ASPECTS ABOUT APPLICATION OF MULTI-CRITERIA DECISION ANALYSIS TO ESTABLISH THE OPTIMAL SOLUTION FOR COMBINED HEAT AND ELECTRICITY GENERATION

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REZUMAT. Lucrarea prezintă unele aspecte privind identificarea criteriilor de optimizare şi a restricţiilor privind alegerea regimului optim de funcţionare de către un producător de energie electrică şi termică. Producătorul deţine instalaţii de cogenerare bazate pe tehnologii diferite şi surse de vârf pentru producerea energiei termice. Sunt analizate un număr de opt variante de funcţionare, considerând şapte criterii. Metoda Multipol este utilizată pentru a examina variantele în funcţie de politica energetică a producătorului.

Cuvinte cheie: instalație de cogenerare, cogenerare de înaltă eficiență, analize multi-criteriale, metoda Multipol

ABSTRACT. This paper presents some aspects regarding the correct identification of optimization criteria and restrictions in order to establish the optimal operating mode by any heat and electricity producer. The CHP plant holds various technologies and separate heat production units for back-up and pick load. A set of eight operating alternatives are analyzed, considering a number of seven criteria. Multipol method is used to examine alternatives in direct line with chosen energy policy of producer.

Keywords: CHP plant, high efficiency cogeneration, multi-criteria analyses, Multipol methode

1. INTRODUCTION

According to Energy Policy of European Union, developed in 2007 and with Energy 2020 document, energy efficiency is one of the central objectives and is a key factor in achieving European long-term energy and climate goals [1], [2]. For achieving 20% primary energy savings in 2020, energy efficiency measures must be taken on the whole energy chain, from energy production, on transmission and distribution sectors to final consumption.

Romania's draft Energy Strategy 2011-2035 highlights the principal objectives of new energy-environment policy [3]:

- Security of energy;
- Competitiveness;
- Sustainable development;
- Environmental protection and climate change mitigation;
- Attracting capital investment for modernization and development of energy sector.

Majority of Romania' urban households are connected to district heating. CHP systems represent attractive, reliable and cost-effective technologies. In Romania, in 2010, total market share of energy produced in cogeneration was 20%, 10% produced in high efficiency cogeneration.

A very important European Line for promoting cogeneration in order to increase the energy efficiency and improve the security of energy supply is 2004/8/EC Directive [4]. The implementation of this Directive in Romania is realized by the GD no. 219/2007. This decision establishes the legal framework for the promotion and development of high efficiency cogeneration of heat and electricity, based on useful heat demand and primary energy savings in the energy market [5]. Another government decision, GD no.1215/2009 sets the criteria and necessary conditions for the implementation the support scheme available to producers of heat and electricity using high efficiency CHP. The methodology presented in ANRE Order no.3/2010 establishes the procedure of determining and adjusting, during the period of application of the support scheme according to the provisions of Government Decision no.1215/2009 regarding the criteria and conditions for implementing the support scheme on the promotion of high efficiency cogeneration based on the useful heat demand [6]. ANRE order no.4/2010 concerns to approval of reference bonuses for electricity, reference price for electricity and reference prices for heat produced and delivered from high efficiency cogeneration plants [7].

This paper presents a study about the correct identification of best operation mode by any producer of heat and electricity in order to meet its proposed objectives. The company trades electricity and heat on two markets: wholesale electricity market (national) and local heat market, and both products have a particularity: they cannot be stored. Due to their technology, producer's access to the electricity market is closely linked to the heat demand, which determines the cost of electricity and competitiveness of the producer on the market. Electricity is traded on competitive markets and because of this; the cost of production is a key element. The strategic importance of the energy sector involves providing insurance of reserve capacity 100% for heating, from beginning, which induces increased operating costs, especially in the context of the operation at loads about 65% less than the facilities have been designed [8]. On the local market CHP Bacau is in direct competition with the insurance of the heat by using individual thermal plants. The issues that affect this competition are:

- Energy costs;
- Continuity and quality of provided service;
- Correct invoicing of consumption.

2. A CASE STUDY. PRODUCTION OF HEAT AND ELECTRICTY IN CET BACAU

Production capacity of CHP of Bacau is 399 MW heat and 64 MW electricity. Currently, from total production of energy 68, 26% is heat production and 31, 73% is electricity production. A simplified scheme is shown in fig. 1. For electricity production are used equipments with specifications from table 1.

Table 1. **Equipments for electricity generation**

Equipment	Model/ Type	Capacity
CHP group no.1	Steam turbine DSL–50– 1	60 MW
	Generator TH 60-2 type	
CHP group no.2	Gas turbine TBM T 130	14,25 MW
	Electrical generator 17	

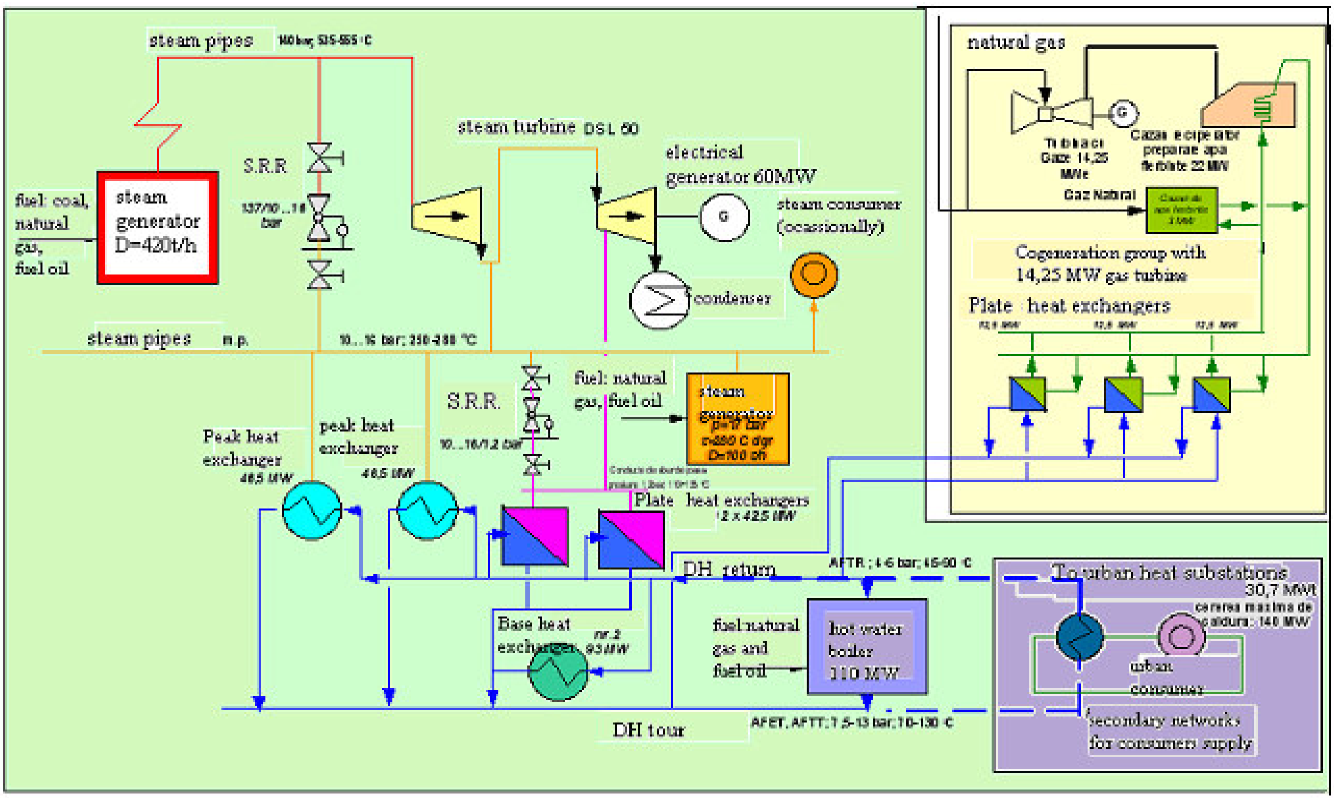

Fig.1. A simplified block diagram of CET Bacau

Heat for district heating and industrial consumers is produced using next capacities, shown in table 2.

Table 2. **Equipments for heat production**

Equipment	Model/ Type	Capacity
Turbine group no.1	Turbine *DSL*–50– 1	187
Steam generator	CRG – 1870	288
Gas turbine	TBM T 130	20,66
Recovery Boiler	Heat Recovery Boiler	22
Hot water boiler for peak load	UT 3700	3
Steam generator for start and heating aid	Babcock	70,8
Base heat exchanger	Plates heat exchanger	42,5
Base heat exchanger	Plates heat exchanger	42,5
Base heat exchanger	Horizontally heat exchanger	93,0
Peak heat exchanger	Vertically heat	52,3
Peak heat exchanger	Vertically heat	52,3
Hot water boiler	Alchemintz	116,3

Instantaneous demand of heat and electricity changes continuously, shows some irregularities daily weekly and seasonal. These trends are not the same for electricity and heat, so that simultaneous production of electricity and heat must take into consideration trends in both markets (electricity and heat), according with performances of plants and availability of primary energy [8]. Proposed medium-term objectives are:

- Maintain the actual heat markets (demand);
- Extend the Electricity market marje;
- Be in line with EU requirements regarding the standards emission for maximum limits of the main pollutants and promote the reduction of GHG.

3. MULTI-CRITERIA DECISION ANALYSIS

Multi-Criteria Decision Analysis (MCDA) is a term which includes a set of techniques developed for helping decision makers in choosing better decisions in a lot of complex problems [9]. Fig. 2 presents the logical scheme used in application of MCDA.

Proposed medium-term objectives are:

- Maintain the actual heat markets (demand);
- Extend the Electricity market segment occupied;
- Be in line with EU requirements on the classification of the emission standards for major pollutants and allowed the reduction of GHG.

There are analyzed a set of eight operating alternatives with different characteristic operation schedules according to supply scheme for winter and summer.

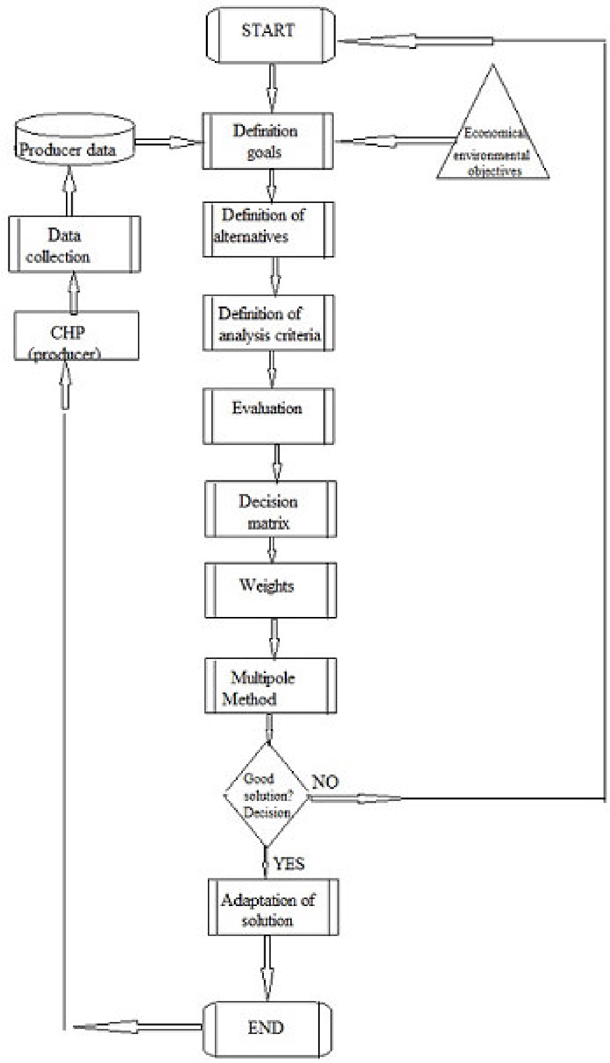

Fig.2. Logical scheme for application of MCDA

The comparative analysis criteria of the possible operation modes are given in table 3.

Table 3. **Comparative analysis criteria**

Criterion	Symbol	Objective function type
Heat price	C1	Minimize
Fuel cost and cost of CO_2 additional emissions, for 1 euro income from electricity	C2	Minimize

The difference between revenue and total variable costs	C3	Maximization
Overall annual efficiency of fuel use	C4	Maximization
Annual primary energy savings (in line to 2004/8/EC)	C5	Maximization
Total revenues	C6	Maximization
Total variable costs	C7	Minimize

In the paper [8] are performed several multi-criteria decision analyses applicable to a CHP plant: Global Utility Method, Ranking method, Electre method, Electre Modified method. For the eight proposed operation alternatives, the decision matrix is presented in table 4. Table 5 shows the obtained results. Alternative 6 is the best option taking account from considered criteria. CHP group no.1 works with increased weight of condensing fuel, CHP group no.2 and peak source for heat production are in stand-by (winter maximum and medium delivered schemes); CHP group no.1 and peak source for heat production are in stand-by, CHP group no.2 produces electricity corresponding to heat load (winter minimum delivery scheme); CHP group no.1 and peak source for heat production are in stand-by, CHP group no.2 produces electricity corresponding to heat load and own energy services provided in non CHP scheme (winter minimum delivery scheme).

Table 4. **Decision matrix**

Alternatives	C1 [euro/MW]	C2 [euro/euro]	C3 [mil euro]	C4 [%]	C5 [mii euro]	C6 [mil.euro]	C7 [mil.euro]
A1	28,4	0,4	2,7	0,62	18,3	20	17,2
A2	28,4	0,5	-3	0,62	17,8	19,5	21,8
A3	26,8	0,4	2,7	0,64	16,4	18,3	15,6
A4	26,8	0,3	4,4	0,63	18,1	19,9	15,9
A5	25,8	0,3	4,6	0,64	17,5	19,3	15,1
A6	25,8	0,3	5	0,64	19,2	20	15,3
A7	25,8	0,4	-1,6	0,63	17,3	18,6	19,9
A8	42,2	0,4	6,4	0,85	11,7	18,2	10,5
k_i^*	0,3	0,15	0,15	0,1	0,1	0,1	0,1

$^*k_I$ – hierarchical set of importance coefficients

Table 5. **Results**

Alternatives	**Utility method**	**Ranking method**	**ELECTRE modified method**	**ELECTRE method**	**Total**	**General classification**
A1	4	4	4	3	15	**IV**
A2	8	8	8	6	30	**VIII**
A3	5	6	5	5	21	**V**
A4	2	3	3	2	10	**III**
A5	3	2	2	1	8	**II**
A6	1	1	1	1	4	**I**
A7	6	7	6	4	23	**VI**
A8	7	5	7	6	25	**VII**

4. APPLICATION OF MULTIPOLE METHOD

To examine alternatives for changing the classification change optics makers, we use the Multipol Method. The aim of using MULTIPOL is to help in decision making by creating a simple and evolutionary analysis matrix of available actions and solutions. MULTIPOL is innovative because of its simplicity and ease in using. Hence, every action is evaluated taking into consideration each criterion with the aid of a simple scale. Evaluation is possible via either questionnaires or meetings with experts, where a consensus is necessary [11].

Hierarchical set of importance coefficients defined in the calculation already made P1 are considered the policy maker. P1 is policy centered on the smallest price of heat production.

If producer would be defined as priority reducing financial losses regardless of the social impact of the chosen option, it can be defined policy P2/ the series coefficients of importance: (0,15 ;0,3 ;0,15 ;0,1 ;0,1 ;0,1 ;0,1).

If producer would define as a priority improving the efficiency of fuel usage regardless of the social impact of extent of the established policy can be defined P3, with a series of important factors: (0,15 ;0,15 ;0,1 ;0,15 ;0,2 ;0,1 ;0,1).

If maximizing producer revenues would define as a priority regardless of the social impact of extent of the established policy can be defined P4, with a series of important factors: (0,15 ;0,15 ;0,1 ;0,1 ;0,1 ;0,2 ;0,2).

The results of applying policies P1-P4 generated the following ranking from table 6.

Table 6. **Final ranking**

Alternatives	P1	P2	P3	P4
A1	IV	IV	IV	IV
A2	VIII	VIII	VIII	VIII
A3	VI	VI	VI	VI
A4	III	III	III	III
A5	II	II	II	II
A6	I	I	I	I
A7	VII	VII	VII	VII
A8	V	V	V	V

5. CONCLUSIONS

In the example of this paper, analysis of final ranking indicates a very good stability to changes in manufacturer's policy for all alternatives considered. So alternatives recommended are A6 and A5.

Multi-criteria decision analysis is a very of good option for the choosing the optimal operating conditions for a company that produces electricity and heat.

For application of MCDA techniques is very important to establish the correct objectives and analysis criteria. The energy policy of the producer has a great impact because this is in direct line with hierarchical set of importance coefficients.

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