Trigeneration – three benefits in one

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Trigeneration is generally understood to mean the simultaneous conversion of a fuel into three useful energy products: electricity, hot water or steam and chilled water. A trigeneration system is actually a cogeneration system with an absorption chiller that uses some of the heat to produce chilled water. This flexibility to use the recovered heat for heating during one season (winter) and cooling during another season (summer) provides an efficient way of maximizing the running hours at high total plant efficiency, benefiting both the owner and the environment.

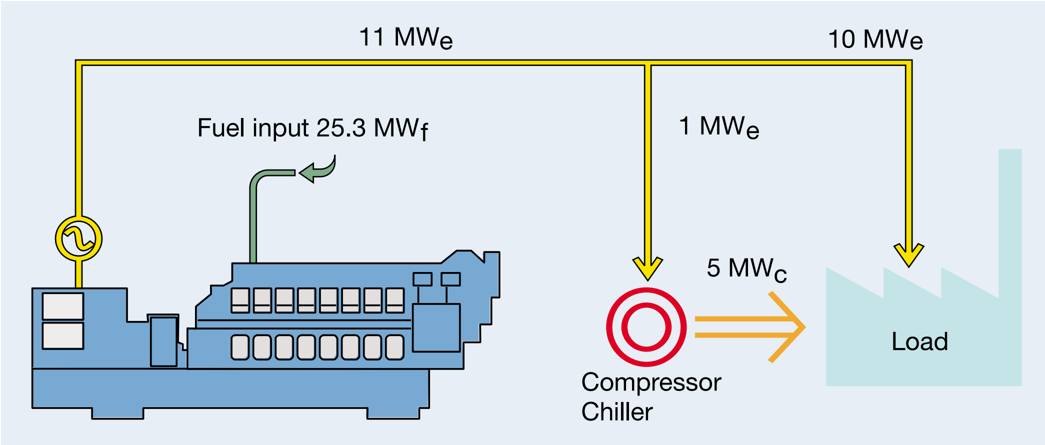

Fig. 1 Power generation and cooling with electricity.

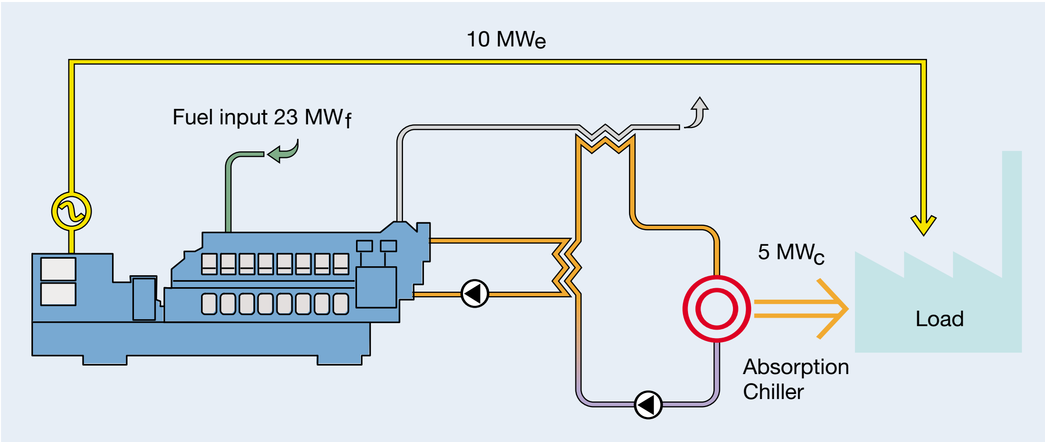

Fig. 2 Trigeneration: power generation, heat recovery and absorption cooling.

Figures 1 and 2 compare two concepts of chilled water production: trigeneration using recovered heat to fire a Lithium-Bromide (LiBr) absorption chiller, and compressor chillers using electricity. As the figure shows, the heat is recovered from both the exhaust gas and the engine high temperature cooling circuit.

Single-stage LiBr-absorption chillers are able to use hot water with temperatures down to 90°C as the energy source, while two-stage LiBr-absorption chillers need about 170°C, which means that they are normally steam-fired. A single-stage LiBr-adsorption chiller producing 6-8°C water has a coefficient of performance (COP) of about 0.7 and a two-stage chiller a COP of about 1.2. This means they can produce a cooling capacity corresponding to 0.7 or 1.2 times the heat source capacity.

Trigeneration and distributed power generation

Since it is more difficult and costly to distribute hot or cold water than electricity, trigeneration automatically leads to distributed power production, since the trigeneration plant needs to be located close to the heat and cold water consumers.

In order to maximize the total efficiency of the plant the concept is based on the joint need for heat and cold water. A power plant located close to the heat and chilled water consumer also has lower electricity distribution losses. Additional drivers of today's trend towards distributed power are safer distribution due to short distribution lines and more predictable electricity prices. The feeling of uncertainty is the result of the change from long-term power delivery contracts towards rapidly changing electricity pricing.

Trigeneration is cogeneration taken one step further by including a chiller (Figure 3). Clearly there is no advantage to making that extra investment if all the recovered heat can be used effectively during all the plant running hours.

However, the extra investment starts to pay off if there are periods when not all the heat can be used, or when no heat demand exists but there is a use for chilled water or air. For example, trigeneration is often used for air conditioning in buildings, for heating during winter and cooling during summer, or for heating in one area and cooling in another area, such as in data centres. Many industrial facilities have such a suitable mix of heating and cooling needs, three examples being breweries, slaughterhouses and chemical plants.

Design considerations

Flexibility in trigeneration can be improved by using hot water and cold water storages, and also by using the topping-up control capacity offered by compressor chillers or direct-fired auxiliary boilers. The running philosophy

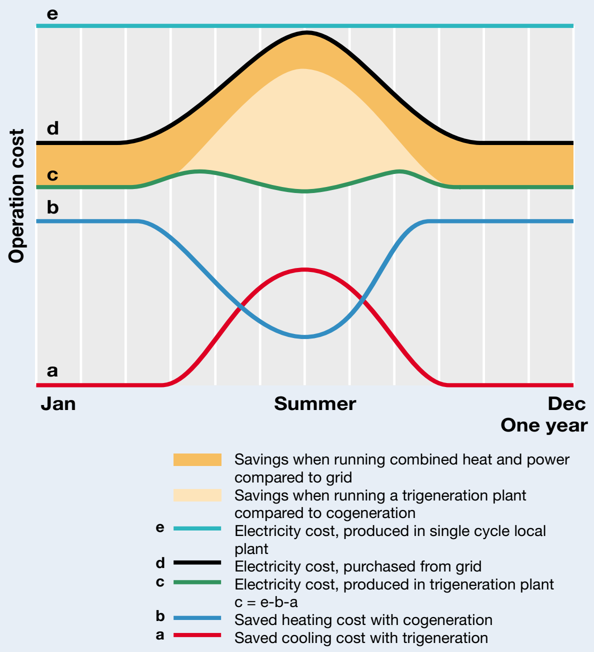

Fig. 3 Cost savings when running a trigeneration plant.

and control strategy are of importance and should be properly evaluated.

Cogeneration and trigeneration are not new inventions - cogeneration is as old as electricity generation itself - so plenty of proven control strategies exist.

The optimal solution is seldom based on a solution where the entire chilled water capacity is produced by absorption chillers. For air conditioning, for instance, most of the annual cooling need can be met with 70% of the peak cooling capacity, while the remaining 30% can be topped up with compressor chillers. This way the total investment cost for the chillers can be minimized. The chiller capacity can be further reduced by including cold water storage, which also gives more freedom to control heating and cooling capacities separately.

Trigeneration is a growing business

As living standards improve, demands for better comfort tend to increase along with more awareness of environmental issues. Better comfort leads to more widespread use of air conditioning and awareness of environmental issues leads to more efficient use of the fuel. Wärtsilä Power Plants has ready-made solutions for trigeneration which can easily be adapted to specific needs and delivered with tight time schedules. ■

Barajas Airport in Madrid

A typical trigeneration project is the power plant for the extension of Barajas Airport in Madrid. The independent power producer, Sampol Ingenieria y Obras S.A (Sampol), teamed up with Wärtsilä to develop a reliable, environmentally friendly and cost-effective trigeneration plant. At the time of writing, the installation work is about to start in the now finished power plant building.

Safety, comfort, efficiency

The power plant, equipped with six Wärtsilä 18V32DF dual-fuel engines, stands for both safety and comfort at the airport. A solution based on reciprocating engines is an excellent way of meeting the special demands for power supply at an airport where reliability and safety is of paramount importance. Power should be available at all times of the year, independent of external factors like weather or gas supply. Safety is maximized by a multiunit installation of multifuel engines on site. If for any reason the gas feed is interrupted, the gas-fired dual-fuel engines will instantly switch over to light fuel oil and continue to run.

The building volume needing both heating and cooling is huge. The new airport terminals have a floor area of 760,000 m² (76 hectares) divided between ticketing, baggage handling and passenger embarkation. Applying the trigeneration concept, the engines are generating money as a baseload plant at top overall efficiency instead of lying idle as emergency generators without contributing to the investment payback.

Top priority on reliability

The heat recovery system at Barajas Airport has additional complexity due to the reliability demands on the power plant. The generator sets must continue running without interruption even if there is a total failure in the heat recovery system.

This is achieved using back-up coolers which will cool away all heat not captured by the heat recovery system.

The plant is normally run in heat mode, which means that the outgoing water temperature is controlled by changing the engine load. The water flow varies depending on the consumption both in the area distribution lines and in the engine plus boiler heat recovery circuit.

Six single-stage absorption chillers will be installed in the power plant building. The chilled water is distributed to the consumers out in the new terminal through a separate piping system. The LiBr-absorption chillers are powered by the 120°C heat recovery circuit and cooled by the cooling towers. ■

Technical data for the Barajas Airport power plant:	
Power at generator terminals	33.0 MW_e
Electrical efficiency	42.4%
Gross thermal power from heat recovery	24.6 MW_{th}
Total thermal power (heat recovery + gas fired boilers)	30.9 MW_{th}
Heat recovery circuit water	120/80°C
Total efficiency of cogeneration	74%
Absorption chiller capacity	18.0 MW_c
Total chiller capacity (absorption + compressor chiller)	37.4 MW_c
Chilled water circuit	6.5/13.5°C
Normal fuel	gas
Back-up fuel	light fuel oil
HT back-up cooling	radiators
LT and chiller cooling	cooling towers