U.P.B. Sci. Bull., Series …, Vol. …, No. …, 2009 ISSN 1454-23xx

POWER, HEAT AND COLD SUPPLY FOR A UNIVERSITY: A CASE STUDY

Eduard MINCIUC, Roxana PATRASCU[1]

Trigeneration technology is a relatively new concept but it has already well penetrated the market. Using this technology for energy production and supply allows increasing energy efficiency of primary fuel consumption and at the same time reduces the environmental pollution. The paper presents an analysis for implementation of a trigeneration plant for energy supply of Politehnica University of Buchaerst, Romania. The analysis aims at establishing the optimal solution for energy supply of the university. The authors have analysed different technical solutions in order to achieve the optimal sizing of the plant from the technical and economic points of view.

Keywords: Trigeneration, tertiary sector, energy efficiency

1. Introduction

Trigeneration is a combined and sometimes simultaneous production of power, heat and cold. A trigeneration plant usually uses a cogeneration technology as a prime-mover and an absorption chilling machine for cold production. The prime-mover generates electricity and heat is usually recovered, being considered as waste heat. During the winter heat can be used for space heating and for preparing warm potable water, and during the summer time heat is usually used only for warm water preparation. For cold production for air conditioning, during the summer time, there can be used an absorption chilling machine that uses waste heat as a driving force.

The main advantages of trigeneration compare to separate energy production are the following:

- Higher energy production efficiency for generating power, heat and cold;
- Lower fuel consumption for the same amounts of generated energy;
- Reduction of pollutant emissions;
- Lower energy production prices due to common use of different equipment and due to lower fuel consumption;
- Lower energy transport losses due to positioning the energy production facility next to consumers or even on the consumers' site;
- A trigeneration plant usually needs less space.

As disadvantages there can mentioned the following:

---

[1] Power Engineering Faculty, University "Politehnica" of Bucharest, Romania

- Due to connection of different equipment with each other there is an interdependence in operation, which lead to a need of a relatively constant energy load;
- Because of the interdependence in operation of different equipment they can operate with low efficiency at part loads;
- A trigeneration plant usually demands a higher safety in operation.

In the tertiary sector almost all consumers use power, heat and cold, therefore this technology can be very suited to satisfying the energy needs. In [1] authors have proposed a methodology for sizing a trigeneration plant. The methodology aims in particular at hotels situated in Mediterranean areas, and it allows sizing a trigeneration plant using only a few data. A measurement methodology for monitoring a trigeneration plant has been proposed in [2]. The authors focused on an office building located in Mediterranean areas. The methodology helps at evaluating the energy demand and improving the management of the entire plant. In [3 and 4] authors have analysed the possibility of energy savings in airports by using trigeneration technology. The first part presents the analysis of energy demands and economical and technical criteria needed for feasibility study. The second part presents an in-depth analysis for an airport with suggestions for optimisation in design and operation. In [5] the authors have presented the results of an investigation into the viability of trigeneration in supermarkets. In [6] the authors have analysed the environmental impact of trigeneration technology compared to separate energy production. There have been analysed several trigeneration plants including one from the tertiary sector. In [7] the authors have analysed the possibility of installing a trigeneration plant at a hotel in Romania. There have been analysed the energy demand and proposed different plant schemes. Based on the technical and economical analysis there been have proposed and optimal solution. In [8] the authors have presented the general aspects of trigeneration and also several examples of trigeneration plants, including plants operating in the tertiary sector. In [9] the authors have presented an analysis of installing a trigeneration plant in an airport. There have been studied all energy demands and proposed different schemes for trigeneration plant. The technical and economical analyses have revealed the optimal solution. In [10] the authors have presented an analysis of implementing a trigeneration plant in a supermarket. The paper presents the energy demands of a supermarket and compares different trigeneration technologies with conventional energy production. In [11] the authors have analysed the potential of using trigeneration technology at malls in Rio de Janeiro, Brazil. The paper has identified the technical and economical potential for use of trigeneration in tertiary sector. The economics of a trigeneration system in a hospital is presented in [12]. The authors have focused on calculating the prices for generated energies. In [13] the authors have presented a simulation and optimisation of operation of a hospital. The results leaded to lower energy consumption and can be used for on-line optimisation. In [14] the authors have performed an analysis for optimising a trigeneration plant. There have been analysed different plant's configuration aiming at identifying the best one.

2. Energy consumption of the university

Presently the energy demands of the university are covered as follows:

- Electricity is supplied from the power grid;
- Heat for heating during the winter period is supplied by a local district heating company;
- The cooling is ensured only at few places using local air conditioning equipment.

In table 1 there are presented the values for instantaneous and annual energy demand.

Table 1

Instantaneous and annual energy demand

Instantaneous maximum energy demand	
Power, MW	3.5
Heat, MW	17.5
Cold, MW	3.5
Annual energy demand	
Power, MWh	7076
Heat, MWh	38239
Cold, MWh	534

Figures 1-3 present the monotonous curves for power, heat and cold demand.

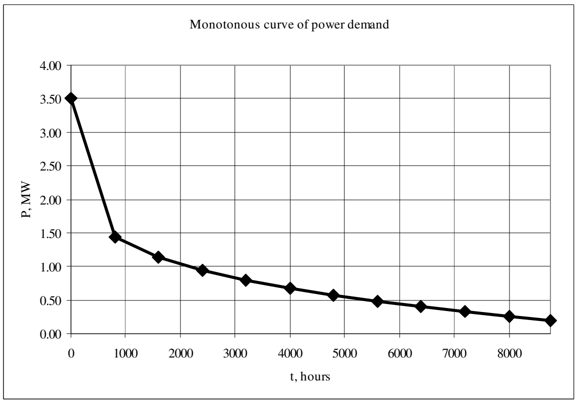


Figure 1: Monotonous curve of power demand.

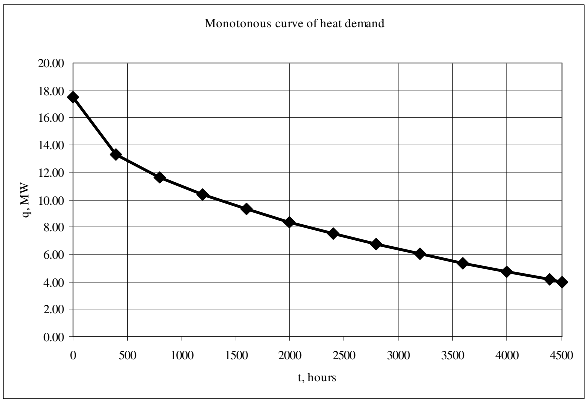


Figure 2: Monotonous curve of heat demand.

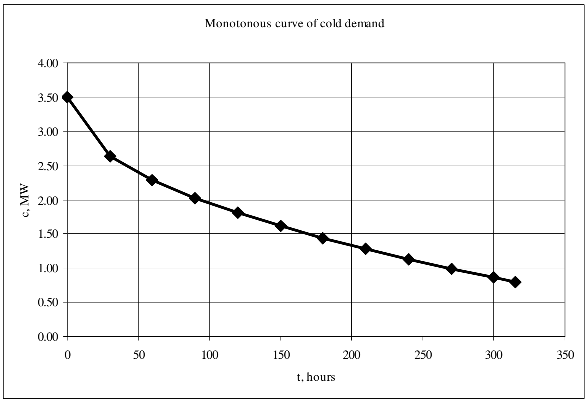


Figure 3: Monotonous curve of cold demand.

3. Assumptions and limitations

For the analysis of different technical solutions there have been considered the following assumptions:

- The power supply is all year round (8760 h);
- The period for heat supply for heating is in accordance with Romanian standards and it is 188 days (4512 h);
- The period for air conditioning has been considered as being 75 days with an average of 6 hours per day and with a coefficient of sunny days of 0.7 (315 h);
- The surplus of electricity produced can be sold to the grid;
- If the plant does not cover all electricity demand, the difference can be bought from the grid;

- The cold produced by peak equipment is generated using compression chilling machine;
- The fuel price (natural gas) has been considered as being 25 €/MWh;
- The electricity price bought from the grid and sold to consumer has been considered as being 105 €/MWh;
- The electricity price sold to the grid has been considered as being 77 €/MWh;
- The heat price has been considered as being 43 €/MWh;
- The cold price has been considered as being 43 €/MWh;
- The maintenance costs for all equipment has been considered as being 20 % from all costs;
- The actualisation rate for the economic analysis has been considered as being 10 %.

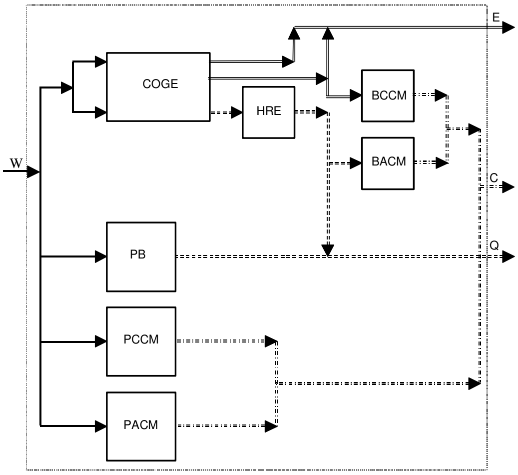
4. Description of analysed solutions

The authors have analysed six different technical solutions for the trigeneration plant. All six solutions use a cogeneration technology for power and heat generation and chilling machines for cold production. There have been adopted three approaches for designing and sizing the plant:

1. Sizing the trigeneration plant based on average power demand;
2. Sizing the plant on maximum cold demand;
3. Sizing the trigeneration plant based on maximum power demand.

For these approaches there has been considered that for cogeneration equipment there would be used gas turbine and internal combustion engine technologies. For cold generation there would be used absorption chilling machine that uses waste heat from cogeneration equipment. The compression chilling machine can also be used for cold production as peak equipment; it can use electricity generated by cogeneration equipment or electricity bought from the power grid.

Figure 4 presents a general scheme of a trigeneration plant. A trigeneration plant usually consists of cogeneration equipment that generates power and heat, and a chilling machine for cold production.



COGE – cogeneration equipment; HRE – heat recovery exchanger; BCCM – base load compression chilling machine; BACM – base load absorption chilling machine; PB – peak boiler; PCCM – peak load compression chilling machine; PACM – peak load absorption chilling machine.
Figure 4: General scheme of a trigeneration plant.

Bellow there are presented six technical solutions that have been analysed:

1. The solution design and sizing has been based on average power demand using gas turbine.
2. The solution design and sizing has been based on average power demand using an internal combustion engine.
3. The solution design and sizing has been based on maximum cold demand during the summer time using gas turbine.
4. The solution design and sizing has been based on maximum cold demand during the summer time using an internal combustion engine.
5. The solution design and sizing has been based on maximum power demand using gas turbine.
6. The solution design and sizing has been based on maximum power demand using an internal combustion engine.

Table 2 presents the technical data for the four analysed solutions.

Table 2

Technical data for the analysed solutions

Solution	1	2	3	4	5	6
Cogeneration equipment	GT	ICE	GT	ICE	GT	ICE
Power, MW	0.815	0.756	1.662	8.73	3.815	3.802
Peak boilers, MW	3x3.5	3x5.8	-	4x3.5	-	4x3.5
Absorption chilling machine, MW	1.78	0.40	3.50	3.5	3.5	1.49
Compression chilling machine, MW	1.72	3.10	-	-	-	2.01

5. Methodology for analysis

The authors have performed technical and economic analyses of all four solutions.

All the solutions have been analysed from the point of view of energy production, energy supply to the university and also, where it was the case, power selling to the grid.

The economic analysis has been performed based on the following criteria:

- Simple Payback Period (SPP);
- Net Present Value (NPV);
- Internal Rate of Return (IRR).

The economic analysis has been performed for a 20 year period of time.

6. Conclusions

Present paper had the aim to analyse three different approaches in design and sizing a trigeneration plant for a costumer from a tertiary sector. The first approach aimed at designing the plant based on the average power consumption, the second one aimed at designing and sizing the plant based on the maximum cold consumption and the third one aimed at designing and sizing the plant based on the maximum power demand.

Table 3 presents the results of economic analysis for the four solutions.

Table 3

Economic criteria for the analysed solutions

Solution	1	2	3	4	5	6
Investment, mln. €	2.7	2.5	2.7	7.3	4.1	4.4
PBP, years	8.9	7.9	6.5	4.0	5.5	3.6
NPV, mln. €	<0	<0	0.84	6.3	2.3	5.0
IRR, %	9	10	14	23	18	26

Analysing table 3 there can be made the following conclusions:

- The optimal solution from the economic point of view is solution 4. Even if it has the greatest investment cost, it also leads to the shortest PBP and greatest NPV;
- Solutions 3, 5 and 6 can also be approved since the economic criteria are also quite promising, even if the PBP for some of them is greater than 5 years;
- The first two solutions can hardly be recommended, since for both of them the IRR is close to the actualisation rate and cannot cover all the risks and NPV is negative.

REFERENCES

[1]. *E. Cardona and A. Piacentino*, A methodology for sizing a trigeneration plant in mediterranean areas. Applied Thermal Engineering 23 (2003) pp 1665-1680.

[2]. *E. Cardona and A. Piacentino*, A measurement methodology for monitoring a CHCP pilot plant for an office building. Energy and Buildings 35 (2003) pp 919-925.

[3]. *E. Cardona, A. Piacentino and F. Cardona*, Energy saving in airports by trigeneration. Part I: Assessing economic and technical potential. Applied Thermal Engineering 26 (2006) pp 1427-1436.

[4]. *E. Cardona, P. Sannino, A. Piacentino and F. Cardona*, Energy saving in airports by trigeneration. Part II: Short and term planning for the Malpenza 2000 CHCP plant. Applied Thermal Engineering 26 (2006) pp 1437-1447.

[5]. *G. G. Maidment, X. Zhao, S. B. Riffat and G. Prosser*, Application of combined heat-and-power and absorption cooling in a supermarket. Applied Energy 63 (1999) pp 169-190.

[6]. *E. Minciuc, O. Le Corre, M. Tazerout and I. Bitir*, Assessment of CO_2 reduction in tri-generation – case studies. Proc. International Conference on Energy and Environment, China (2003).

[7]. *C. Constantin, V. Athanasovici, E. Minciuc and I. Bitir*, A new solution for energy supply of the hotel Unirea from Iaşi city, Romania. Proc. COFRET, France (2004).

[8]. *E. Minciuc, M. Scripcariu and I. Bitir-Istrate*, Trigeneration: concept, solutions and realisations. Proc. International Conference Energy of Moldova (2005).

[9]. *C. Constantin, V. Athanasovici, E. Minciuc, I. Bitir-Istrate and R. Pătraşcu*, Implementing of trigeneration solution into Romanian tertiary sector – Feasibility study for Bucharest Otopeni International Airport. Proc. CIEM 2005, Romania.

[10]. *G. G. Maidment and R. M. Tozer*, Combined cooling heat and power in supermarkets. Applied Thermal Engineering 22 (2002) pp 653-665.

[11]. *M. T. Tolmasquim, A. S. Szklo and J. B. Soares*, Economic potential of natural gas fired cogeneration plants at malls in Rio de Janeiro. Energy Conversion and Management 42 (2001) pp 663-674.

[12]. *D. Ziher and A. Poredos*, Economics of a trigeneration system in a hospital. Applied Thermal Engineering 26 (2006) pp 680-687.

[13]. *A. W. M. van Schijndel*, Optimal operation of a hospital power plant. Energy and Buildings 34 (2002) pp 1055-1065.

[14]. *H. Li, R. Nalim and P. –A. Haldi*, Thermal-economic optimization of a distributed multi-generation energy system – A case study of Beijing. Applied Thermal Engineering 26 (2006) pp 709-719.