A Case Study on Electricity and Chilled Water Production of a Gas District Cooling Plant

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Abstract

The paper presents the study on the production of electricity and chilled water of a gas district cooling (GDC) plant. The plant was designed as a cogeneration and GDC plant. The electricity was generated by two 4.2 MW gas turbines. The chilled water was produced by the combination of two unit absorption chillers and four unit electric chillers. The absorption chiller and electric chiller capacities are 1250 RT and 325 RT respectively. Electricity generated was supplied to the user as well as for in-plant consumption The designed standard was to operate the two turbines during the day and only one turbine during the night. While the absorption chillers were to be operated during the day, the electric chillers were to operate during the night for charging the thermal storage tank. The chilled water from the storage tank was designed to supplement the chilled water requirements during the day. From the analysis of two weeks operating data, one week for year 2004 and one week for year 2005, it was noted that variations occurred in terms of turbine operating hours and the chillers operating hours from that of the designed values. Preliminary findings indicated insufficient capacities of the electric chillers and the thermal storage tank were the main reason to the variations.

Keywords: Absorption Chillers, Chilled Water, Cogeneration, Electric Chillers, Gas District Cooling (GDC).

INTRODUCTION

Gas district cooling is part of a centralised air conditioning system in which chilled water is produced and supplied to the buildings. In a typical GDC system, gas boilers would produce the heat required by the absorption refrigeration system to produce chilled water. In recent years, the concept of cogeneration has become more popular in GDC plants. The system is environmentally friendly. The paper presents a study on the electricity and chilled water generation of a GDC plant which functions as a cogeneration and gas district plant.

GDC PLANT

The plant is a combination of a cogeneration and GDC plant. It is equipped with two 4.2 MW gas turbines, two heat recovery steam generators (HRSG), two boilers, two 1,250 tons of refrigeration (RT) absorption chillers (ACs), four 325 RT electric chillers (ECs) and a 10,000 tons of refrigeration hours (RTh) thermal storage tank.

Figure 1 shows the process flow of the plant. Electricity generated by the two gas turbines was supplied to the client as well as for in-plant use. Similarly for the chilled water produced it was supplied to the client and for in-plant use.

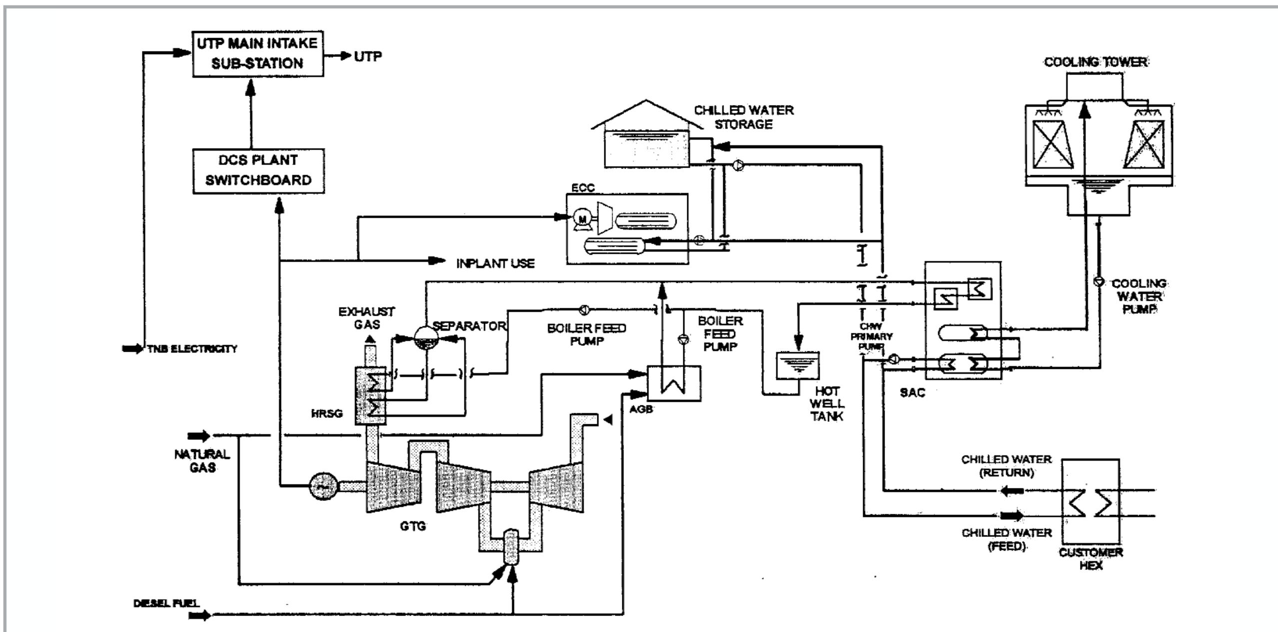

Figure 1: Process flow of the plant

The plant was operated on 24 hr basis and was designed to have the two turbines operating during the day and one turbine during the night. The operating schedule for the chillers was designed to have the ACs to be operated during the day and the ECs to be operated during the night for charging the thermal storage tank. The ECs were designed to operate using the electricity supplied from Tenaga Nasional Berhad (TNB). This was to take advantage of the lower night tariff offered by TNB. The storage tank was designed to supplement the chilled water requirements during the day.

METHODOLOGY

Hourly operating data on electricity and chilled water produced for two weeks, one week during October 2004 (1st to 7th) and one week during April 2005 (11th to 17th), were collected and analysed using the following formats:

- Hourly electricity generated, supplied to client, used by the plant and chillers.
- Hourly chilled water produced and supplied to client.

The weeks selected were based on typical working days, whereby the demand for electricity and chilled water varied from minimum to maximum.

ELECTRICITY GENERATION

The graphs on the total kWh generated, exported to the client and consumed by the ECs during the week of October 2004 and the week of April 2005 are shown in Figure 2 and Figure 3.

The following points are noted on the mode of the power generation and utilisation:

- During the daytime two turbines were operated, normally from 7.00 a.m. to 10.00 p.m., while on Saturday it was only until 1.00 p.m. Only one turbine was on operation during the remaining hours. While on Sunday, only one turbine was in operation.
- The electricity generated was exported to the client, operating of the ECs and also for in-plant usage.
- There was an increase in electricity generated during weekdays for the week of April 2005 (11th to 17th) compared to the week of October 2004 (1st to 7th). However there is no noticeable increase for Saturday and Sunday. Similar observations noted for the electricity consumed by the ECs. During the week of October 2004, the maximum and minimum electricity generated were 110,000 kWh and 60,000 kWh respectively. While for the week of April 2005, the maximum and minimum electricity generated were 120,000 KWh and 60,000 kWh respectively.
- The electricity generated was for 24-hour period. The peak production occurred from about 9.00 a.m. to about 6.00 p.m. with a maximum of 7,000 kW for the week of April 2005 and 6,500 kW for the week of October 2004. From 6.00 p.m. the quantity generated began to decrease and reaching a minimum at about 11.00 p.m. The minimum recorded for the week of October 2004 was 2,500 kW, while for the week of April 2005 was 3,000 kW. On the average, the two turbines were operated for 16 hours, while for the remaining 8 hours only one turbine was kept in operation.
- In terms of electricity generated, the hourly average kWh recorded for the week of October 2004 was 4,000 kWh, with minimum of 2,000 kWh and maximum of 6,500 kWh. The average electricity generated increased by 5 percent during the week of April 2005, with a minimum of 1,700 kWh and a maximum of 5,000 kWh.

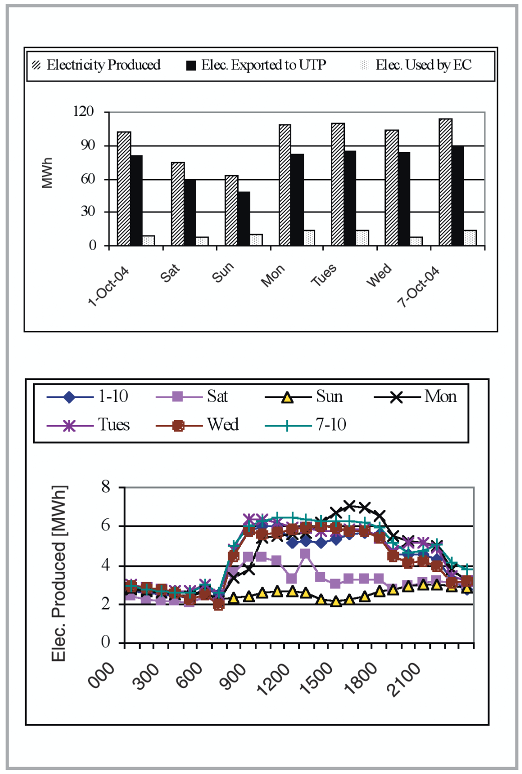

Figure 2: Electricity generation from 1 to 7 October 2004

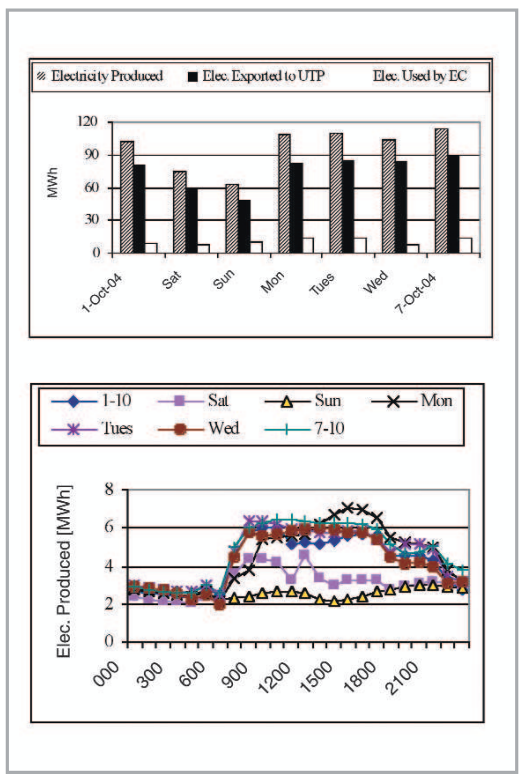

Figure 3: Electricity generation from 11 to 17 April 2005

Table 1: Summary of chilled water (CW) production by the ACs and ECs for 1 – 7 October 2004 and 11 – 17 April 2005

			AC-1	AC-2	Avg. AC's output/day	EC-1	EC-2	EC-3	EC-4	Avg. EC's output/day
1 ~ 7-Oct-2004	1	Avg. Chiller's Output/day [RTh]	10301	9839	**10070**	3735	1911	2372	2430	**2612**
	2	Coefficient of Performance (C.O.P.)	1.42	1.51	1.46	3.27	3.20	3.87	3.17	3.38
	3	Avg. Chillers' hours/day	20.57 hrs./day Max.28 and Min. 8 hrs.			42.71 hours/day Max. 53 hrs. and Min. 34 hrs.				
	4	Avg. No. of units operated	02 Nos.			04 Nos.				
	5	Avg. CW supplied to UTP/day	27030 RTh (11.6 % losses)							
11 ~ 17-Apr-2005	1	Avg. Chiller's Output/day [RTh]	10872	9177	**10025**	2825	3991	2460	4045	**3330**
	2	Coefficient of Performance (C.O.P.)	1.19	1.0	1.10	3.18	3.10	3.02	3.07	3.09
	3	Avg. Chillers' hours/day	11.71 hours/day Max. 16 and Min. 4 hrs			51 hours/day Max. 70 hrs and Min. 27 hrs.				
	4	Avg. No. of units operated/day	02 Nos.			04 Nos.				
	5	Avg. CW supplied to UTP/day	29232 RTh. (12.4 % losses)							

- During the week of October 2004, the KWh used to operate ECs varied from a minimum of 7,580 kWh to 13,800 kWh maximum, with an average of 10,900 kWh per day. While during the week of April 2005, the electric consumption by the ECs varied from a minimum of 9,500 kWh to 21,100 kWh maximum, with an average of 16,000 kWh per day.

CHILLED WATER PRODUCTION

The chilled water production for the week of October 2004 (1st to 7th) are shown in Figure 4, while Figure 5 shows the chilled water production for the week of April 2005 (11th to 17th). Figure 6 shows the hourly production of chilled water by the ACs. Detailed analysis on the chilled water production is included in Table 1.

Some of the points noted for the chilled water production are:

- The two ACs and four ECs produced the chilled water. The practice was that the ACs were perated during the day and early part of the night to meet the chilled water requirements. While the operation of the ECs were based on the requirement to charge the thermal storage tank.

- The ECs were operated during the day to supplement the chilled water requirements unable to be fulfilled by the ACs and the thermal storage tank.

- The plant output of the chilled water, during the week of October 2004, was rather stable on Monday, Tuesday, Wednesday and Saturday and fluctuating on Thursday, Friday and Sunday.

- The daily average production of chilled water by both ACs during the week October 2004 and week of April 2005 were 10,070 RTh and 10,025 RTh respectively. The differences between the average outputs of both chillers during both weeks were 4.5 percent and 15.6 percent respectively. While the average coefficient of performance (COP) of both chillers for the week October 2004 and April 2005 were 1.46 and 1.10 respectively. During the week of October 2004 the average chillers' hours per day was 20.57 hrs with the maximum and minimum of 28 hrs and 8 hrs respectively. While during the week of April 2005 the average chillers' hours per day was 11.71 hrs with the maximum and minimum of 16 hrs and 4 hrs respectively, a decrease of 43 percent from the week of October 2004.

- The daily average chilled water production by the ECs for the week of October 2004 and the week of April 2005 were 2,612 RTh and 3,330 RTh respectively. The differences between the maximum and minimum outputs by the chillers during both weeks were 48.8 percent and 39.2 percent respectively. While the average COP of the four chillers for October 2004 and April 2005 were 1.38 and 3.09 respectively. During the week of October 2004, the average chillers' hours per day was 42.71 hrs with a maximum of 53 hrs and a minimum 34 hrs. While during the second week of April 2005, the average chillers' hours per day was 51 hrs with a maximum of 70 hrs and a minimum of 27 hrs. This is an increase of 19.4 percent from the week of October 2004.

- The daily average of chilled water supplied to the client during the week of October 2004 was 27,030

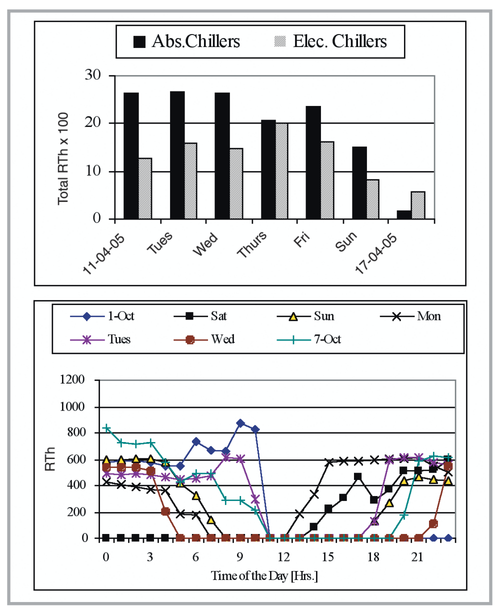

Figure 4: Chilled water production from 1 to 7 October 2004

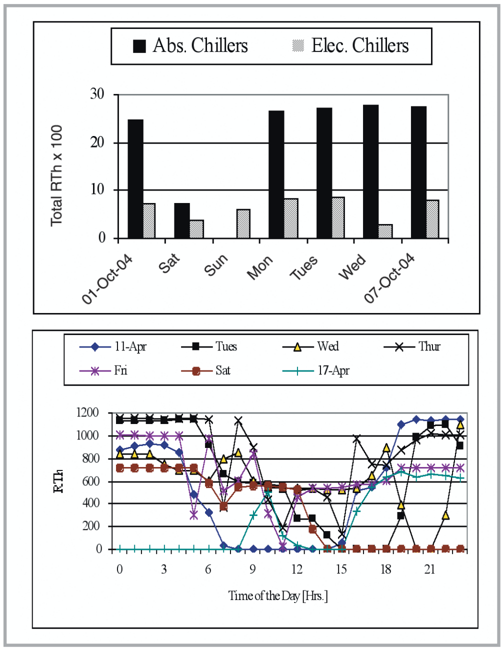

Figure 5: Chilled water production from 11 to 17 April 2005

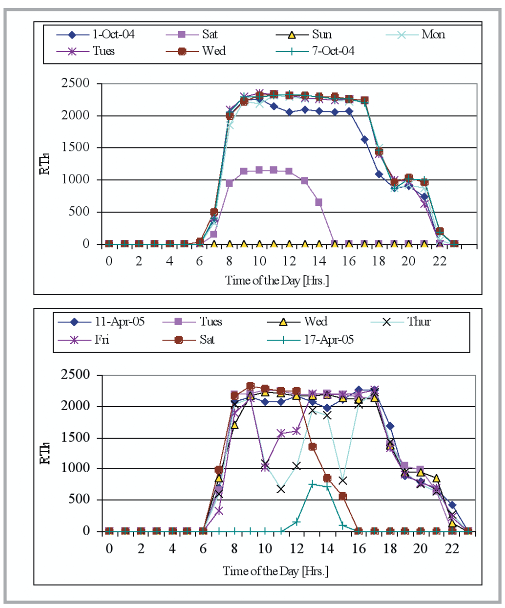

Figure 6: Chilled water production by ACs for week of Oct 2004 and April 2005

RTh with 11.6 percent losses. While the daily average for the second week of April 2005 was 29,232 RTh with 12.4 per cent losses.

- Scheduling of chilled water production was based on historical profiles and on the basis of day-to-day requirements.

DISCUSSION

Gas Turbines

- The maximum output recorded from the two turbines was 7,000 kW. This is 83.3 percent of the rated capacity. While for a single turbine the minimum recorded was 3,000 kW, which is 71.4 percent of the rated capacity.

- In general the operations of the turbines were not based on specific hourly schedules. The on and off of the gas turbines were based on the key performance indicator (KPI) set by the management. For enhancement, the turbine operations should also take into consideration so as to optimise operating time in order to reduce fuel consumption.

Chillers

- The average recorded daily output of the two ACs was 10,070 RTh with the daily average chillers' hours of 20.57. Hence the average hourly output of each AC chiller was 490 RT. This is 39.2 percent of the rated capacity. While the recorded average COP was 1.46.

- The daily average recorded output of the four ECs was 2,812 RTh with the daily average chillers' hours of 42.71 hours. Hence the average output of each EC was 65.8 RT which is 20.2 percent of the rated capacity. The recorded average COP was 3.38.

- The ECs were to operate during the night for charging of the thermal storage tank. However, from the analysis of the data for the two weeks it is noted that the ECs were operated during the day, from the minimum of three hours to full twelve hours, using the electric power generated by the turbines. On most occasions two ECs were on operations. This was due to insufficient capacity of the thermal storage tank. The feedback obtained was that insufficient time available to charge the thermal storage tank.

- The benefit of thermal energy storage i.e. to store cooling energy at night for use during the next day, was not being optimised. Hence this requires to be overcome. Possible options are to install additional electric chillers and a thermal storage tank. If sufficient additional ECs are installed which would enable the charging of the thermal storage tank to be completed during the night, operating of ECs could only be confined during the night. Hence operating time of the turbines could be reduced, which could lead to reducing of gas consumption. In addition, this will provide opportunity to maximise the use of electricity from TNB during off peak period.

CONCLUSION

The electricity and chilled water produced did not adhere strictly to design conditions. The main problem was that due to insufficient electric chiller capacities. More balanced scheduling which could optimise the plant operations could be achieved if additional chillers and a thermal storage tank are added to the system. A detailed analysis is required in order to ascertain the additional capacity of the electric chillers and the thermal storage tank, which could fulfill the requirements.

ACKNOWLEDGEMENT

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