

Integration of trigeneration technologies in buildings

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INTRODUCTION

During last years, the demand for electricity in Spain increased with an annual average power consumption increase rate of 4% [1] with an important contribution of the use for air-conditioning. This fact has expanded the market potential for small scale trigeneration. This expansion will be also promoted by the new law on cogeneration [2].

Trigeneration technology is able to supply all the energy services required in a building with a single integrated unit producing electricity and recovering the waste energy to produce heating, domestic hot water and cooling using different thermally-activated HVAC technologies.

This brief paper describes the concept of trigeneration systems, studies the integration of this equipment in buildings and analyses the present situation and new applications of this technology for small scale applications.

TRIGENERATION CONCEPT

The integration of the trigeneration technology in buildings is an alternative to the actual energy supply situation. A building demands different energy services: electricity, hot water for heating and DHW, steam (for example in hospitals) and cooling. These needs can be covered buying electricity from the grid and producing heat locally with boilers and cooling with conventional air-conditioned units or alternatively with a trigeneration system suitable to produce all the energy services required with a single source of primary energy.

The trigeneration concept refers to the simultaneous production of mechanical power (usually converted to electricity), heat (at low and high temperatures) and cooling (using heat at high temperature) using only one source of primary energy as fossil fuels or some appropriate types of renewable energy sources (biomass, biogas, solar thermoelectrical plants, etc). The recovered thermal energy is used to generate heat and cooling thus increasing the overall efficiency of the system with respect to the more conventional separate production of electricity and heating and/or cooling that produce a given saving in primary energy that will depend on the specific technologies and application.

INTEGRATION OF COOLING TECHNOLOGIES INTO COGENERATION SYSTEMS

Several distributed generation technologies are suitable to produce electricity using different fuels, some are already commercialized, such as Gas-Turbines, I.C. Engines, etc and some are in the development process, such as Fuel cells (Solid Oxide,

Phosphoric Acid, PEM), Stirling engines, etc. All these systems produce thermal waste heat at different temperature levels.

According to the quality of the recovered heat of the equipment selected it will be possible to integrate different thermally-activated HVAC technologies with cogeneration systems. Gas-turbine and Solid Oxide Fuel Cells generate recoverable energy at very high temperatures suitable for efficient double effect chillers. While microturbines and small I.C. Engines are suitable to drive single effect absorption chillers or desiccant cooling technologies and PEM Fuel Cells produce heat at a temperature range adequate for their integration with adsorption chillers.

NEW TECHNOLOGIES FOR SMALL CAPACITY TRIGENERATION

New technologies and products are being developed to satisfy the increasing demand of small scale systems for trigeneration in buildings. The current market includes power generation technologies with a capacity lower than 200 kW: new reciprocating engines, Stirling engines, ORC (Organic Rankine Cycles), Micro Gas Turbines and Fuel Cells. On the other hand the options for chilled water production using the mentioned power generation systems are water/LiBr Chillers activated with low temperature heat, ammonia/Water chillers, Adsorption Chillers and Thermochemical heat pumps. These units cover a range from 5 to 100 kW of cooling capacity.

INTEGRATION OF TRIGENERATION SYSTEMS

The trigeneration technology is a great solution to supply energy to the building sector (commercial, residential, offices, hotels...).

In Industrial applications the energy demand is very regular across the year, but in buildings the energy demand is highly variable due to the external ambient conditions, the occupancy, the different building uses, etc. The flexibility of a trigeneration equipment is able to adapt to the customer's service requirements, despite the high variability in energy demand characteristic of building applications.

The integration of the trigeneration systems into DHC (District Heating and Cooling) networks is an excellent application that will play an important role in the near future. DHC produces the energy in production centres, to supply electricity, heating, DHW and cooling to the consumers through a net of pipes and substations. The integration of polygeneration systems, including renewable energy sources into these energy networks is very important to achieve a better matching with the energy demand at the lowest environmental impact. An example of this kind of applications is the existing Polygeneration Plant ParcBit in Mallorca described in detail in the European project CAMELIA [3]. Many other DHC systems are in the planning or construction stage, an example is the urban and clean industries business park area build on a common basis of innovative sustainable construction in Cerdanyola del Valles (Barcelona) in the framework of the European project POLYCITY [4].

CURRENT SITUATION AND FUTURE DEVELOPMENT

The vast majority of absorption chillers are water/LiBr hot water systems driven by hot water, so the energy efficiency is limited and also a cooling tower is required. Some

demonstration projects or new developments are in progress to overcome these kind of problems using directly the exhaust gas or using ammonia/water chillers.

The European Project HEGEL (High Efficiency polyGEneration applications) is developing co- and trigeneration technologies to be integrated in different buildings [5]. One of the demonstration sites of this project is a trigeneration system based on a Capstone C30 Micro gas turbine and an air-cooled absorption chiller driven by thermal oil to produce 17 kW of cooling (see figure 1).

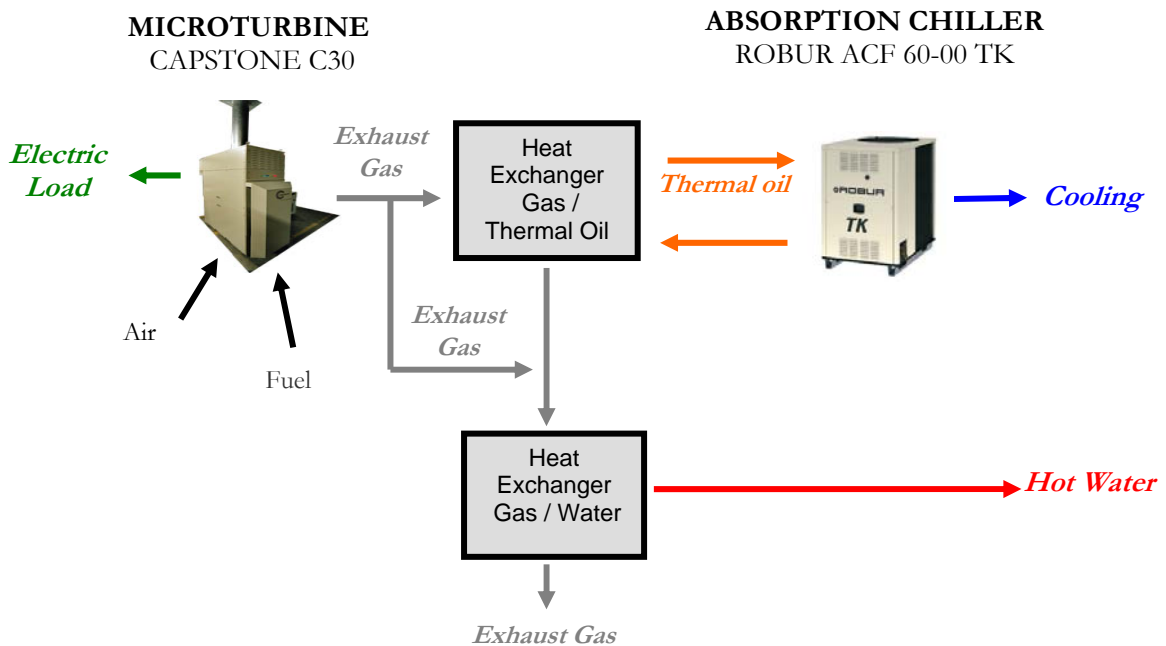


Figure 1 – Trigeneration configuration of the European project HEGEL

It is possible also to design systems with additional heat production to increase the flexibility of the systems with respect to cooling load changes. The Double Effect Absorption Chiller Yazaki CH-KE4040 is designed to use directly the exhaust gas from a power generation system in a trigeneration configuration using two generators, one directly heated by the exhaust gas coming from the microturbine or IC engine and the other one heated using natural gas, LPG, etc. This system do not requires any intermediate heat exchanger so the driving temperature increases and can be operated as a double effect system with a higher (COP 1.04).

Another optional configuration for trigeneration systems is based on the use of post-combustion. The exhaust gas of the turbogenerator has enough O_2 to be mixed with fuel and produce a post-combustion to heat the solution of the Absorption chiller in the Generator and evaporate the refrigerant. Currently there is a study about the possibility of using this configuration with absorptions Chillers manufactured by Broad.

Also a new promising configuration for trigeneration systems is the simultaneous use of the flue gas and cooling water from IC engines to operate Single/Double Effect Chillers. In Double Effect Chillers, the flue gas is used to heat the main generator and the second generator uses two heat sources, the condensing refrigerant from the main generator and the cooling water of the IC engine.

New ideas are being developed to integrate trigeneration systems in different areas. An example for this is the integration of an Absorption Chiller and a Micro gas turbine in a municipal sewage treatment plant (see figure 2) where the Biogas obtained from the sewage treatment is used to fuel the microturbine and the cooling production of the absorption chiller reduces the humidity of the Biogas in the pre-treatment and also it cools the ambient air to obtain a higher efficiency in the microturbine.

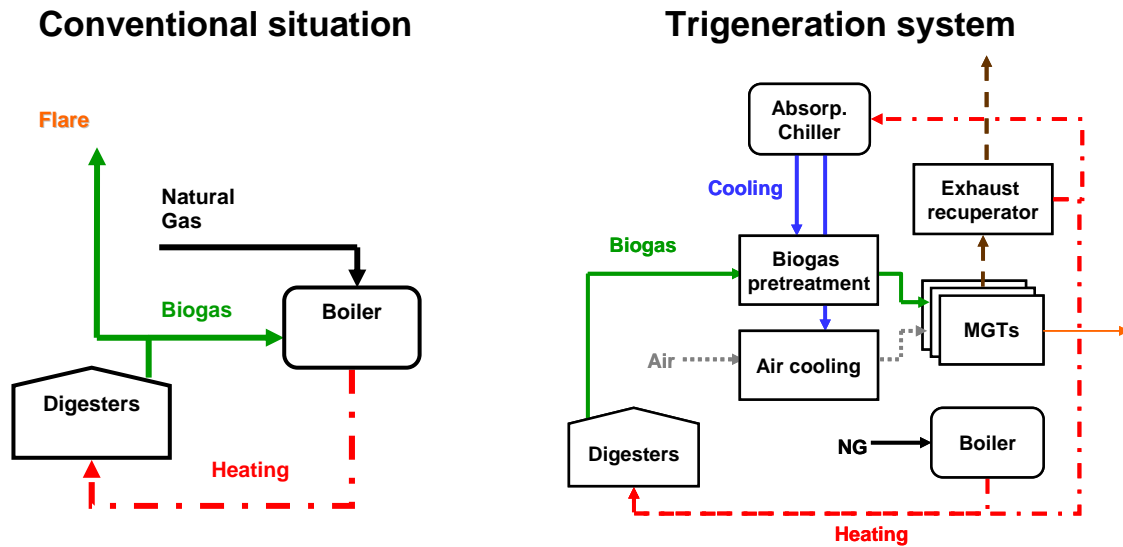


Figure 2 – Trigeneration system integrated in a municipal sewage treatment plant

Another future application of great interest is the production of desalted water along with electricity, heat and cooling using steam or an organic working fluid at low temperatures. An example of this innovative technology is the Osmosol project [6]. In this study thermal solar collectors are used to drive a turbine/ expander to move a high pressure pump of a Reverse Osmosis desalination plant that could be used also to produce electricity and recover the waste heat from the condenser for heating and/or cooling.

CONCLUSIONS

The main conclusions that can be draw from this brief technology review are the following:

- An increasing research and development effort is currently made to improve the integration of cogeneration and sorption chillers using directly the exhaust gases, combined use of engines cooling and gases, new SE/DE configurations, etc.
- New commercialised or ready to enter the market technologies are now available with a higher efficiency for small capacity trigeneration systems.
- New trigeneration configurations and applications are being explored that can expand the market for trigeneration.
- However there is still an important lack of field data on the real operation of small capacity trigeneration systems.

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