Aspects regarding the use of recovered energy for air conditioning

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Abstract. In the paper the authors analyze the possibility of using the energy recovered from combustion gases, for air cooling. The objective is to evaluate the thermal potential of combustion gases from a cogeneration plant with a 3 MW electric power, located in Buzau. The monitoring data for the cogeneration system shows that the average flue gas temperature at the exit to the atmosphere is 125° C and the mass flow rate of the combustion gases is 18351 kg/h. The thermal potential of combustion gases isused for the preparation of hot water at 85°C for the operation of a LiBr-H₂O solution absorption plant. Finally, the authors present a comparative study between the classic cooling system using chiller with mechanical vapor compression (VCM) and the absorption plant supplied by recovered energy from the cogeneration system, high lighting the advantage of the proposed trigeneration system.

1. Introduction

EU promotes the use of renewable energy for heating and cooling in order to reduce primary energy dependency and decrease greenhouse gasses emissions. The member countries have developed their own strategies and introduced a range of incentives to meet the EU targets for 2020.

As a member of the European Union, Romania is required to implement the environment acquis and to adopt EU regulations into national law. The main national target, and part of Romania's 2020 objectives, is to improve the environment and living standards while ensuring resource efficiency. The National Sustainable Development Strategy 2013-2020-2030 recognizes technology as a key instrument to achieving a bette renvironment [1]. The total national level cogeneration capacity that shall be installed up to 2020 is estimated at 2400 MW (in 2014 was 1820 MW). The savings in primary energy is estimated at 800 ktoe [2], [3].

As can be seen, the majority of the energy policies and regulations differ from country to country due to different patterns of energy demand and supply, fuel prices, climate and environmental conditions.

In fact, a facility operating a local cogeneration or Combined Heating and Power (CHP) plant that produces electricity and heat is about three times more efficient, and it reduces greenhouse gases by similar amounts. But to realize these benefits, all the heat by-products of cogeneration must beused all the time. Using the heat from a CHP system is usually straight forward during winter, but this same heat can be used in summer months to drive an absorption chiller to provide chilled water for air conditioning.

In spite of the benefits of cogeneration and trigeneration, their development is slowed down by many obstacles. The commissioning of new systems is

relatively expensive and requires a real investment that can discourage different investors. The investment cost is very high for cold cogeneration or trigeneration because of the high cost of absorption system (ABS), representing a major obstacle to the development of these systems. Besides the first cogeneration system put into operation are becoming out dated for some countries and need to be replaced, which is a non-negligible cost.

On the other hand, cogeneration and trigeneration are penalized by the decrease of prime materials and electricity prices, which extends the pay back time for the investment. Also, technical progress made in classical domains such as isolation, which allows the reduction of heat and cold demand or the development of renewable energies (water, sun, wind), diminishes the interest for cogeneration and trigeneration.

The ABS offer advantages comparing to conventional mechanical vapor compression systems: - no use of CFC or HCFC refrigerants.

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- in ABS there is no refrigerant to produce greenhouse (global warming) and ozone depletion layer effect. The water is the working fluid and this is environmentally friendly and there for not be excluded in the future;

- ABS may be designed to use a wide range of thermal energy sources, such natural gas, hot exhaust from furnuces, heating water from solar panels and waste heat from a turbine or other industrial process ;

- due to the absence of moving parts in the entire system the operation is essentially quite and not appaer vibration and noises;

- low electrical power consumption for pumping refrigerant absorbant solution.

If the heat source is a residual heat from CHP, absorption systems can offer the lowest cost to produce chilled water. Since other alternative sources of driving ABS are used, other than electrical power, their

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installation can be a solution to reduce total electricity consumption in places where it is hard to obtain electrical power or where the price is higher. Thirdly, due to the absence of moving parts, absorption systems produce significantly lower vibrations and noises compared to large centrifugal systems.

Cogeneration and trigeneration are matters of great current interest. Recently a number of norms and legislative measures have been introduced which are apt for promoting extensive use of these technologies and consequently significant application developments are expected. The topics examined in this report concern small cogeneration plants, that is to say those covering electrical power generation up to 1MW, which use for that purpose internal combustion engines.

The space cooling demands for the Romania rise more steeply from 2% now to 63% of the heat demand for 2050 [4].

2. Description of the trigeneration installation.

2.1 The trigeneration system existence

ECOGEN ENERGY cogeneration plant is located in Buzau and works with natural gas. The components of system are (figure 1):

- thermal engine with 3 MW_{electric power};

- a heat recovery plant from the combustion gases and cooling circuits, each with a capacity of 3 $MW_{thermalenergy}$ required for preparation of domestic hot water.



Fig. 1. Schematic cogeneration system ECOGEN ENERGY

2.2. The trigeneration system –proposed solution

The proposed solution consists in recovering waste gas from the combustion gasses to prepare the hot water to power an ABS. The hot water is prepared with a heat exchanger (flue gas / water) integrated into the exhaust gases circuit. The exhaust heat exchanger is the 'shell and tube' type combustion gasses from exhaust chimney flow inside the tube while water flows through the pipes. Heat is transferred from combustion gasses to the water through the tube walls, which results in the water heating up. The overall heat transfaer coefficient is improving by using baflle on the water side. Due to easy of maintenance, it was decided for gas flow inside the tubes.

This heat energy is utilized as an excellent heat source in the generator of the vapour absorption refrigeration system.



Fig. 2. Schematic trigeneration system ECOGEN ENERGY – the solution proposed

2.3. The evaluation the thermal potential of combustion gasses from a cogeneration plant

The thermal potential of the combustion gasses was calculate using the following relationship:

$$\dot{Q} = \dot{m} \cdot c_n \cdot \Delta t = 263.16 kW$$

Where:

- \dot{Q} heat losses by combustion gasses [W]
- *ṁ* –combustion gasses mass from thermal engine
- c_p combustion gasses specific heat,

 $c_p = 1.3 \ kJ/kg \cdot K$

- Difference of temperature entering/leaving $\Delta t = 125 - 90 = 35^{\circ}C$

The result was a thermal flow of 263kW, available to prepare domestic hot water to supply the ABS (for generator).

Technical data for exhaust gas / hot water heat exchanger (EHE) are show in Table 1:

Table 1. Technical date for EHE

Tube	Material Cu 60x2mm	
Velocity of hot exhaust gases	5.4m/s	
Surface	803m ²	
Length	10.4m	
Number of tube	435	
Pressure drop hot exhaust gases side	716Pa	
Velocity of hot water	0.18m/s	
Pressure drop hot water side	291Pa	
Hot water mass flow	12.57kg/s	

2.4. ABS Design

It must be noticed that the cooling power is the product of the heat output of the CHP (263kW).

The absorption chillers employed for this purpose are characterised by a cooling capacity of up to 180kW and the schematic diagram is presented in figure 3. To energise absorption chillers it is possible to use hot water at relatively low temperature values, between 80° C and 85° C and to produce chilled water at an outlet temperature of 7° C. Evaporative cooling towers are usually used to reject the heat generated in absorption chillers, and are adopted chiefly on account of the low heat rejection temperatures required by the chiller (27/31°C). In table 2 are presented the performances of the absorption chiller taken into account for this study.



Fig. 3. Schematic diagram for ABS.

Table 2.Performances of ABS [5]

Nominal cooling capacity (model name Carrier 16LJ01-03) [kW]	180
Water chilled temperature (inlet/outlet) [°C]	12/7
Water cooling tower temperature (inlet/outlet) [°C]	27/31
Hot water temperature (inlet/outlet) [°C]	85/80
COP [-]	0.84

The table above shows also that the CHP does satisfy all the thermal energy needed. For this reason, there is no need for an additional system to drive the ABS.

3. The economical analysis

Below is the analysis of the investment and operating costs for two air conditioning system solutions with cooling capacity by 180kW:

- ABS - one single stage LiBr-water solution driven by thermal energy recovered from the thermal engine; -Vapour compression system (VCS) (Chiller).

Both systems prepare cooling water inlet/outlet

temperature 12/7 °C.

The economical analysis for each plantis based on the following:

- the chilled water is provided for 24 hours continuous;

- the cost of maintenance was not considered;

- the equipment and service cost are calculated at current prices.

In Table 3 is presented the investement cost of each solution.

ABS LiBr-H ₂ O		CHILLER	
Equipement	Cost [euro]	Equipement	Cost [euro]
ABS	47150	Chiller	70000
Cooling tower	30000	Cooling tower	30000
Pumps	300	-	-
Exhauster	700	-	-
Exhaust gas/hot water heat exchanger	182000	-	-
Investment	260150	-	100000

Table 3.Investement cost

It can be seen from table 3 that the investment costs of the chiller air conditioning system are about 2.6 times lower than those of the absorption refrigeration plant.

For the evaluation of the service costs, it must be taken into account the electric power absorbed by each equipment of the two type plants according to the technical data from catalogue.

The values of operating costs are presented in table 4, respectively figure 4 considering 10-year life time depending of the compressor from VCS.

Results show that:

-the operating cost of VCS in 10 years is 489947 euro, higher than ABS

-the investment cost of VCS is less than 16150 euros than the ABS

-in the fourth year the investment and consumption cost of ABS is 314357 euro and for VCS is 350186 euro -from four year onwards the ABS determing a savings of 35828 euroversus VCS.

Table 4.Operating costs					
	ABS	Chiller	EURO for ABS	EURO for chiller	
Consumption for 1h kWh	9.75	45	1.55	7.14	
Consumption for 24h	234	1080	37.13	171.36	
Consumption for 1 year	85410	394200	13551.7	62546.4	
Consumption 10 year	854100	3942000	135517	625464	



*Price kWh 0.6 RON fara TVA, 0.714 RON with TVA

Fig. 4. Energy costs for operation.

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Table	5.	Costs	tor	investment +	service
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	ABS	Chiller	
Year	EURO	EURO	
1	273701.72	162546.4	
2	287253.44	225092.8	
3	300805.16	287639.2	
4	314356.88	350185.6	
5	327908.6	412732	
6	341460.32	475278.4	
7	355012.04	537824.8	
8	368563.76	600371.2	
9	382115.48	662917.6	
10	395667.2	725464	



Fig. 5.Payback period for investment + service cost

The results of the study about the cost of the investment and service listed in Tabel. 5, show that ABS has lower costs after about four years as it can be seen in figure 5.

For the first system analysed the total cost is no higher then 400000 euro. The economy given by investment and service cost is becoming more important after 10 years. The difference between both values is 330000 euro, which represents a 45% from the total costs of the chiller system.

For this project to be viable, the payback period must be short, because only in this case the project will generate benefits, which will recover the investment made and provide a more cost effective alternative reference.

4. Conclusions

Regarding the study conducted in this paper, for a residential building, it can be seen that trigeneration systems using ABS powered with hot water prepared by EHE have a greater payback period than the conventional VCS systems using electrical power. Moreover, the use of hot water to drive the system makes it more feasible to implement.

Another fact that sustains the ABS is that the annual savings and in comes are greater than those of the VCS over 10 year, being aware that the lifespan is 20 years.

An aspect that can have an impact on deciding to choose one system over the other, is the total costs for implementing the system (investement and service cost). The result of the economic balance is also very attractive because beyound having a short payback time, around 3.6 years, it brings significant savings (net present value), in the first 10 years of operation in comparrison to the conventional system.

At this moment, in accordance with the economical outlook, the implementation of ABS leads to a recovery over 300000 euro while the total overall electrical consumption is decresed and low CO_2 emission will be generated in atmosphere.

References

1. https://www.export.gov/article?id=Romania-Energy

2. ******* Odysee - GEN-RO3 Promotion of high efficiency cogeneration, (2018)

3. EUROSTAT – Combinated heat and power (CHP) data, (24.12.2016)

4. COMMISSION STAFF WORKING DOCUMENT, (2016)

5***Catalogue Carrier