TRIGENERATION – AN EFFICIENT POWER AND ENERGY SOLUTION FOR PUBLIC BUILDINGS

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The costs of providing electrical power, heating and air conditioning for large public buildings and industrial complexes are becoming progressively more expensive as public utilities continue to increase their charges in line with fuel costs. Additionally, many traditional methods of heating and cooling these buildings can cause environmental damage due to the use of outdated technologies.

The trend today is to build more efficient climate control systems for building complexes instead of having many smaller electrically driven units for heating and cooling. A combined heat and power (CHP) plant can provide electrical power as well as heating and chilling for these buildings in a single power and energy source on-site, providing significant operational and efficiency advantages since separate systems are not necessary. This method of combined power and multi-thermal energy production is known as 'trigeneration'; it is, in fact, combined heat and power taken one stage further by including an absorption chiller which supplies chilling without using electrically driven chilling compressors.

Public buildings can benefit

The concept of trigeneration is based on the joint need for power, heating and chilling in a building or factory. A plant located close to the hot and chilled water consumers also has lower electricity distribution losses. Many industrial facilities and public buildings have a suitable mix of heating and cooling needs to benefit from a trigeneration power plant, for example the food industry, shopping malls, hospitals and airports.

To maximize the total efficiency of a trigeneration plant, the plant needs to be located close to the end-users since it is more difficult and costly to distribute hot or chilled water than electricity. When installing air conditioning, 70 percent of the plant's peak cooling capacity is enough to meet most of the building's annual cooling needs, while the remaining 30 percent can be topped up using compressor. 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 capacities separately.

The running philosophy and control strategy are of importance and should be properly evaluated. The optimal solution is seldom based on one where the entire chilled water capacity is produced by absorption chillers.

Installing air-conditioning with absorption chillers

For trigeneration, a single-effect absorption chiller connected to the hot water system is the most suitable solution. In the winter the peak hot water demand, which exceeds the recovered heat from the engine plant, is covered by a stand-alone hot water boiler. The same boiler is then topping up the heat feeding the single-effect absorption chiller to produce cold water summertime.

Absorption chillers are heat-driven cooling machines. Instead of a mechanical compressor they use a thermal system, utilizing lithium bromide (LiBr) as an environmentally sound alternative to CFCs. They are used in a large number of petrochemical power and district cooling schemes today to provide custom-designed refrigeration solutions with capacities up to 25 MW producing chilled water down to 2 °C.

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-absorption chiller producing water at 6-8 °C 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.

Gas engine features

Reciprocating engines which burn gas as fuel offer several specific advantages for power and district heating and chilling production. They have a very high electrical efficiency, which is also maintained at part loads and over a long period of time under severe operating conditions. The lean-burn engine is less derated than gas turbines by ambient temperature, altitude and back-pressure, nor does it suffer from reduced electrical efficiency or loss in rated output as it accumulates running hours. Lean-burn gas engines can easily handle varying load and frequent starts and stops. The gas engine is also insensitive to variations in the operating conditions.

Both exhaust gas and engine cooling can be fully used in hot water production. The total efficiency depends on the temperature levels of the interconnection, but can reach 93% with a low return water temperature level. For higher return water temperatures when interconnected to absorption chillers, e.g. 75 °C, some of the cooling water of the LT circuit must be rejected. As the return water temperature fluctuates over the year, careful design is needed to optimize the plant for the most viable configuration.

A sound investment

An investment in a trigeneration plant starts to pay off when there are seasonal periods when the power plant's waste heat can be fully used. For example trigeneration is 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. This flexibility provides an efficient way of maximizing the running hours at high plant efficiency, benefiting both the owner and the environment.

Energy efficiency in practice at Milan, Madrid and Detroit Airports

Power and thermal energy needs are huge in new air terminal buildings. The buildings themselves can have a floor area of up to 760,000 m² (as in Madrid), divided between ticketing, baggage handling and passenger embarkation. A trigeneration plant can supply all of the power, heating and chilling needs efficiently and securely.

At an airport it is of utmost importance that power and thermal energy is available at all times of the year, independent of external factors such as inclement weather and interrupted gas supplies. Power security can be maximized by a multi-unit installation of dual-fuel engines on site. If for any reason the gas feed is interrupted, the gas-fired dual-fuel engines will instantly switch over to LFO and continue to run.

LINATE AIRPORT, MILAN, ITALY

In summer 2007, the Finnish company Wärtsilä and EuroPower SpA handed over a 24 MWe trigeneration power plant at Linate airport, Milan in Italy. The plant was built for Malpensa Energia Srl, whose shareholders are the Milan airport management company SEA Aeroporti Milano and the Milan multi-utilities company AEM Milano.

The trigeneration power plant is equipped with three Wärtsilä 20V34SG gas-fuelled generating sets, together with their ancillary equipment, exhaust heat recovery economizers and two gas-fired boilers. The plant is located inside Linate airport.

The plant operates on baseload but, by providing both heating and air conditioning, it is designed to flexibly and economically meet the variations in heat demand in summer and winter. The heat output of the plant is 82 MWth in winter and 72 MWth in summer, with a year-round electrical power output of 24 MWe.

The heat is delivered as hot water at 125°C and hot water at 70°C to the airport buildings and also to a small village close to the airport. The plant also delivers electricity to the Italian national grid. Normally the generating sets run in parallel with the grid but they also serve as emergency sets to maintain airport services in the event of a break in the grid supply.

BARAJAS AIRPORT, MADRID, SPAIN

Another example of a trigeneration power plant can be found at the Barajas airport in Madrid. The airport extension in Madrid has been one of the most important European engineering and construction projects in recent years. It involved the construction of two terminals, a main passenger terminal that includes ticketing, baggage handling and passenger embarkation and a second satellite passenger terminal connected to the main terminal by underground train. The extension project also included the addition of new runways, a new road system for access to the airport, and various airport related services.

AENA (Aeropuertos Españoles y Navegación Aérea), the Spanish Airport Authority, chose a Spanish engineering company Sampol (Sampol Ingenieria y Obras S.A.) in 2003 to supply power and thermal energy to the new extension. Sampol and their power partner

Wärtsilä, Finland, were able to satisfy AENA's requirements for a cost-efficient cogeneration plant that is both technically advanced, environmentally friendly and able to guarantee the extremely high level of reliability necessary for this key facility in such an important location. The trigeneration plant was commissioned in January 2005.

Under the EPC (engineering, procurement and construction) contract for the new building, Wärtsilä was responsible for the supply of the entire power plant which consisted of the plant engineering, equipment, installation, commissioning and start-up of the six Wärtsilä 18V32DF dual-fuel engines and their auxiliaries, the heat recovery boilers, the engine hall ventilation systems and the engine control system.

Connected to both the airport's terminal grid and the public grid, the trigeneration plant generates a net output of 33 MWe. It provides electricity on a continuous basis, as well as thermal energy for the extension's heating and cooling. The plant's engines, heat production equipment and chillers each have their own clearly allocated areas in a new building alongside the airport's newest and biggest runway.

The plant's six Wärtsilä 18V32DF engines burn natural gas as main fuel and light fuel oil (LFO) as the back-up fuel, and their emissions comply with the local environmental laws. In compliance with Spanish and other European engineering and construction standards, the plant meets the airport's own regulations. The plant is normally run in heat mode; this means that the outgoing water temperature is controlled by changing the engine load. Owing to heat and chilling load variations the plant contains a gas boiler and compressor chillers for peaking and stand-by operations.

DETROIT METROPOLITAN AIRPORT, USA

Wärtsilä has also delivered three Wärtsilä 18V34SG gas engines for a combined heat and power (CHP) plant at the Detroit Metropolitan airport in the USA. The Wärtsilä CHP plant has been operating continuously since April 2002, delivering 16 MWe of power and 7 MWth of heat to Detroit airport's Edward H. McNamara Terminal. The new, state-of-the-art McNamara Terminal (phase one) opened in February, 2002, replacing an older terminal originally known as the Jim Davey Terminal.

The two-million-square-foot (185,000 m^2) midfield McNamara terminal, phase one, featured 99 gates, 18 luggage carousels, an 11,500-space parking garage and an automated express tram system, which traverses the 1.6 km length of the building. The terminal building phase one included a connecting link (concourse A) with the existing terminal buildings, an east concourse with 66 aircraft gates, a passenger tunnel, a west concourse with eight jet gates and 25 commuter aircraft gates, an 11,000-space parking garage, a three-level roadway system, 1800 m^2 of apron and taxiways, support facilities, and the Wärtsilä CHP power plant located immediately adjacent to the new control tower at the terminal. Phase one of the McNamara terminal expansion already helped the airport to gain new operational efficiency, but construction and expansion continued into phase two which was fully completed in 2006.

With continuous development and expansion, a reliable, on-site power supply can be more efficient and profitable than buying electricity from the grid. In fact, DTE Energy Services operates this facility on an economic dispatch basis, selling excess electricity to the local grid when the CHP plant's cost of generation is lower than that of other suppliers to the grid, and in turn buying electricity from the local grid when the local grid price is lower than the CHP plant cost.

Another benefit of this installation was to quickly restore airport operations during the August 2003 grid blackout that affected the entire eastern United States. This grid blackout lasted for many hours, and the on-site CHP facility enabled Detroit Metro Airport operations to be restored very quickly.

"Because of the above blackout, Northwest Airlines is now implementing a PLC-based load shed system that will enable the CHP plant to be used for stand-by power in the event of a total loss of utility power," says Mr David Kiselewski, Plant Manager of Metro Energy LLC, a division of DTE Energy Services. "The system will be fully automatic, shedding terminal loads by priority to match the available generation from the CHP plant. This will ensure the Detroit Metro Airport can operate normally should a future power outage occur," he continues. ■

Wärtsilä enhances the business of its customers by providing them with complete lifecycle power solutions. When creating better and environmentally compatible technologies, Wärtsilä focuses on the marine and energy markets with products and solutions as well as services. Through innovative products and services, Wärtsilä sets out to be the most valued business partner of all its customers. This is achieved by the dedication of over 18,000 professionals manning 160 locations in 70 countries around the world. Wärtsilä is listed on the Nordic Exchange in Helsinki, Finland.

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