THE INFLUENCE OF PRICES, BONUSES AND TAXES OVER THE OPTIMAL SIZING OF A COGENERATION SYSTEM

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Această lucrare prezintă concluziile principale rezultate în urma analizării modului de influență, asupra dimensionării optime a centralelor de cogenerare, a prețurilor de valorificare a energiei electrice şi termice, a prețului de cumpărare a combustibilului, a bonusurilor ce pot fi accestate de soluția de cogenerare respectiv a taxelor ce trebuiesc plătite de către aceasta. Se au în vedere valori, ale mărimilor a căror influență a fost analizată, specifice pieței de energie, respectiv legislației aflate în vigoare în România.

The present paper reveals the main conclusions drawn analyzing the influence way concerning the optimal sizing of a cogeneration system, of the electricity and thermal energy prices, the price of the fuel, the taxes and the bonuses (guaranteed by law for cogeneration usage). The analysis that was done took into consideration values that were specific to Romanian energy market and law.

Keywords: cogeneration (CHP), optimal sizing, prices, taxes, bonuses.

1. Introduction

Promotion of energy production from cogeneration systems is one of the key ways to comply with various legislative provisions concerning environmental protection and reduction of greenhouse gas emissions. This because high efficiency cogeneration systems have fundamental advantages consisting in low emissions of CO_2, NO_x, SO_x relative to separate processes for thermal and electrical energy production.

Although from the point of view of energy efficiency, and of the reducing emission of greenhouse gases, the cogeneration advantages are undeniable, the implementation of this type of installation must be most of the time justified in terms of the economical efficiency and obtained profit [1].

So, the sizing calculations, to determine the optimal solution of cogeneration from technical and economical point of view, are very important in the promotion and implementation of such facilities.

But, the factors which characterizes the cogeneration solution, such as: the technology taken into account, the nature and the type of energy consumers, fuel

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type used, the taxes and the prices, the energy market, the legislation and the environmental impact are in a continuous development and evolution. Therefore, the purpose of this paper is to present, how sizing calculations, to determine the optimal solution of cogeneration, are influenced by changing the value of some of the factors listed before.

2. Starting points, hipothesis

Analyzing the cogeneration development scenarios from European Union countries it can be observed that in near future is expected a significant growth of cogeneration units installed capacity [2].

This growth is driven mainly by industrial sector. Also, district heating remains a strong segment for cogeneration, which a lot of capacity replacement and growth in new and renovated urban areas.

However, in the context of decentralized energy production and by developing of small and medium cogeneration units adapted to the specific energy needs of a small family houses, is estimated that small and medium scale cogeneration will also have a high degree of development in European Union countries [1].

Considering all of the above, in this paper will be analyzed mainly the solution of small and medium scale cogeneration. Also, will be analyzed mainly the cogeneration solution applied to the urban consumers and/or tertiary consumers. This sector presents a high interest in Romania because many consumers were disconnected from district heating systems and because the district heating networks and distribution systems are in a very bad condition. So, high efficiency cogeneration systems can be a solution to revive this sector [3].

Regarding the cogeneration technology it's considered the internal combustion engines because they are most used technology in the small and medium scale cogeneration solutions. Also, due to the fact that the cogeneration solutions will be used in residential areas, the fuel used must be as clean as possible. Therefore, are considered that the cogeneration plants will use natural gas as fuel.

The cogeneration solution for urban consumers it's characterized mainly by an electric energy demand and a thermal energy demand related to domestic hot water consumption throughout the year and the heat consumption for heating in winter. So, figure 1 shows shape and size for the annual energy demand variation curves [4]. These energy demand variation curves will be used for calculation example presented in this paper.

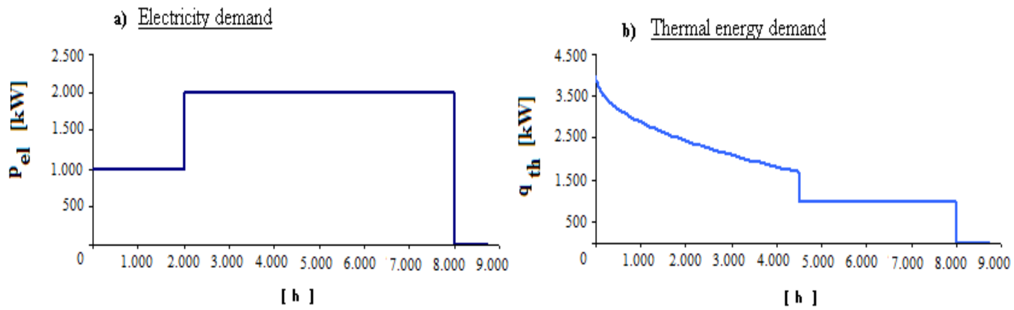


Fig. 1 Annual variation of the energy demand: a) electric energy; b) thermal energy

where: P_{el} [kW_{el}] is the consumer electrical power required and q_{th} [kW_{th}] is consumer thermal power required.

Starting from this energy demands shown in figure 1, it will be established how the optimal sizing of a cogeneration system is influenced by the price of electricity, the price of thermal energy, the price of the fuel, the taxes and bonuses (guaranteed by law for cogeneration usage).

Sizing the cogeneration plant entails the choice of capacities, type and numbers of the cogeneration equipment and the choice of auxiliary facilities and facilities used as peak thermal installation. But the optimal sizing requires the establishment of the above elements according to a certain decision criteria. The decision criteria can be a technical, an economical or a criteria that refers at the environment impact. Also, an optimal sizing means to establish the optimal operating regimes for the cogeneration plant equipments.

Thus for determining the optimal sizing solution for a cogeneration system is necessary to establish the main technical, economical and environmental indicators that will be taking into account.

As an indicator that characterizes the sizing of cogeneration plant it will be used coefficient of cogeneration, more accurate the nominal value of the thermal coefficient of cogeneration. He represents the ratio between the thermal energy delivered by the cogeneration installation and maximum heat demand of the consumers.

In the sizing calculations is used the thermal coefficient of cogeneration because the nominal value of it, determines the equipment capacity, the value of investment and depending on the operation regimes of the cogeneration plant he influence the related cost and the revenues.

If instantaneous values are taken into account cogeneration coefficient is given by:

$$\alpha_{cg}{}^{n} = \frac{q_{icg}{}^{n}}{q_{th}{}^{\max}} \quad (1)$$

were: $\alpha_{cg}{}^{n}$ is the thermal nominal coefficient of cogeneration; $q_{icg}{}^{n}$ [kW_{th}] is the nominal thermal power of cogeneration units; $q_{th}{}^{max}$ [kW_{th}] is the maximum thermal power required by consumers.

The optimisation of the cogeneration coefficient it will be made based on a decisional economical criteria. In this case the sizing calculations took into account the optimisation of the cogeneration coefficient based on the net present value (NPV) economical criteria. This economical indicator it is given by:

$$NPV = \sum_{i=1}^{n} \frac{V_i - C_i}{(1+a)^i} - I_p \quad (2)$$

where: V_i [€] are the annual income on a year ¨i¨; C_i [€] are the annual cost of production on a year ¨i¨; I_p [€] is own investment; a [%] is actualization rate; n [years] is duration of study for which the calculations are made.

Used as an indicator of the effectiveness of an investment project, for it would be acceptable, must meet the condition that the NPV ≥ 0. In case of comparison of several projects it is choosing the one with the highest value of the NPV's.

Regarding the interaction between cogeneration plant and the consumer, it is considered that after sizing the cogeneration plant, the energy demands of the consumer can be covered integrally by the cogeneration system with the help of the peak thermal installations, when we refer to the thermal energy and with the help of National Energy System when we refer to the electrical energy.

Also, it's considered that it can be capitalized, on the free energy market, all the electrical energy surplus produced by the cogeneration plant. Regarding to the transmission and distribution network it is considered that the cogeneration source is near the consumer. As a result, the energy lost on these networks can be considered negligible. Also, electricity and heat requirements afferent to the own services of cogeneration plant will be considered negligible.

Regarding the cogeneration equipment it's considered that in sizing calculation are used theoretical data. Theoretical data are based on statistical analyses that were made on real cogeneration equipments existing on the market.

Thus, to establish main technical data for internal combustion engines it will be used the graphs from figure 2.

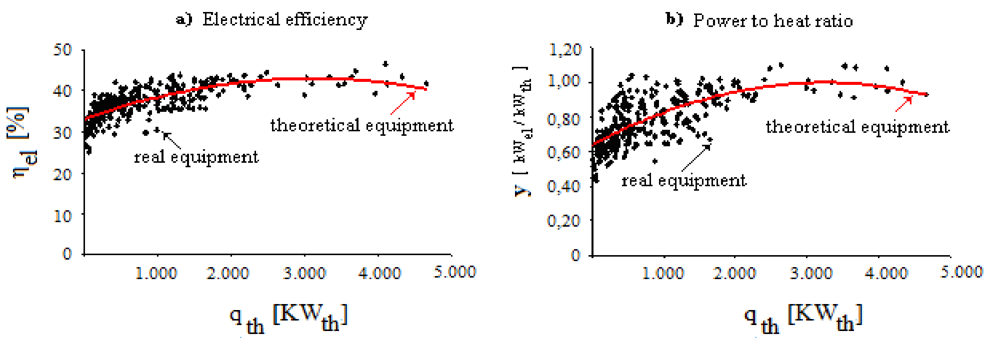


Fig. 2 Variation of nominal electrical efficiency (a), and of nominal power to heat ratio (b) in function of nominal thermal power, for internal combustion engines

The graphs from figure 2 were obtained using a database with real cogeneration equipments existing on the market [5]. The dots correspond to real cogeneration equipments and their average values are considered related to the ¨theoretical¨ cogeneration equipments.

To achieve accurate results especially from the point of view of the NPV value, in the sizing calculations it is recommended the use of real cogeneration equipments existing on the market. But, in this case if in the sizing calculations it had been used a database with real cogeneration equipment about the obtained results it wouldn’t have said whether if they reflect the influence of the prices, bonuses, taxes or the influence of the considered database. Because of the database it is possible that a part of the analysis to lead in a ¨zone 1¨ with high efficiency equipments while another part of the analysis can lead to a ¨zone 2¨ with very poor efficiency equipments. Because of this the theoretical equipments are used with the assumption that in ¨zone 2¨ we can have high efficiency equipments but they were not found and as a result they were not included in the database.

3. Establishing the influence mode of the analyzed factors

Any variation of the following factors: electricity prices to the consumer, electricity price to the national power system, thermal energy prices, the purchase price of fuel, taxes and bonuses, leads to new values of the net present value economical criteria. This because any modification of the above listed factors leads to a modification of the costs or revenues related to the cogeneration plant. Therefore in this paper is analysed only the influence of the above factors over the nominal value of the thermal coefficient of cogeneration.

Thus, figure 3 shows the fuel price influence over the nominal value of the thermal coefficient of cogeneration.

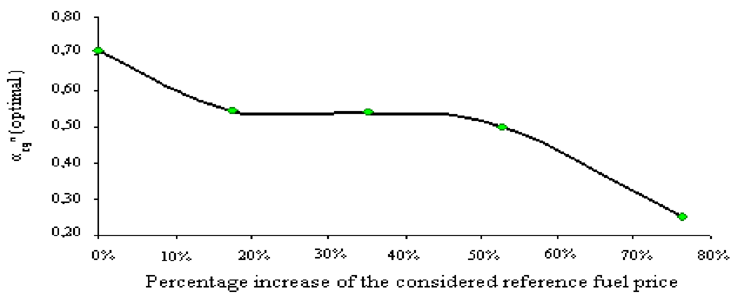


Fig. 3 Optimal value of the thermal coefficient of cogeneration in function of the increase of the considered reference fuel price

In the calculation example shown in figure 3 all the input data are kept constant and only the value of the fuel price is changed (23,88 €/MW_{cb}h is the value considered for the reference fuel price).

From figure 3 it can be observed that always a change of the fuel price value leads to a change of the nominal value of the thermal coefficient of cogeneration. Generally, higher values of fuel prices lead to lower nominal capacity of the cogeneration equipments that are installed in cogeneration plant.

Regarding the influence of electricity price and price of thermal energy over the nominal value of the thermal cogeneration coefficient is presented for analysis figure 4 and figure 5.

Figure 4 shows the annual amounts of energy produced by the cogeneration plant and sold to the consumers or to the national power system in function of the nominal value of the thermal cogeneration coefficient.

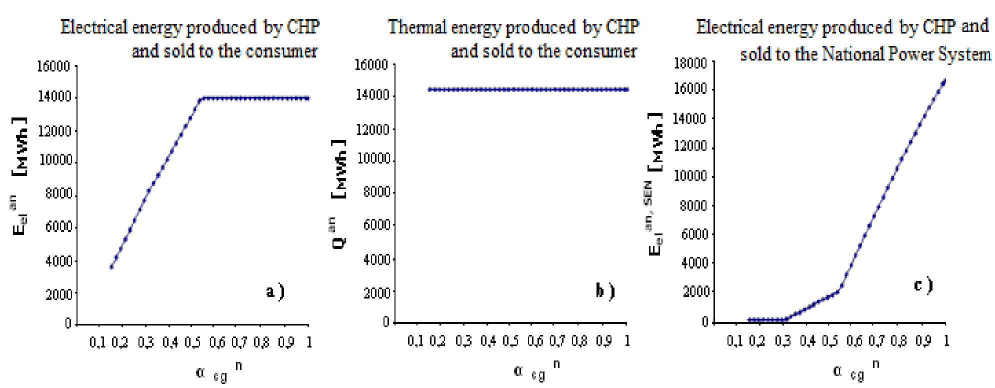


Fig.4 CHP annual amounts of energy produced in function of the nominal value of the thermal cogeneration coefficient

Figure 5 shows how the optimal value of the nominal thermal cogeneration coefficient is influenced by the change of the electricity price and price of thermal energy.

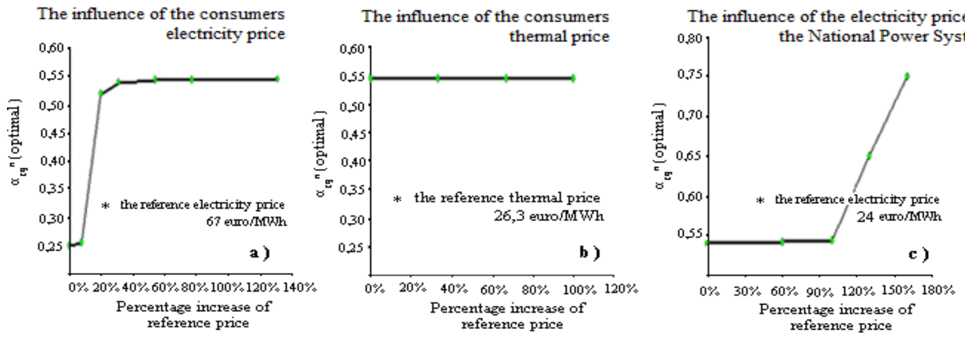


Fig. 5 Optimal value of the nominal thermal cogeneration coefficient in function of the electrical and thermal energy prices

As it can be seen, in figure 4 and figure 5, only correlated with quantities of energy produced by the cogeneration plant, the change of the electricity price or thermal price lead to changes of the optimal value of the nominal thermal cogeneration coefficient.

From figure 4.a it can be seen that a certain limit value of the nominal coefficient of cogeneration can be established ($\alpha_{cg}^{n} \approx 0, 53$). Over this value the amount of electric energy produced by cogeneration plant remains constant, being equal with the maximum amount of electric energy required by the consumers. Based on the results shown in figure 5.a can say that an increase of the electricity price for the consumers leads to an increase of the optimal value of the nominal thermal cogeneration coefficient. This effect is valid only if the analyzed values of the nominal thermal cogeneration coefficient are not greater than the limit previously set with the figure 4.a. If the values are higher then an increase of the electricity price for the consumers will not change the optimal value of the nominal thermal cogeneration coefficient.

In figure 4.b can be seen that the nominal value of the thermal cogeneration coefficient does not affect the annual amount of heat produced by the cogeneration plant and delivered to the customers. This is normal because of the assumption considered above, namely: the consumer heat demand is covered entirely by the cogeneration plant (with cogeneration installations and with peak thermal installations). Based on the results shown in figure 5.b can say that an increase or a decrease of the thermal price does not affect the optimal value of the nominal thermal cogeneration coefficient, which is actually a consequence of those specified on the figure 4.b.

In figure 4.c can be seen that a certain limit value of the nominal coefficient of cogeneration can be established ($\alpha_{cg}^{n} \approx 0, 30$). Under this value the annual amount of electric energy produced by cogeneration plant and sold in the national power system is zero. Based on the results shown in figure 5.c can say that an increase of the electricity price sold in national power system leads to an increase of the optimal value of the nominal thermal cogeneration coefficient. This effect is valid only if the analyzed values of the nominal thermal cogeneration coefficient are higher than the limit previously set with the figure 4.c. If the values are smaller then, a variation of the electricity price sold in national power system will not change the optimal value of the nominal thermal cogeneration coefficient.

Regarding the taxes concerning at cogeneration solution, are taking into account only those related to environmental protection and to the Romanian fiscal legislation.

The main environmental tax applied to the cogeneration solution is carbon tax. A carbon tax is a tax on the carbon content of fuels, effectively a tax on the carbon dioxide emissions from burning fossil fuels (coal, oil, gas). Thus it can be said that introduction of carbon tax is equivalent to a change of fuel price. So the carbon tax influence over the nominal value of the thermal coefficient of cogeneration is similar to the fuel price influence, which was analyzed before.

About the taxes related to Romanian fiscal legislation we make the assumption that only corporate income tax is applied to the cogeneration solution. The corporate tax in Romania is an annual tax in principle that affects all profits made in Romania by corporations and other entities. Thus income and capital gains earned by corporations are taxed at a flat rate. The standard corporate income tax rate is 16% and in figure 6 can be seen how the change of this value affect the nominal value of the thermal coefficient of cogeneration. It can be said that generally, higher values of the income tax rate lead to lower nominal capacity of the cogeneration equipments that are installed in cogeneration plant.

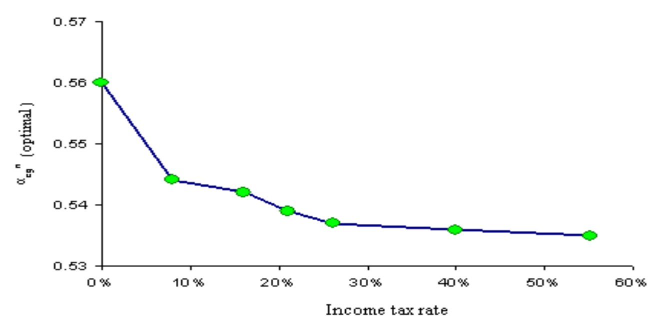


Fig. 6 Optimal value of the nominal thermal cogeneration coefficient in function of the income tax rate value

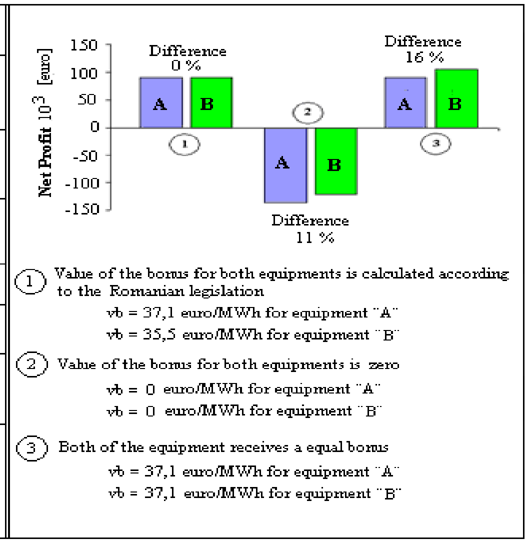
Regarding the bonus type support scheme for cogeneration in Romania the producer of cogeneration electricity and heat receives for each electricity unit produced in high efficiency conditions and delivered into the national power system a fixed amount of money called bonus [6]. So this bonus for cogeneration can be seen as an increase of the price for the electricity delivered into the national power system. Thus the bonus influence over the nominal value of the thermal coefficient of cogeneration is similar to the influence of the price for the electricity delivered into the national power system, which was analyzed before.

But the value of the bonus for cogeneration calculated according to the Romanian legislation [6] may influence the selection of the optimal cogeneration equipment from an economical point of view. This can be seen in the calculation example presented in table 1.

Table 1

Influence of the bonuses for the cogeneration solution over the cogeneration equipment selection

Equipment		¨A¨	¨B¨
Thermal power	[kW]	**1.677**	**1.677**
Electrical power	[kW]	1.562	1.562
Electrical efficiency	[%]	41,4	41,5
Thermal efficiency	[%]	44,5	44,6
Global efficiency	[%]	85,9	86,1
Power to heat ratio	[kW_{el}/kW_{th}]	0,93	0,93
Primary energy savings (achieved by using a cogeneration system instead of separate power and heat generation equipment)		**16,33 %**	**16,54 %**



Observation: the net profit it is given by formula 2 with the consideration that actualisation rate is equal to zero.

In table 1 can be seen that, if we have to choose between two cogeneration equipments with same thermal power then, the choice is influenced by the value of the bonus for cogeneration solution. Thus if are taking into account the Romanian legislation related to the bonuses for cogeneration solution, then can be choose either the equipment ¨A¨ or the equipment ¨B¨. Both of the equipments leads to the same value of the net profit because the value of the bonus they receive are different. But it can be seen in table 1 that if the values of the bonus are equal for both of the equipment then always equipment ¨B¨ must be chosen because of his better technical performance and because he brings a higher profit.

4. Conclusions

In sizing calculations for cogeneration solutions in order to produce a meaningful result, the level of detail and accuracy must be a high as possible. So since the cogeneration plant is expected to operate for a lengthy period, escalation of the fuel price, price of electricity, price of thermal energy, taxes and bonuses over time should be included in a realistic manner in the determination of the optimum size of a particular cogeneration system. It can be see in this paper that changes in one of the above parameters drastically affect the financial and technical indicators and can also affect investment decisions.

In conclusion to make a correct decision in a sizing calculation for cogeneration solutions it is necessary to analyze how the value of the technical and financial indicators changes when one or more of the input parameters derivate by a certain amount from the expected value. This procedure is known as the sensitivity analysis. So, is recommended to identify the best cogeneration system after the sensitivity analysis is carried out, to make sure that the selected system is still financially attractive with possible variation in the values of some critical parameters.

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