo Okamoto, Fumichika Sueyasu, Toshiyuki Tsukamoto, Atsuya Uno, and Keiji Yamamoto. “Long term failure analysis of 10 peta-scale supercomputer.” In HPC in Asia session at ISC2015, Frankfurt, Germany, July 12-16, 2015.

19.5.2 Conference Papers

[4] Atsuya Uno, Hajime Hida, Fumio Inoue, Naoki Ikeda,Toshiyuki Tsukamoto, Fumichika Sueyasu, Satoshi Matsushita, Fumiyoshi Shoji, “Operation of the K computer Focusing on System Power Consumption,” HPCS2015, 2015, Japan. (In Japanese)

[5] Lili Jin, Kouji Yutani, Hiroyuki Yamano, Hiroyuki Takitsuka, Satoshi Matsusita, Toshiyuki Tsukamoto, “計算科学研究機構における設備最適運転条件の検討その２,” Proceedings of the 49th Japanese Joint Conference on Air-conditioning and Refrigeration(Tokyo). (In Japanese)

[6] Satoshi Matsushita, Hiroyuki Takitsuka, Toshiyuki Tsukamoto, “スーパーコンピュータ施設における低騒音空調機の省エネ運用,” Proceedings of the 49th Japanese Joint Conference on Air-conditioning and Refrigeration(Tokyo). (In Japanese)

[7] Hiroyuki Takitsuka, Toshiyuki Tsukamoto, “冷却塔の効率改善その２,” Proceedings of the 51th Japanese Joint Conference on Air-conditioning and Refrigeration(Tokyo). (In Japanese)

[8] Kouji Yutani, Hiroyuki Yamano, Lili Jin, Masanori Toi, Tatsuo Takahashi, Makoto Yamada, Toshiyuki Tsukamoto, Satoshi Matsushita, Keiji Yamamoto, “New power supply system by direct current compensation demonstrative test report of power fluctuation mitigation in K-computer facility”, 電気学会 B 部門大会,2017,Japan. (In Japanese)

19.5.3 Invited Talks

None

19.5.4 Posters and presentations

[9] Fumio Inoue, Atsuya Uno, Toshiyuki Tsukamoto, Satoshi Matsushita, Fumichika Sueyasu, Naoki Ikeda, Hajime Hida, Fumiyoshi Shoji, “電力消費量の上限を考慮した「京」の運用,” IPSJ-SIGHPC 2014-HPC-146 No.4, 2014. (In Japanese)

[10] Atsuya Uno, Hajime Hida, Naoki Ikeda, Fumio Inoue, Toshiyuki Tsukamoto, Fumichika Sueyasu, Fumiyoshi Shoji, “「京」におけるジョブ単位の消費電力推定の検討,” IPSJ-SIGHPC 2014-HPC-147 No.20, 2014. (In Japanese)

19.5.5 Patents and Deliverables

None