A MODELING AND OPTIMIZATION APPROACH BASED ON GENETIC ALGORITHMS FOR A HYBRID TRIGENERATION SYSTEM WITH STIRLING ENGINE

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REZUMAT. Aceasta lucrare prezinta abordarea optimizarii unui hub energetic de trigenerare bazata pe algoritmi genentici. O centrala de trigenerare cu motor Stirling este o solutie de perspectiva fiind capabila sa inlocuiasca simultan in case energia electrica din sistem, incalzirea centrala si generarea de apa calda si aer conditionat sau instalatii de refrigerare. Autorii propun un model matematic bazat pe o functie obiectiv compusa din doua componente: functia de energie primara si un termen de eroare (functie de penalizare) egala cu diferenta dintre energia primara calculata prin doua metode independente. Minimizarea functiei obiectiv este realizata apoi pe baza unei scheme care foloseste algoritmi genetici (AG).

Cuvinte cheie: hub de energie, trigenerare, algoritm genetic.

ABSTRACT. This paper presents a trigeneration energy hub optimization approach based on genetic algorithms (GAs). A trigeneration plant with Stirling engine is a perpective solution, able to simultaneously replace in houses the electric power supplied from the system, centralized heating and hot water generation and air conditioning or refrigeration air instalations. The authors propose a mathematical model based on a compound objective function with two components: the primary energy function and an error term (a penalty function) equal to the difference between the primary energy computed on two independent ways. The minimization of the objective function is then accomplished based on a GA scheme.

Keywords: energy hub, trigeneration, genetic algorithm

1. INTRODUCTION

Many of the current energy infrastructures evolved in the second half of the XX century could be doubted that they would meet tomorrow's demands. Many of the plants are nearing the end of their life expectancy. In additions other problems like the growing demand of energy, the dependence on fossil energy resources, the restructuring of energy industry and the general objective of using more sustainable and more durable energy sources lead to the question whether the change of some portions of existing systems is sufficient to meet these challenges or a more radical change in the design is needed.

Industrial consumers, commercial and residential require different forms of energy provided by different infrastructures. Until now, different infrastructures are often taken into consideration and operated independently. Combining different energy forms can lead to some benefits allowing the exchange of power between them which is a major opportunity to improve the system. Transformation, conversion and different forms of energy storage can be done in facilities called energy hubs.

Using renewable energy sources, cogeneration and trigeneration facilities of small to medium power and other energy sources that can be located near the consumer load within a local power system represents the new concept of energy production known as distributed generation.

Nomenclature

Trigeneration system

W_e – output electrical power
$W_{e,pr}$ – input electrical power
W_f – output thermal energy (cooling)
W_{fe} – thermal energy (cooling) produced by electricity conversion
W_{ft} – thermal energy (cooling) produced by thermal power conversion
W_t – output thermal energy (heat)
W_{pr} – input primary power
dW_{pr} – deviations between computed primary energies
$W_{tot,in}$ – total input energy (at hub's entry)

$W_{tot,out}$ – total output energy (at hub's output)
COP_{st} – coefficient of performance of the Stirling engine
COP_{eg} – coefficient of performance of the electric generator
COP_{he} – coefficient of performance of the heat exchanger
COP_e – coefficient of performance of the refrigeration instalation (electricity – cooling)
COP_t – coefficient of performance of the refrigeration installation (thermal – cooling)
α_e , α_t – power distribution coefficients, electricity - heat
β_e , γ_e – power distribution coefficients, electricity - cooling
β_t , γ_t – power distribution coefficients, thermal - cooling
Pr_g – gas prices
Pr_e – price of electrical energy taken from the system
Pr_{eo} – price of produced electrical energy
Pr_{to} – price of produced thermal energy (heat)
Pr_{feo} – price of thermal energy (cold) produced from electrical energy
Pr_{fto} – price of thermal energy (cold) produce from thermal energy
Pr_{fo} – price of thermal energy (cold)

Genetic Algorithm

GEN – number of generations
POP – number of chromosomes in the population
R_i – crossover rate
R_m – mutation rate
Corr – initial value of the correction step for the mutation rate
Corr_d – decay coefficient of the correction step for the mutation rate
k – weighting coefficient of primary energy in the objective function
F_{obj} – objective function

2. TRIGENERATION PLANT WITH STIRLING ENGINE

The concept of trigeneration techniques means the combination of two well-known techniques today: cogeneration (combined and simultaneous production of heat and electricity) and the production of cooling through absorption or compression [5].

Conceptual analysis of the systems involves the definition of the trigeneration systems components and their interconnection system. A typical trigeneration system consists of four components: primary engine, electric generator, heat exchanger (chiller) and control, monitoring and protection system.

An important difference in the class of CCHP systems (Combined Cooling, Heating and Power) lies in how to connect the cooling production plant. The first option involves conversion of heat into cooling by absorbtion or adsorbtion, while the second options consists in processing electric power in refrigeration systems[6]. Each trigeneration process has its own balance of energy transformations.

We are exploring variations of energy conversions, from thermo-electrical, thermal-cooling and electrical-cooling conversion processes.

From exploring the above conversion processes, the basic conceptual scheme from Fig. 1 can result for the CCHP system (energy hub). The energy hub is a virtual concept that describes the interface between energy producers, consumers and transmission or transportation infrastructure.

In the thermal engine family, the Stirling engine defines a heat machine with closed-cycle regenerative hot air.

There are several design alternatives of the Stirling engine from wich the majority belong to the reciprocating machinery (alternative pistons) category.

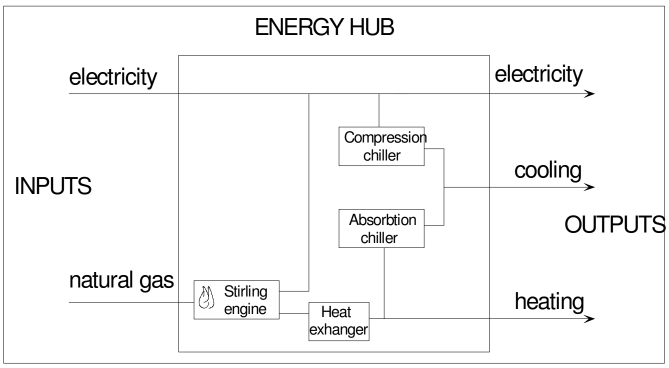

Fig. 1. Example of an energy hub.

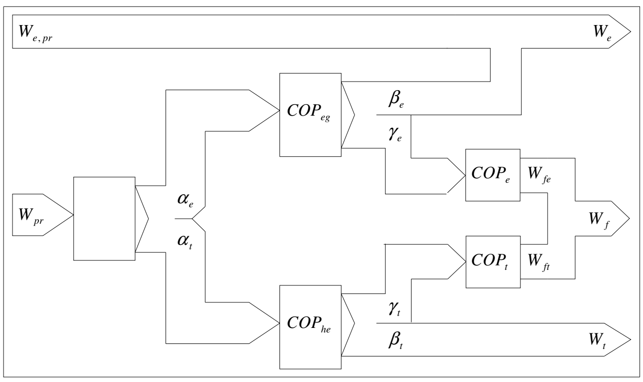

Fig. 2. Energy balance for Stirling engine-trigeneration.

Usualy the Stirling engine is included in the category of external combustion engines, though the heat source can be not only fuel but also firing solar or nuclear energy. A Stirling engine works by using an external heat source and a heat sink, each of which is kept to predetermined temperature limits and a sufficiently large temperature difference between them.

Stirling engine advantages became apparent advantages compared with the increase of energy cost, lack of energy resources and environmental problems like climate change. Increasing interest in Stirling engine technology has boosted research and development in this area.

The energy balance of a trigeneration solution with Stirling engine, absorption chiller and compressor chiller, to be used as a study case is shown in Fig. 2.

With respect to the energy balances for the trigeneration system from Fig. 1 and 2, the following equations can pe deduced.

Electricity required at the exit of the hub:

$$\left(W_{pr} \cdot COP_{st} \cdot \alpha_e \cdot COP_{eg}\right) \cdot \beta_e + W_{e,pr} = W_e \quad (1)$$

Cooling energy at the exit of the hub:

$$\left(W_{pr} \cdot COP_{st} \cdot \alpha_e \cdot COP_{eg}\right) \cdot \gamma_e \cdot COP_e = W_{fe} \quad (2)$$

$$\left(W_{pr} \cdot COP_{st} \cdot \alpha_t \cdot COP_{he}\right) \cdot \gamma_t \cdot COP_t = W_{ft} \quad (3)$$

$$W_f = W_{fe} + W_{ft} \quad (4)$$

Thermal energy required at the exit of the hub:

$$\left(W_{pr} \cdot COP_{st} \cdot \alpha_t \cdot COP_{he}\right) \cdot \beta_t = W_t \quad (5)$$

where:

$$\alpha_e + \alpha_t = 1 \qquad \beta_e + \gamma_e = 1 \qquad \beta_t + \gamma_t = 1 \quad (6)$$

If $\beta_e = 0$ all electricity is used for cooling, if $\beta_e = 1$, all electricity is used to power up electricity consumers.

If $\beta_t = 0$ all thermal power is used for production of cooling; if $\beta_t = 1$ all thermal power is used for heating.

Using the above notations:

$$\begin{aligned} &\delta_e = COP_{st} \cdot \alpha_e \cdot COP_{eg} \cdot \beta_e, \\ &\delta_f = COP_{st} \cdot \alpha_e \cdot COP_{eg} \cdot (1-\beta_e) \cdot COP_e + \\ &\qquad COP_{st} \cdot (1-\alpha_e) \cdot COP_{he} \cdot (1-\beta_t) \cdot COP_t \\ &\delta_t = COP_{st} \cdot (1-\alpha_e) \cdot COP_{he} \cdot \beta_t \end{aligned} \quad (7)$$

the energy balance from equations (1) – (5) can be rewritten as:

$$W_{pr} \cdot \delta_e + W_{e,pr} = W_e \quad (8)$$

$$W_{pr1} \cdot \delta_t = W_t, \qquad W_{pr1} = \frac{W_t}{\delta_t} \quad (9)$$

$$W_{pr2} \cdot \delta_f = W_f, \qquad W_{pr2} = \frac{W_f}{\delta_f} \quad (10)$$

where W_{pr1} and W_{pr2} are the input primary energy computed using as primary information the thermal or the cooling output energies W_t and W_f.

The primary energy at the Hub entry can be approximated as the average of energies W_{pr1} and W_{pr2}, while the primary electric power results as:

$$W_{pr} \approx \frac{W_{pr1} + W_{pr2}}{2} \quad (11)$$

$$W_{e,pr} = W_e - W_{pr} \cdot \delta_e \approx W_e - \frac{W_{pr1} + W_{pr2}}{2} \cdot \delta_e \quad (12)$$

If coefficients α, β and γ are adequately designed, energies W_{pr1} and W_{pr2} should be equal. However, for a random set of coefficients α, β and γ, there will exist a deviation between the two computed primary energies:

$$dW_{pr} \approx \left(W_{pr1} - W_{pr2}\right)^2 \quad (13)$$

3. GENETIC ALGORITHMS

Genetic algorithms are adaptive search heuristic techniques based on the principles of genetics and those of natural selection, set by Darwin (best adapted to survive). The mechanism is similar to the biological process of evolution. This process has a feature that only species that adapt best to the environment are able to survive and evolve over generations, while those less adapted do not survive and with time disappear as a result of natural selection. The probability of species to survive and evolve over generations becomes even greater as the degree of adaptation increases, which in terms of optimization means that the solution approaches it's optimal phase.

A genetic algorithm is a computer model that emulates the evolutionary biological model for solving problems of optimization or search. It includes a set of individual elements represented in the form of binary strings (population) and a set of biological natural operators defined on populations. With the help of operators, the genetic algorithms manipulate most promising strings, evaluated by an objective function, searching for better solutions. Genetic algorithms began to be recognized as optimization techniques starting with the works of John Holland.

As practical applications, genetic algorithms are often used in solving optimization problems, planning or search.

4. NUMERICAL APPLICATION

The energy balance described in Section 2 can be used to define an objective function for the optimal design of the energy conversion process into the generic energy hub form Figures 1 and 2. Thus, the conversion systen is completely defined or designed if conversion coefficients δ_e, δ_t and δ_f or alternatively α_e, β_e and β_t are known. As equastions (7) and (8) – (10) show, the conversion system has an infinity of values for coefficients α_e, β_e and β_t that could satisfy the energy balance. However, a limited number of these values insure the minimum value of the primary energy used by the trigeneration system ($W_{pr} + W_{e,pr}$).

On the other hand, since the input primary energy W_{pr} can be computed starting from the heating W_t or cooling W_f output energies, as shown in equations (9) and (10), the objective function must take into consideration an additional penalty term to reflect the deviation between the two values of the computed primary energy, dW_{pr}. This deviation is generated by inappropriate values choosen for coefficients α_e, β_e and β_t. Hence, the objective function will be:

$$F_{obj} = k \cdot \left(W_{pr} + W_{e,pr}\right) + \left(1-k\right) \cdot dW_{pr} \qquad (14)$$

In paper [10] we have an example of optimization of trigeneration facility after the objective function from relation (14).

If we take into account the primary energy prices (electrical and gas) the objective function can be written as:

$$F_{obj} = k \cdot \left(\Pr_g \cdot W_{pr} + \Pr_e W_{e,pr}\right) + \left(1-k\right) \cdot \Pr_g dW_{pr} \qquad (15)$$

The problem described by equations (8) – (15) is a non-linear optimization problem with many local minima. This type of problem can be succesfully and efficiently addressed by modern metaheuristic optimization techniques, such as the GAs described in section 3. Since the optimization problem was generated based on 3 independent variables (coefficients α_e, β_e and β_t), a possible solution can be encoded for the GA using a chromosome with 3 genes, like the one from Fig. 3. This chromosome uses real values for genes, hence special crossover and mutation operators for real valued encoding schemes must be used [7].

α_e	β_e	β_t

Fig. 3. The encoding scheme for the GA.

To illustrate how the proposed method can be used to optimally design the structure of the energy hub from Figures 1 and 2, the following numerical values have been used:

- price of primary energy:

$$\Pr_e = 0{,}16 \text{ [lei/kWh]} \qquad \Pr_g = 0.1 \text{ [lei/kWh]} \qquad (16)$$

- performance coefficients:

$$COP_{eg} = 0.95,\ COP_{he} = 0.6,\ COP_{st} = 0.88,$$

$$COP_e = 0.7 \text{ and } COP_t = 0.7, \qquad (17)$$

To adjust the parameters of the GA, aspecial analysis was driven over the influence of parameters k, R_i, R_m, Corr, Corr_d and POP. The GA was run for different values of the above parameters, in order to choos the best combination. These tests emphasized the following conclusions:

- the efficiency of the GA is less sensitive to crossover and mutation rates. Hence modest, average values were choosen for this parameters (R_i = R_m = 0.7).

- the efficiency of the GA is influenced in a greater extand by the value of the weighting coefficient k. Thus, for small values of k (when the penalty term dominates the input primary energy) the searching process stops in local minima. Larger values (close to 1) reduce the influence of the penalty term and the solution identified by the GA produces higher deviation dWpr. The optimal value of k was set to 0.7.

- too large values of parameter Corr may determine a chaotic behavior of the GA, while too large values (close to 1) of parameter Corr_d will determine a very slow convergence of the searching process. The optimal values were set to Corr = 0.2 and Corr_d = 0.99.

- a too small number of chromosomes in the population of the GA may determine a premature convergence of the GA in local minima, while too large values determine higher computational efforts. The best size of the population may be choosen between 100 and 200 individuals.

- output energies:

$$W_e = 500 \text{ [kWh]}, W_f = 500 \text{ [kWh]} \& W_t = 500 \text{ [kWh]} \quad (18)$$

Using the above values of parameters k, R_i, R_m, Corr, Corr_d and POP, the GA was run to determine the best configuration of the energy hub from figures 1 and 2. Thus, the optimal values of these coefficients α_e, β_e and β_t, considering the fact that the coefficient α_e is upper limited at the value of 0.25 because the Stirling engine cannot convert more than 25% of the primary energy into electricity, are:

α_e = 0,25; β_e = 0,638 and β_t = 0,490 (19)

This way we can obtain the optimal values of thermal energies (cooling) resulted from electric and thermal energy conversion into cooling (W_{fe} and W_{ft}):

W_{fe} = 136,12 [kWh] and W_{ft} = 363,88 [kWh] (20)

The input eletric energy at the Hub entry is:

$W_{e,pr}$ = 156,203 [kWh], (21)

the primary chemical energy at the Hub entry is:

W_{pr} = 2575,341 [kWh], (22)

while the total energy at the Hub entry will result:

W_{tot} = 2731,55 [kWh], (23)

the performance coefficient of the trigeneration facility will be:

$$COP = 0.552\,, \qquad (24)$$

the prices for the energy produced by the trigeneration facility (not taking into account the initial investement price and the maintenance costs of the facility) are:

$$\mathrm{Pr}_{eo} = 0.1196\ \text{[lei/kWh]},\quad \mathrm{Pr}_{to} = 0.1894\ \text{[lei/kWh]},$$
$$\mathrm{Pr}_{feo} = 0.1709\ \text{[lei/kWh]},\quad \mathrm{Pr}_{fto} = 0.2706\ \text{[lei/kWh]},$$
$$\mathrm{Pr}_{fo} = 0.2434\ \text{[lei/kWh]} \qquad (25)$$

To see how the trigeneration facility behaves in a dynamic regime we modified the value of energy necessary for the consumer W_e, W_t and W_f between 100 and 900 kWh.

For a variation of energy at the hub output, W_e , the following energy variations were obtained: fig. 4.

We note the variation of electricity to consumers is taken entirely from the system what leads to a constant load of the trigeneration facility (α_e, β_e and β_t are constant). Thus, the coefficient of performance of the facility and the prices for the energies will remain the same.

For a variation of thermal energy (heat) to the output of the hub, W_t , the coefficients α_e, β_e and β_t were obtained from table table 1, and the energy variations shown in fig. 5.

Table 1

Variation of coefficients α_e, β_e and β_t depending on W_t

W_e [kWh]	W_f [kWh]	W_t [kWh]	α_e	β_e	β_t
500	500	100	0.25	0,9090	0,1287
500	500	200	0.25	0,8324	0,2380
500	500	300	0.25	0,7686	0,3318
500	500	400	0.25	0,6889	0,4179
500	500	500	0.25	0,6387	0,4902
500	500	600	0.25	0,5608	0,5623
500	500	700	0.25	0,4853	0,6294
500	500	800	0.25	0,4348	0,6858
500	500	900	0.25	0,3352	0,7531

Note that the variations of thermal energy (heat) to the consumer is taken largely by the trigeneration facility but also, as the thermal energy rises at the output of the hub, cold is produced more and more from eletrical energy that is being absorbed from the system. The performance coefficient of the facility will increase (fig. 6) and the price of cooling energy will decrease (fig.7).

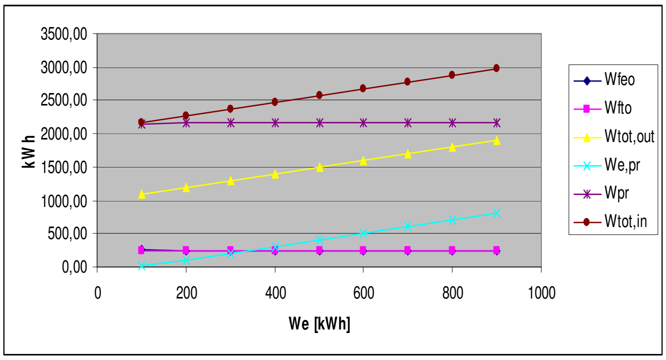

Fig. 4. Variation of energy W_{fe}, W_{ft}, $W_{tot,out}$, $W_{e,pr}$, W_{pr}, $W_{tot,in}$ depending on W_e.

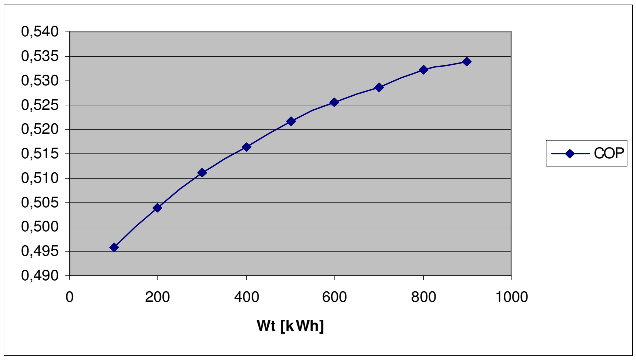

Fig. 6. Variation of the performance coefficient of the trigeneration facility depending on W_t.

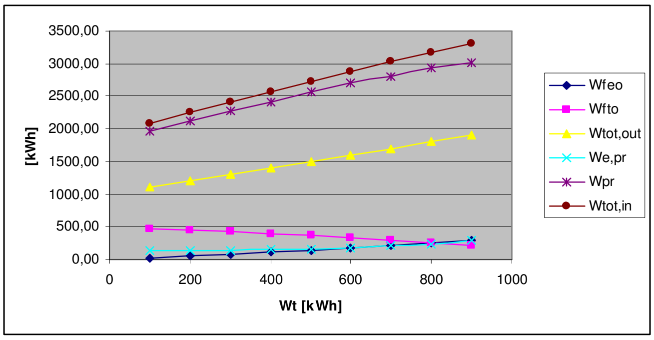

Fig. 5. Variation of energy W_{fe}, W_{ft}, $W_{tot,out}$, $W_{e,pr}$, W_{pr}, $W_{tot,in}$ depending on W_t.

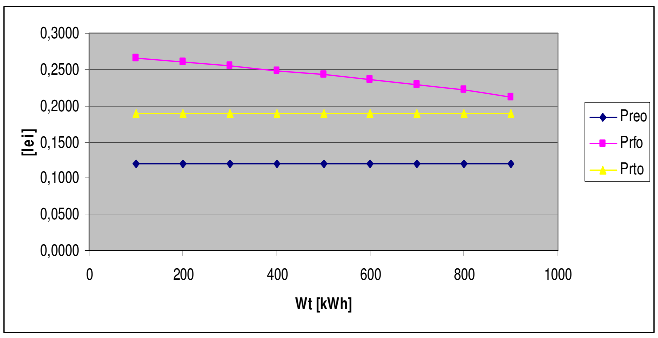

Fig. 7. Variation of energy prices depending on W_t.

For a variation of thermal energy (cooling) to the output of the hub W_f the following coefficients were obtained, α_e, β_e and β_t from table 2, and the variations of energies presented in fig. 8.

Table 2

Variation of coefficients α_e, β_e and β_t depending on W_f

W_e [kWh]	W_f [kWh]	W_t [kWh]	α_e	β_e	β_t
500	100	500	0.25	0,6393	0,9258
500	200	500	0.25	0,4451	0,8227
500	300	500	0.25	0,3093	0,7347
500	400	500	0.25	0,2528	0,6506
500	500	500	0.25	0,2024	0,5850
500	600	500	0.25	0,1596	0,5318
500	700	500	0.25	0,1364	0,4852
500	800	500	0.25	0,0906	0,4504
500	900	500	0.25	0,0598	0,4189

As we increase the thermal energy (cooling) necesary for the consumers, the energy is equally produced from electric energy and from heat. Mainly the variation of thermal energy (cooling) is taken by the trigeneration facility, but we can notice a slight increase in electrical energy taken from the system. Thus the coefficient of performance of the facility will decrease (fig. 9) and the price of produced cold energy will increase (fig.10).

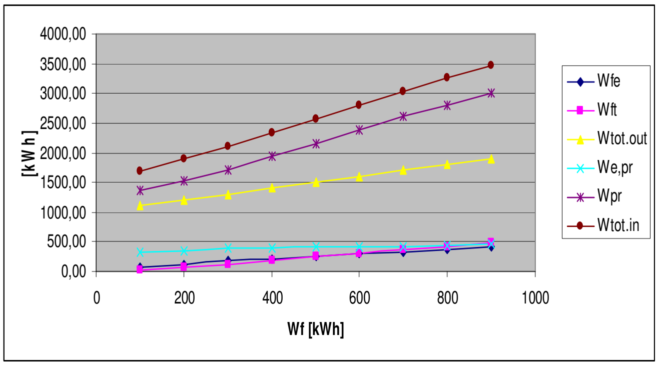

Fig. 8. Variation of energy W_{fe}, W_{ft}, $W_{tot,out}$, $W_{e,pr}$, W_{pr}, $W_{tot,in}$ depending on W_f.

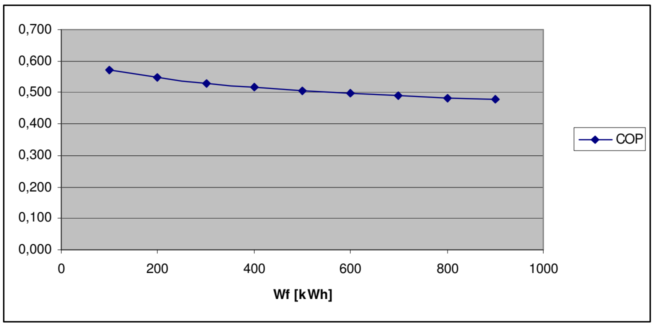

Fig. 9. Variation of the performance coefficient of the trigeneration facility depending on W_f.

If a heat exchanger is being used with a higher coefficient of performance (COP_{he}=0.8) we obtain the following results:

- to the variation of electrical energy needed by consumers, W_e, the energy variation curves are as in figure 11.

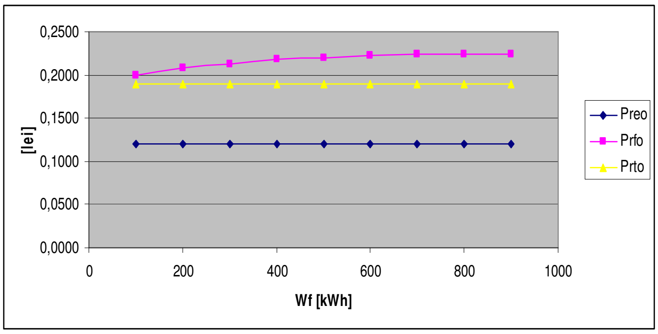

Fig. 10. Variation of energy prices depending on W_f.

Like in case COP_{he}=0.6, the variation of electrical energy is taken entirely from the system, except the thermal energy (cooling) that is produced only from thermal energy (heat). In this case the performance coefficient of the trigeneration facility grows at COP=0.644. The production price of the cold will be 0.2029 lei/kWh

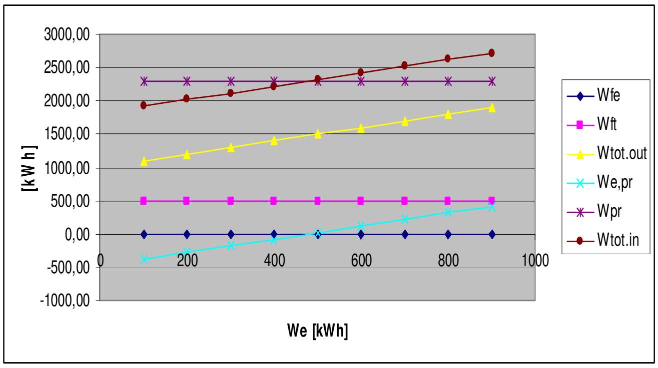

Fig. 11. Variation of energy W_{fe}, W_{ft}, $W_{tot,out}$, $W_{e,pr}$, W_{pr}, $W_{tot,in}$ depending on W_e.

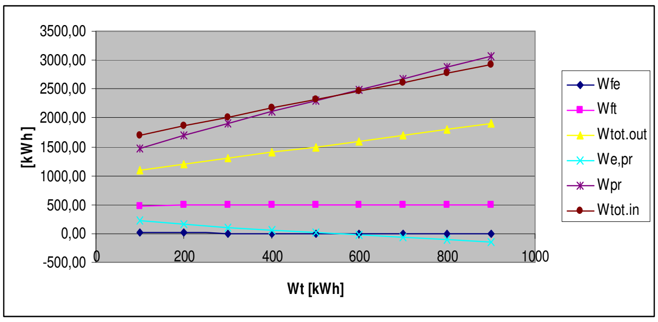

Fig. 12. Variation of energy W_{fe}, W_{ft}, $W_{tot,out}$, $W_{e,pr}$, W_{pr}, $W_{tot,in}$ depending on W_t.

- to the variation of the thermal energy (heat) necessary to consumers, W_t, the variation curves of energy will be as in fig. 12.

We can observe that the variation of thermal energy (heat) is taken over by the trigeneration facility and as W_t rises, the electrical energy produced by the facility will also rise, but it is not used for the production of cold energy.

The performance coefficient of the facility will rise like in fig. 13.

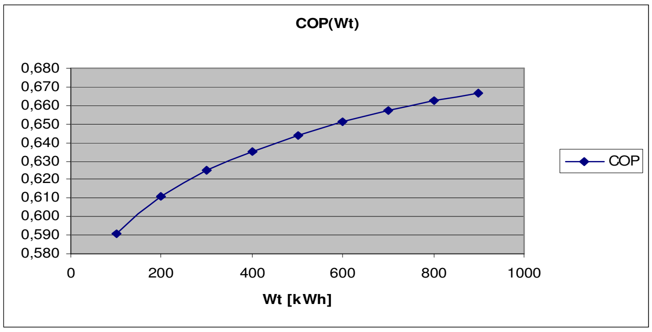

Fig. 13. Variation of the performance coefficient of the trigeneration facility depending on W_t.

- to the variation of thermal energy (cooling) necessary to consumers, W_f, the variation curves of the energy will be like in fig. 14.

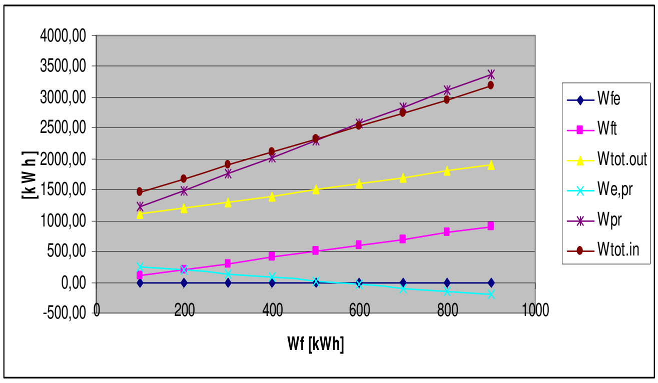

Fig. 14. Variation of energy W_{fe}, W_{ft}, $W_{tot,out}$, $W_{e,pr}$, W_{pr}, $W_{tot,in}$ depending on W_f.

In this case, the variation of thermal energy (cooling) is taken over by the trigeneration facility and as W_f rises, the electrical energy absorbed by the system will decrease. The performance coefficient of the facility will decrease as in fig. 15.

For this solution, (COP_{he}=0.8) we can observ that the cold it's being produced entirely of thermal energy (heat), which shows us that there is no need for a compression chiller. The greater the amount of thermal energy needed for consumers (heat or cold) the amount of produced electric energy will increase and at some point will overcome the value of energy necessary to consumers so the excess of energy is delivered to the system. This can be seen in the drop of electrical energy demanded by the consumers.

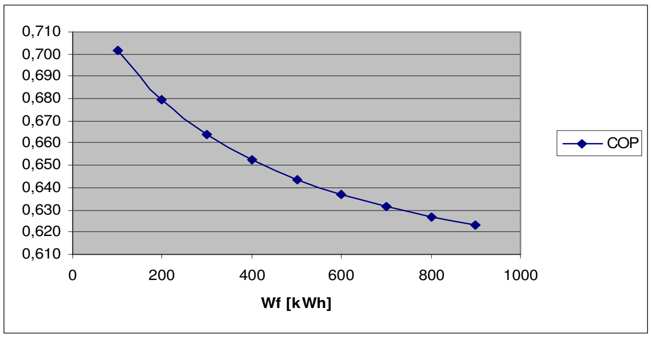

Fig. 15. The variation of the performance coefficient of the trigeneration facility depending on W_t.

The investment for a compression chiller would be justified only in the case we do not want to deliver the energy to the system.

5. CONCLUSIONS

The paper presents a GA – based optimization procedure to determine the optimal structure of an energy hub based on a trigeneration system with Stirling engine. The model consists of an 2 inputs (electricity and fuel) – 3 outputs (electricity, cooling and heating) energy hub. The proposed model was analysed to tune the parameters of the GA and then it was applied to produce the optimal solution of the optimization problem. The optimal solution was computed using as optimization criterion the minimum cost for primary energy.

For a better trigeneration efficiency solution of the energy, the hub can be improved, new components can be added, like solar collectors or wind turbines, photovoltaic cells, etc. The implementation of such systems can lead to a more rational use of fuels with reduced emissions and with increased comfort.

BIBLIOGRAPHY

[1] **Pavel Atănăsoae**, *Trigeneration, an efficient solution for the combined heat and power plants of Romania*, **5-th International Conference on Electrical and Power Engineering EPE 2008, Buletinul Institutului Politehnic Iaşi, tomul LIV (LVIII), fasc. 3, 2008, p.499-502, ISSN 1223-8139.**

[2] **Martin Geidl, Gaudenz Koeppel, Patrick Favre-Perrod, Bernd Klöckl, Göran Andersson, Klaus Fröhlich,** *The Energy Hub – A Powerful Concept for Future Energy Systems,* **Third Annual Carnegie Mellon Conference on the Electricity Industry, 13 – 14 March 2007**

[3] **Allan Jones MBE,** *CHP trigeneration*, **London Climate Change Agency 12 July 2007**

[4] **Arina Negoitescu, Adriana Tokar, Daniel Ostoia,** *A Study Regarding the Performances of Trigeneration Systems,* **Analele Universitatii "Eftimie Murgu" Resita Anul Xv, Nr. 1, 2008, ISSN 1453 - 7394**

[5] **Rodica Frunzulică, Mirela Sanda Țoropoc,** *Tri-generation, an Efficient Solution for the Future also in Romania. Possibilities and Limits of Application.*

[6] **Badea Nicolae,** *Sisteme autonome de generare a energiei prin trigenerare utilizând combustibili ecologici - sagetrigen*, Raportul **stiintific si tehnic, Galati, 2007.**

[7] **M. Gavrilas,** *Artificial Intelligence and Applications in Power Systems,* **Vol. I, Ed. "Gh. Asachi" Iasi, 2002.**

[8] **Martin Geidl and Goran Andersson,** *A Modeling and Optimization Approach for Multiple Energy Carrier Power Flow*, **Power Systems Laboratory, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland**

[9] **Mehrdad Setayesh Nazar, Mahmood R. Haghifam,** *Multiobjective electric distribution system expansion planning using hybrid energy hub concept*, **Electric Power Systems Research 79, 2009.**

[10] **Eugen Hopulele, Mihai Gavrilaş, Ciprian Afanasov,** *Optimal design of a hybrid trigeneration system with Stirling engine*, **6-th International Conference on Electrical and Power Engineering, EPE 2010, Iaşi, ISSN: 978-606-13-0077-8.**

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