A CHCP System Constituted by Microturbine and Exhaust Absorption Chiller

G. Caruso, L. De Santoli, F. Giamminuti, P. Sodani

University of Rome "La Sapienza" - SAE – Servizio di Ateneo per l'Energia
P.le Aldo Moro 2, 00185 ROME (ITALY)

ABSTRACT

The combined heat, cooling and power production (CHCP) is one of the most interesting methods to increase the system global efficiency by supplying electric and thermal power needs both in winter and in summer, and at the same time reducing CO_2 emissions.
Global efficiency increase is related to the use of waste heat which can be also used to produce cooling energy by means of a absorption chillers.
A CHCP programme is planned in a specific area in the "University City" of the University of Rome "La Sapienza" (approximately 1000.000 cubic meter and an energy bill of some 10 M€) and it consists of a gas micro-turbine and a direct exhaust absorption chiller/heater, and will be realised in the area of Pharmacology Institute buildings, being the first example in Italy.
The realization is the first step which will be further implemented in other areas of "University City"; the paper deals with the energy savings evaluation, both from the economical and environmental point of view.

KEYWORDS

Energy, Cogeneration, CHCP, Microturbine

INTRODUCTION

The rapid growth in population and industrialization, and the associated increase in energy demand and consumption, requires more and more attention in selecting environmentally compliant and efficient energy conversion systems. Subsequently, for current and future generating facilities, the utility companies and the independent power producers have to face up to operational restrictions, increased efficiency requirements, variations in energy prices, concerns about future environmental legislation and the uncertainty over future utility demands [1].
The traditional energy cycle in most developed countries is the combustion of fossil fuels and/or the use of nuclear fuels in a large central power plant to generate electricity. The electricity is then delivered to users over a high-voltage transmission and lower-voltage distribution network. At least 50 to 70% of the energy content of the fuel is lost at the power plant alone through energy conversion inefficiencies and is discharged in the form of waste heat into the environment. Further losses (up to 8%) occur in the electric power transmission and distribution network in the form of electric current losses and power transformation losses (step-up and step-down transformer losses).
Distributed energy production plants, such as microturbines, are small, modular power generation systems located on or near the site where the energy that is

generated is used. Unlike centralized energy resources, such as large power plants, they provide an opportunity for local control of power generation and more efficient use of waste heat to boost overall efficiency and reduce emissions.
The combined heat, cooling and power production (CHCP) is one of the most interesting methods to increase the system global efficiency by supplying electric and thermal power needs both in winter and in summer, [2], [3], [4].
The CHCP (also called tri-generation) station is constituted by an engine (gas micro-turbine), an asynchrony generator for electric power production and a direct exhaust absorption chiller/heater for the summer and winter air conditioning systems. By making use of heat energy that is normally wasted, CHCP systems can meet a building's electrical and thermal loads with a lower input of fossil fuel, yielding resource efficiencies of more than 80%.

DESCRIPTION OF THE PROJECT

The City University "La Sapienza" is a small district of Rome, but it can assume a remarkable symbolic impact and of sensibility promotion due to the importance of the Institution that covers the area, becoming expression of a new sensibility regarding the environment, through a rational use of the energy. With the intention to place the university City in a vanguard position in the use of renewable and low-emission energy sources, it has been decided to subdivide the district in "islands", each characterized from different energy sources. As a first step of this energetic new organization, a CHCP programme is planned in a specific area in the "University City" (approximately 1000.000 cubic meter and an energy bill of some 10 M€) and it consists of a gas microturbine and an exhaust absorption chiller, and will be realised in the area of the Pharmacology Institute building, being the first example in Italy.

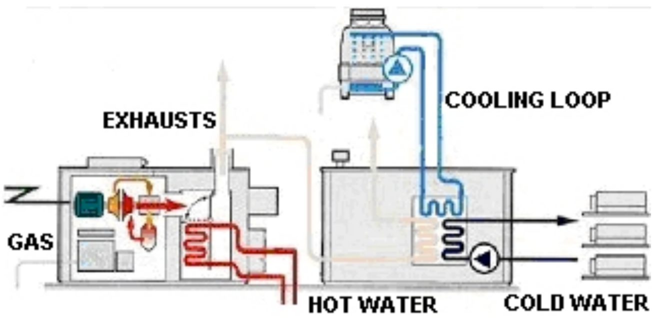


Fig. 1 – Scheme of the CHCP plant

The tri-generation system will provide by the microturbine about 100 kW_e and 160 kW_t for heating during winter; in the summer season the hot exhaust gases will be used to operate an direct exhaust absorption chiller, selected to produce cold water (110-120 kW_f) for air conditioning. The realization is the first step which will be further implemented in other areas of "University City"; the energy savings and the advantages of the technology, both from the economic and environmental point of view have been evidenced.
The definition of the optimal dimension of a CHCP is initially based on calculations about the economic convenience. These calculations need to analyze the electrical and thermal loads and the electricity and the fuel costs, in order to perform an economic evaluation. To verify the optimal size of the system, a simulation of the

consumptions has been carried out, for the typical days of the year, week and festive, month for month. The examined configurations, make reference to various sizes of cogenerator system, each in combination with different sizes of absorption groups.
In order to measure, in synthetic and effective way, the correspondence of the foreseen solutions for the CHCP system to the requirements of energetic saving, the following parameters have been used:

- the achieved primary energy savings from each of the selected cogenerative solutions in comparison with traditional plants;
- the emissions of carbon dioxide avoided.

The selected plant configuration produces 100 kW_e, 160 kW_t heating and 120 kW_t cooling and the target is to save about 52.000 Nm^3/year of gas as consumption, reducing the CO_2 production of more than 90 ton/year.

EXPECTED ADVANTAGES

A CHCP plant introduces advantages in term of energy efficiency, energy saving and environmental protection, well known on a large scale in EU and now acknowledged also by Italian legislation. The possibility to take advantage of the economic benefits due to the emission of "green certificates" makes the investment in this type of technology more and more interesting, promoting and favouring a wide diffusion in residential, commercial and industrial sectors. In [5] a preliminary analysis of the economic and environmental benefits has been described and it is briefly summarized. In particular, the contributions of the system both from the economic and environmental side; the cost savings for the University structures derived from the new co-generative configuration, the lower gas consumption and the reduced emissions of greenhouse gases, will be briefly discussed.
From the economic analyses carried out it was clear that, if the hypotheses placed to the base of the economic evaluation will be verified during of the real operation of the CHCP system, it will be possible to save approximately 35.300 €/year, with a time of recovery of the investment for the main components (turbine, absorption chiller and cooling tower) of approximately 4-5 years.
The environmental advantages connected with the use of a co-generation system are now discussed. A total efficiency of 80% has been estimated for the CHCP system. In the performed analyses, it could be derived that the installation of the microturbine allows, only considering the winter season, the recovery of approximately 227,700 kWh_t. This recovery corresponds, in terms of gas consumption, to a reduction in the fuel requirements of approximately 29,772 Nm^3 in the winter period[1]. To this value, it should be added the saving, in the summer season, related to the production of cooling energy because of the adoption of the absorption heat pump. The saving of 170,800 kWh of cooling energy allows a reduction (in the consumption of electric power) of approximately 85,400 kWh_e[2]. Assuming the efficiency of production of thermo-electrical plant equal to 40%, a further saving in terms of gas not consumed (equal to approximately 22,300 Nm^3 per year) is obtained. The above calculations allow therefore to quantify the annual gas saving in approximately 52,100 Nm^3/year; this value can easily be translated in a reduced CO_2 production of 97 ton/year[3].

---

[1] Boiler efficiency assumed equal to 80%.
[2] Absorption heat pump efficiency: 2.
[3] The carbon dioxide production from the combustion of methane has been estimated equal to 1,86 kg/Nm^3, without considering the oxidation factor.

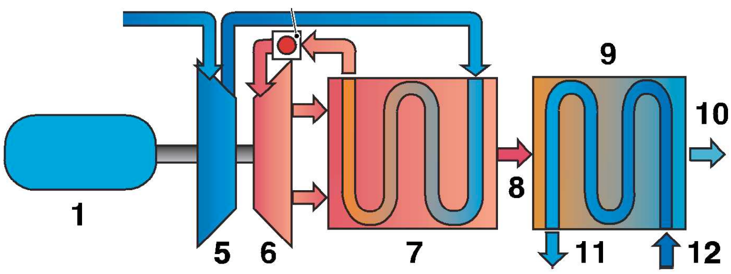
A further interesting aspect to analyze is related to the reduction of the losses that normally occur during the transport and the transformation of the electric power along the distribution networks (5-8%). A last interesting consideration on the benefits of the co-generation regards the use of "absorption" for the production of cooling energy during the summer season. The absorbers, with respect to the traditional electrical cooling systems, require only small amounts of electric power for their operation. The resource to this technology allows therefore a very interesting reduction of the electrical peaks demand, which, in the last years, more and more frequently occurs in correspondence of the warmer months of the year.

DESCRIPTION OF MAIN EQUIPMENTS

The main equipments selected in the present project are a TURBEC T100 PH S3 microturbine and a BROAD BDE10 IX 270-K-15 indirect-fired absorption chiller.

The Microturbine

The Turbec T100 Power (T100 P) microturbine produces electrical power (100 KW_e) with an efficiency of 30% [6]. It can be used in processes where the hot exhaust gases are used directly for drying, cooling, or feeding an absorption chiller. The T100 PH (Power and Heat) unit includes an exhaust gas heat exchanger. This combination allows the T100 to produce combined heat and power achieving very high overall efficiencies. The hot gases leaving the microturbine can be used to produce hot water. The total efficiency of the microturbine will in this way be maximized.
The main components for the microturbine unit are shown in Fig. 3:
The Turbec T100 uses a radial centrifugal compressor to compress ambient air. The pressure ratio is about 4.5:1. The compressor is mounted on the same shaft as the turbine and the electrical generator.



1. Generator; 2. Inlet air; 3. Combustion chamber; 4. Air to recuperator; 5. Compressor; 6. Turbine; 7. Recuperator; 8. Exhaust gases; 9. Exhaust gas exchanger; 10. Exhaust gas outlet; 11. Hot water outlet; 12. Water inlet

Fig. 3 – Main components of the TURBEC T100-PH microturbine [6]

The electrical efficiency of the gas turbine is increased with a recuperator. The recuperator is a gas-to-air heat exchanger attached to the microturbine. The heat is exchanged from the hot exhaust gases to the compressed air that is fed to the combustion chamber. The preheated compressed air is mixed with the fuel. During start up an electrical igniters in the combustion chamber ignites the mixture.
The combustion chamber is of lean pre-mix emission type, achieving exhaust gases with low emissions of NO, CO and unburned hydrocarbons.
The turbine drives the compressor and the generator. When the combustion gases leave the combustion chamber the temperature is approx. 950°C and pressure is

approximately 4.5 bar. As the combustion gases expand through the turbine the pressure decreases to nearly atmospheric pressure and the temperature drops to approx. 650°C.
The electric power is generated by a permanent magnet rotating at high speed. The Turbec T100 is controlled and supervised by an automatic control system so the unit needs no personal attendance under normal operation
The exhaust gas heat exchanger is of gas-water counter-current flow type. The temperature of the exhaust gases is approx. 270°C, entering the exhaust gas heat exchanger, during the winter season, or the exhaust-type chiller during summer. The thermal energy from the exhaust gases is transferred to the hot-water system by the exhaust gas heat exchanger. The outlet water temperature depends on the incoming water conditions, temperature and mass flow. The exhaust gases leave the exhaust gas heat exchanger through an exhaust pipe and the subsequent chimney.

The Absorption Chiller

The selected BROAD BDE10 IX 270-K-15 indirect-fired absorption chiller has a cooling capacity of 120 kW. It is a single stage exhaust type chiller characterized, among others, by the following features [7]:

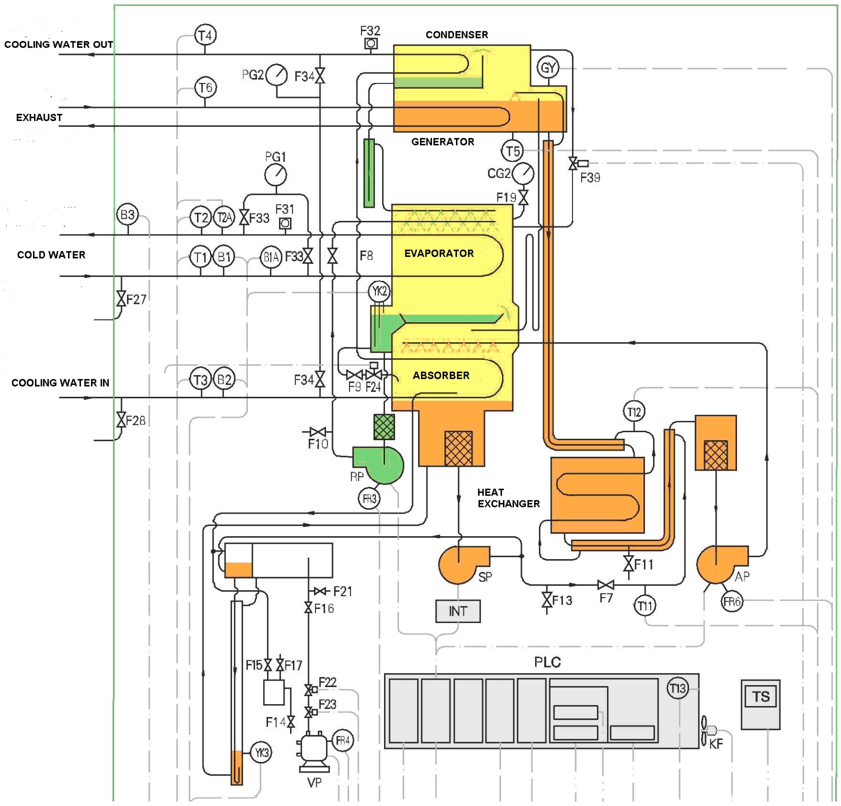


Fig. 4 – The BROAD indirect-fired absorption chiller P &ID [7]

- Auto crystallization detection, freezing, auto decrystallizaiton, defreezing system shoot the trouble crystallization that had puzzled absorption chiller manufacturers for more than 50 years.
- Auto purge system. Use inline falling head purge device to auto purge collection chamber so that the good vacuum condition can be maintained.

- Plate heat exchanger. Solution is completely heat exchanged, only 2°C ~ 5°C temperature difference, which is 15% energy saving than tubular heat exchanger.
- Turbulator in high - temperature generator (HTG) dramatically reduces exhaust heat loss, about 10% energy saving.
- Refrigerant level probe avoids refrigerant water waste at part load, which increases energy efficiency.

CONCLUSIONS

Today, environmental considerations are an obvious factor in the development of power generation systems. The importance of this dimension will increase further in the years ahead as a result of ever more stringent environmental legislation and increasing public awareness of “green” issues.
In the high efficiency thermo-electrical power plants the production of electrical power involves the discharge of large amounts of heat in atmosphere. Recovering this energy through co-generation systems and using it for heating or cooling purposes involves remarkable benefits in the reduction of the pollution and in the environment conservation.
Only through the diversification of the energy sources, his dissemination over the territory and the optimization of the production processes the energy saving and the rational use of energy will be able to obtain great economic and environmental advantages.
The present project is developing in the framework of a new organization of the energetic sources in the City University “La Sapienza of Rome where each district will be characterized with different energy sources. The project consists in the installation of a CHCP plant based on a gas microturbine and an exhaust absorption chiller, and it will be realised in the area of the Pharmacology Institute building, providing several economic and environmental advantages.

REFERENCES

1. Chambers A. K. and Potter I., 2002, *Options for Co-generation,* Carbon and Energy Management, Alberta Research Council
2. U.S. Department of Energy National Renewable Energy Laboratory, 2003, “*Gas-Fired Distributed Energy Resource Technology Characterizations” -* NREL/TP-620-34783.
3. Carnö, J., Cavani, A., and Liinanki, L., 1998, Micro Gas Turbine for Combined Heat and Power in Distributed Generation, *ASME Paper 98-GT-309*.
4. Campanari, S., and Macchi, E., 2001, Potential Developments in Gas-Fired Microturbines: Hybrid Cycles and Trigeneration, *Cogeneration and On-site Power Production, 2(2)*
5. De Santoli L. et al., 2006, Economic and environmental advantages of a CHCP system realized by microturbine and direct exhaust absorption chiller/heater*, to be presented at WREC 2006*
6. TURBEC T100 microturbine Technical Description
7. BRAOD IFA absorption chillers Technical Description