THE INFLUENCE OF ENERGY DEMAND OVER THE OPTIMAL SIZING, FROM A TECHNICAL-ECONOMICAL POINT OF VIEW, OF COGENERATION PLANTS EQUIPPED WITH A GAS ENGINES

Alexandru Cosmin PAVEL[1]

Abstract: The present paper reveals the main conclusions regarding the influence of energy demands over the optimal sizing, from a technical-economical perspective, of cogeneration plants equipped with gas engines. The optimal sizing, the technical-economical efficiency estimation, of a cogeneration plant is obtained by applying the economical evaluation criteria and determining the optimal value of the nominal cogeneration coefficient.

Starting from the electrical and thermal energy demand from urban consumers the optimal value of the nominal cogeneration coefficient is determined, by using net present value (NPV) economic analyzes.

Depending on the electrical and thermal energy demand, for a compulsory nominal cogeneration coefficient, the operating mod of the cogeneration plant was established, determining the characteristic operation mod. Thus the primary energy quantities consumed and the electrical and thermal energy produced by each of the installed equipments are determined. The establishment of the operation mod determined the elements required for the economical estimation regarding the economical performance of the cogeneration plant. The optimal solution for the cogeneration plant sizing is determined in accordance with the values of the nominal cogeneration coefficient.

Ultimately we emphasized the influence of the main energy demand variation over the optimal sizing value of the cogeneration plant.

Keywords: cogeneration, energy demand variation, net present value

[1] Power Engineering Department, University “Politehnica” of Bucharest, Romania

1. Introduction

The optimal sizing, the technical-economical efficiency estimation, of a cogeneration plant is obtained by applying the economical evaluation criteria which use the actualization method – ex: net present value (NPV), internal rate of return (IRR), etc. – determining the optimal value of the nominal cogeneration coefficient (α^n).

The sizing of a cogeneration plant consist in the process of choosing the right type and number of the main energetic equipment used by cogeneration plant, which, in fact, means the optimization of the nominal cogeneration coefficient of the plant.

2. The influence of energy demand variation over the optimal sizing of a cogeneration plant equipped with gas engines

Starting with a random energy demand from an urban consumer and using the following assumptions, the optimal value of the nominal cogeneration coefficient sizing is determined, using the economical criteria NPV-maximum. Also, by modifying the energy demand structure, the influence of the main energy demand variations is emphasized, over the optimal dimensioning value. It's considerate that the cogeneration plant is equipped with engines using as fuel natural gas.

The hypothesis considered when choosing the mathematical model for optimum sizing from a technical-economical point of view are:

- the optimum value of the nominal cogeneration coefficient is found using a NPV iteration result;
- the thermal energy provided by the cogeneration plant is urban, considered only for heating and hot water;
- the energy demand for heating is determined using the annual classed curve, mathematically illustrated in a relation which depends on the maximum heat demand, the outside temperature, number of days-degree and the heating season duration, values which are known for the cogeneration plant location;

- the annual classed curve of the hot water consumption is estimated considering it constant at the average annual demand;

- the heat loss during transmission and distribution will be negligible; this hypothesis does not change the final result, because in all cases, the location is the same and the heat loss is the same;

- the annual classed curve of the electrical energy demand is estimated considering it constant at the average annual demand;
- the heat demand of the consumer is completely provided by the cogeneration plant, with the cogeneration equipments and the top thermal equipment, considered to be the heated water boilers;

- it is presumed that the energy demanded by the consumer is provided by cogeneration plant, by using the same type of equipment and working at the same capacity.

- the endowment is consider to be made with real equipment, existing on the market ;

- during the entire utilization, the boiler and the cogeneration equipment's efficiency was considered constant, regardless of the installations charging;

- it is presumed that electrical energy exchange with the national electric system is possible in both directions, from cogeneration plant to national electric system and in reverse, depending on the value of the electrical power produced in cogeneration, compared to the one demanded by the consumers;

- the sizing of the cogeneration plant pursues a certain thermal pattern demand; the cogeneration equipments is following the thermal demand from the consumers;

- the cogeneration equipment can't operate at less then 50% from it's nominal capacity;

- the cogeneration equipment's nominal thermal capacity must always be bigger or at least equal to the average hot water demand of urban consumers;

Using a random electrical and thermal energy demand from an urban consumer, the maximum heating demand (q_i^M), the average hot water demand (q_{acc}^{md}), the average electric power demand (P_{el}^{md}) and the maximum heat demand from an urban consumer (q_u^M) are determined. The annual heating period length and the annual amount of hours when the cogeneration plant is used are also established. Next, a nominal cogeneration coefficient is chosen according to the previous hypothesis:

$$\alpha^n \geq \frac{q_{acc}^{md}}{q_u^M} \tag{1}$$

With a thermal and electrical energy demand and having found a value for the nominal cogeneration coefficient, the cogeneration plant operating mode is established. In this mode the cogeneration plant's characteristic types of functioning and loading are determined, resulting primer energy quantities consumed and the electrical and thermal energy produce by each of the installed equipments. The establishment of the operation mod determined the elements required for the economical estimation regarding the economical performance of the cogeneration plant.

For different values of the nominal cogeneration coefficient the calculation are remade and the optimal sizing solution for cogeneration plant is determinate using the economical criteria NPV.

First off all in order to emphasize the influence of energy demand values variation over the optimal sizing value, two fractions which characterize the energy demand structure are defined:

$$R_1 = \frac{q_u^M}{P_{el}^{md}} = \frac{q_i^M + q_{acc}^{md}}{P_{el}^{md}} \quad [kW_t/kW_e] \tag{2}$$

$$R_2 = \frac{q_{acc}^{md}}{q_i^M} \quad [kW_t/kW_t] \tag{3}$$

Secondly, the structure of the energy demand will be modified according to the following hypothesis:

A. the energy demand is modified so that:

R1 = constant; R2 = constant;

B. the average electric power demand (P_{el}^{md}) is modified so that:

R1 = variable; R2 = constant;

C. the maximum heating demand (q_i^M) is modified so that:

R1 = variable ; R2 = variable;

D. the average hot water demand (q_{acc}^{md}) is modified so that:

R1 = variable ; R2 = variable;

Attention: taking in account the real structure of the urban heat and hot water demand from Romania, the R2 fraction can change between 0.15 and 0.25.

The calculation results, when the energy demand structure is fluctuating according to the previous assessments, are illustrated as follows:

Fig.1: regarding the hypothesis from point ¨A¨, the optimal nominal cogeneration coefficient stays approximately the same, no matter the simultaneous variations of the energy demand, but at once with an increase of energy demand the values of NPV economical criteria are increased, that means a good gain for the cogeneration plant.

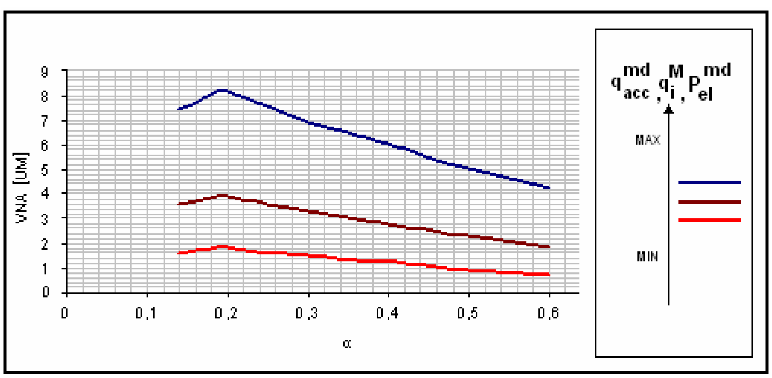

Fig.1 The influence of energy demand variation over the optimal sizing value of αn, according to the hypothesis described at point "A"

Fig.2: an increasing electrical energy demand leads to an increase of the optimal nominal cogeneration coefficient value. This happens because the cogeneration equipments produce more electrical energy in cogeneration mode. It is also noticed that this increase in electrical energy demand favors the

cogeneration solution from an economical point of view, the NPV values being bigger.

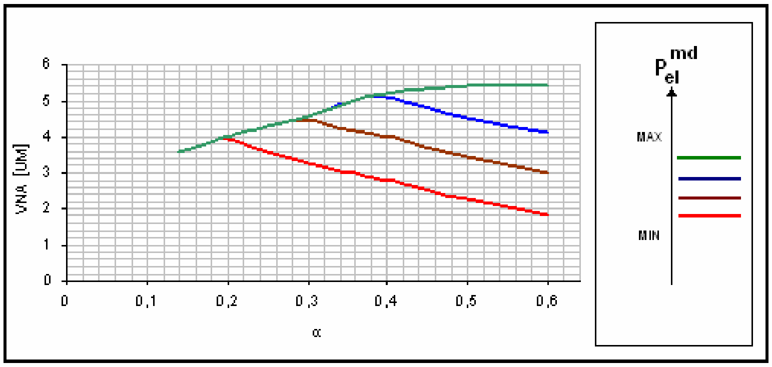

Fig.2 The influence of energy demand variation over the optimal sizing value of αn, according to the hypothesis described at point "B"

Fig.3: shows that a decrease of heating demand also leads to a change of the optimal nominal cogeneration coefficient domain. The increase of the optimal nominal cogeneration coefficient is noticed, due to the fact that the annual heat demand curve for heating and hot water is flattened. In this situation it can also be observed that a small fluctuation in heating energy demand does not have a radical influence over the cogeneration optimal solution from an economical point of view, of the NPV criteria. In case of big variation of heating request we notice that its decrease leads to a drop of NPV, having a bad influence on the cogeneration optimal solution.

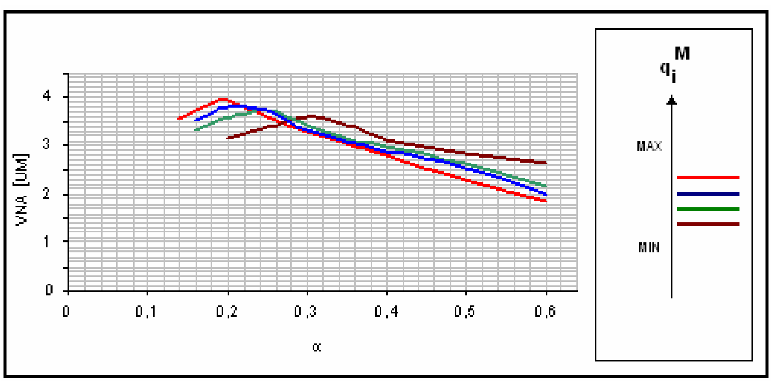

Fig.3 The influence of energy demand variation over the optimal sizing value of αn, according to the hypothesis described at point "C"

Fig.4: an increase of hot water demand does not lead to a radical change of the optimal nominal cogeneration coefficient; the increase of hot water demand favors the cogeneration solution from an economical point of view, the NPV values being bigger.

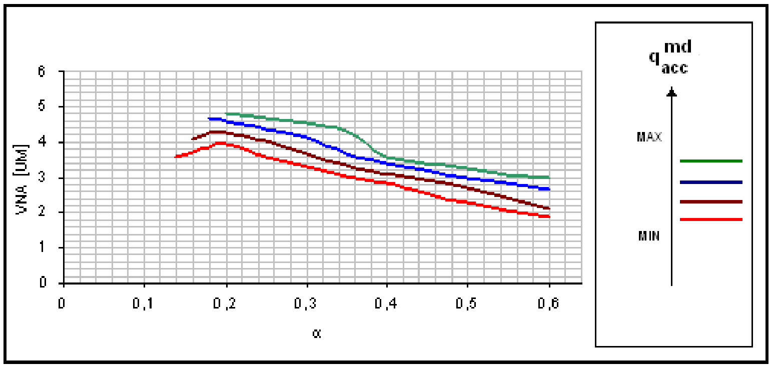

Fig.4 The influence of energy demand variation over the optimal sizing value of αn, according to the hypothesis described at point "D"

3. Conclusion:

The sizing of a cogeneration plant is radically influenced by the absolute value of urban heat and electrical energy demand and mostly by its structure, thus proving the necessity of cogeneration plants sizing depending on the technical-economical optimization of the nominal cogeneration coefficient.

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