CO-GENERATION SYSTEM FOR RIBF

Takashi Emoto*, Tadashi Fujinawa, Eiji Ikezawa, Masayuki Kase, Kenichi Yamaguchi, Yasushige Yano, Cyclotoron Center, RIKEN, Saitama, Japan

Abstract

A 6 MW electric power co-generation system (CGS) was installed in the RIKEN Accelerator Research Facility (RARF). The CGS improves the reliability and overall energy efficiency of power supply for the entire facility by utilizing heat and power simultaneously from one fuel source.

INTRODUCTION

The RIKEN Accelerator Research Facility (RARF) has been constructing the radioisotope (RI) beam factory (RIBF) that is a new cascade of a fixed-frequency ring cyclotron (fRC), an intermediate-stage ring cyclotron (IRC), and a superconducting ring cyclotron (SRC). The power consumption of the present and new facilities will be more than 30MW, including the experimental apparatus and utility. The reliability and efficiency of power supply for the entire facility are an important issue. Any monetary interruption and sag of power supply not only affect momentary operation but also cause long-term interruption to the cryogenic refrigerators for the superconducting-magnets. The large heat capacity super-conducting magnet has to keep running under normal and contingency operating conditions. The present cryogenic system has to discharge helium gas when there is power failure for more than one hour. The energy conservation is another important issue. Changing energy economics, combined with legislative and regulatory initiatives, has resulted in increased emphasis on efficiency in industrial energy utilization especially in large power consumed facilities.

A co-generation system (CGS) has been introduced into the new facility in order to increase the overall efficiency and reliability of power supply. The CGS configuration is to use a gas turbine to drive an electrical generator, taking hot exhaust from the turbine into a steam generator. The gas turbine energy generates electricity and the thermal energy of steam via absorption chillers makes chilled water for cooling the equipment and air-conditioning the entire facility. The CGS that produces both heat and power simultaneously increases overall efficiency and can be arranged to operate for emergency power supply. The natural gas fuelled CGS has almost no emission of sulphur oxides (SOx) and less emission of nitrogen oxides (NOx). Greenhouse gas emissions are also reduced by the high efficiency of the CGS.

CO-GENERATION SYSTEM

Figure 1 shows a schematic diagram of the CGS for the RIBF and Figure 2 shows a view of the CGS. The gas fuelled CGS generally uses either gas turbines or gas reciprocating engines as the power generator. Gas engines have better electrical conversion efficiency. However, they do not provide sufficient exhaust heat to operate the absorption chillers. The hot exhaust is introduced into a heat-recovery steam generator (HRSG). The steam from the HRSG is led to the absorption chillers and to the building heating system. Part of the steam is injected into the combustion chamber, which has the following advantages. 1) A substantial increase in power can be obtained from the gas turbine engine; 2) The part-load efficiency is improved; 3) The production of NOx is reduced. The steam injection and a wide range of turbine operation give the variable output generation of the electricity and the steam production.

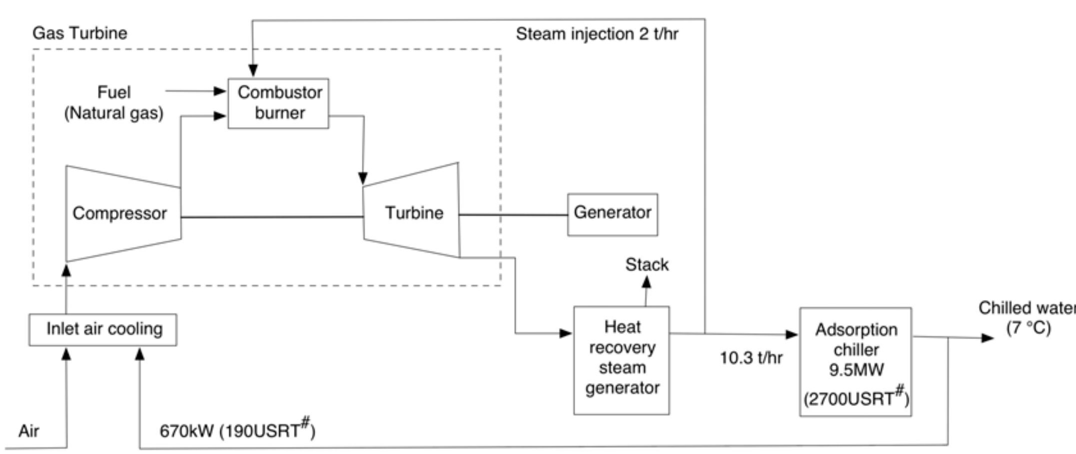

Figure 1: Schematic diagram of the CGS for RIBF.

* emoto@riken.jp.

United States Refrigeration Ton, 1USRT=3.51685kW

Figure 2: A view of the CGS.

The installed model is the GPC60 DLE made by Kawasaki Heavy Industries, Ltd. The base ability of this model is produce 5.3 MW of electric power and 13 tonnes per hour of steam. The typical electric power gained from steam injection (8 tonnes per hour of steam) is 1.3MW for the base configuration. The expected performance of the CGS with the full refrigerator load in 2007 is shown in Table 2.

Table 2: CGS Facility in 2007

Electric output at 15°C	5,790 kW
Steam production	10,300kg/hr
Electrical efficiency	32.1%
Overall efficiency	64.4%
Total refrigeration capacity	9.5MW
NOx emission	32.3 ppm

The total capacity of refrigerators is 9.5MW (2700USRT#) with five 1.4MW (400USRT) and two 1.2MW (350USRT) absorption chillers (supplied water temperature 7°C). To maintain the gas turbine output capacity in hot weather, part of chilled water is used to cool the compressor-inlet air. The heat that is removed from the magnets and their power supplies is 8MW through the cooling towers (supplied cooling water temperature 35°C). This high-volume and low temperature dissipated heat can be used to produce chilled water by the adsorption chillers. However, the adsorption chillers require the heat source temperature more than 80°C, which is not practical temperature for cooling the magnet and their power supplies.

The CGS can operate in parallel with the electricity grid or in standalone. Operation in parallel allows greater flexibility and reliability as the grid can provide immediate stand-by if the CGS is not operational. And if the grid is out of service, the CSG sustains the essential loads, such as the cryogenic refrigerator. Figure 3 illustrates the simplified configuration for the CGS connected at the load utilization level and shows bus arrangement, interconnections, major ratings of equipment, and switching and interrupting devices. Normally the CGS goes along with a local substation either for buck up power supply or to export excess electric power. A switch in Figure 3 (HSCB: high speed circuit breaker) between the CGS bus and the substation bus is closed under normal condition. The essential loads are supplied through the CGS bus. When power fails, the CGS bus is isolated from the substation bus within 20 milli-seconds and the CGS preserves the essential loads. At the same time the computer control system starts power protective relay initiation, equipment shutdown trips, and circuit breaker operations.

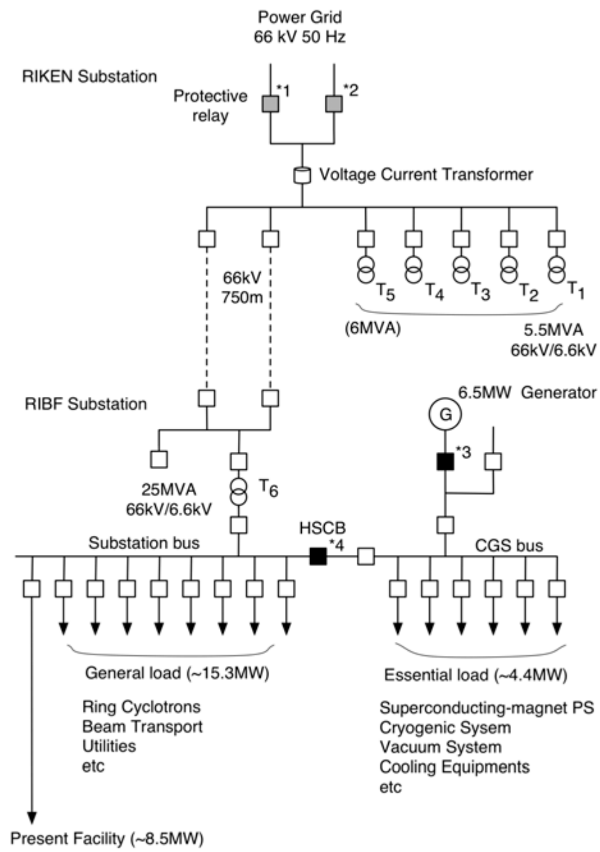

Figure 3: Simplified configuration for the CGS connected at utilization level. *1~*4:Synchronized by power protective relay initiation.

OPERATION

At present, the CGS operates only in the daytime of weekdays and Saturdays because there is insufficient demand for thermal loads and the low electricity charges during the nighttime. The CGS operates primarily for electricity generation because of lower demand for thermal loads. This may present a problem that the current overall efficiency (40.2%)[1] is not as high as the operation mode in 2007. The steam injection and a wide range of turbine operation allow the CGS to produce variable electric and thermal output, which enables flexible operation in different phases of construction and according to seasonally fluctuating demand for the facility. There has been power failure twice caused by lightning and voltage sag up to this point. In either case, the CGS was isolated and successfully preserved the essential loads. The operation statistics in FY2003 is shown in Table 3. Some improvement of the turbine was made to increase the maximum electric output to 6.5 MW from 6.3 MW in 2004.

Table 3: CGS Operation in FY2003.

Operation time	270 days (3,362.2hrs)
Scheduled shutdown	69 days
Scheduled inspection	17 day
Maintenance & improvement	17 days
Electric output power	19,544,220 kWh
Average electric output power	5.93MW (12.45hrs/day)

The initial estimation of the time period needed to obtain overall economic benefit enough to yield a simple payback 11.4 years. However the results remain to be seen since the RIBF construction has not been completed and there is uncertainty about future gas and electric contracts with utility companies.

CONCLUSION

The CGS has been successfully introduced into new facility, improving the reliability and energy efficiency of power supply toward the full load operation.

REFERENCE

[1] H. Hasebe, et al. RIKEN Accelerator Progress Report 37 (2004) 7.