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Economic Criteria for Optimal Sizing of Fuel Supply Plants in a District-Heating Power-Station

"Improving of electric-power supply of consumers and increasing the supply's safety are directly influenced by the decision of sizing equipments in the electric power stations"

1. PROBLEM FORMULATION; HYPOTHESES

Optimal sizing of the fuel supply plant in a district-heating power-station, operating with two fuels (main and auxiliary fuel) takes into consideration the optimal number of supply lines for each fuel type (their capacity), and the spare fuel amount in the intermediary bunker.

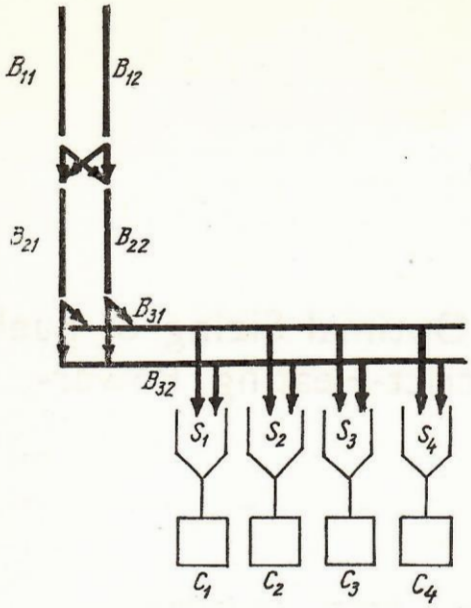
The paper analyses the most complex situation, i.e. the hypothesis according to which the main fuel is coal, and the auxiliary one, naphtha. One supposes that each fuel can alone meet the maximal requirements of the boiler house, hence, if need be, they may integrally substitute each other. By investigating this case, one can also directly deduce the conclusions concerning the situation when the spare fuel is gaseous.

As the power-plant also serves for heating, it produces two energy types, electric energy and heat, both having their own specific requirements as concerns damages for non-delivery.

We shall investigate, in what follows, whether it is rational to limit the plant sizing to the two fuels, by partially or totally giving up any spare fuel. In order to make things simpler, the whole pumping station for liquid fuel was considered as a unique fuel line, and the spare pump was considered to be a second line.

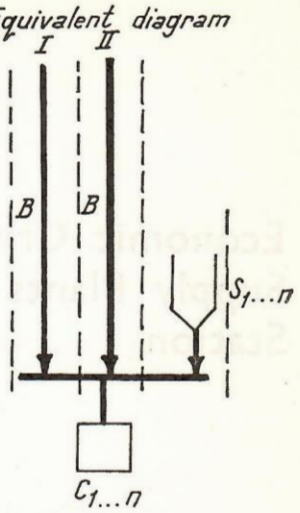
In the present day designing practice of fuel supply in Romanian power-stations, a generalized type is adopted for the whole solid fuel flow; there is a two-line supply diagram, each of them sized for the maximal output [1].

a) Physical diagram



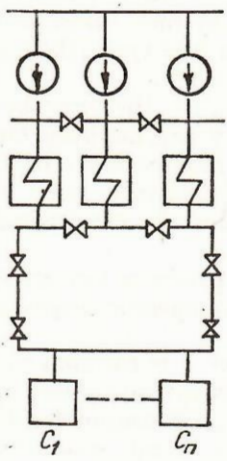
a

b) Equivalent diagram



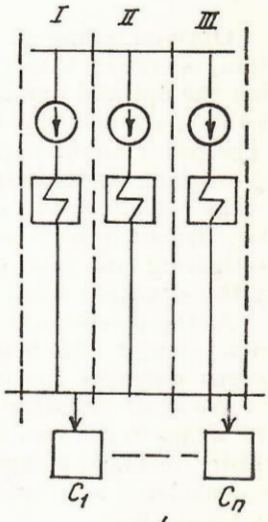
b

c) Solid fuel supply



c

d) Liquid fuel supply



d

Fig. 1 - Fuel diagrams for the calculation example

For liquid fuel supply lines, according to the Operating regulations of the Electric Energy Ministry [2], it is necessary to apply, within the pumping stations, a solution with two spare pumps. Fig. 1 shows the fuel supply diagram, in the normal sizing situation according to [1] and [2], as well as the equivalent diagram adopted for the system from the operating-safety viewpoint.

With a view to analysing the above mentioned problem, following covering assumptions were made:

a) the operation of the district-heating power-station is continuous, and the thermal and electric loads are maximal;

b) the coal bunkers in the boiler house represent, from the safety viewpoint, a parallel supply way, for a limited time duration. This duration varies linearly between two extreme amounts, represented by the maximal volume of each bunker V_1, and the minimal re-supply volume V_2 (Fig. 2). The working time with the coal in stock varies hence between t_1 and t_2;

c) the casual emptying of a bunker does not influence the operation of the units supplied from the other bunkers, as the minimal spare amount V_2 is sufficient;

d) there are no restrictions in using the second fuel for the yearly amounts, necessary to replace the main-fuel supply interruptions;

e) analysis is done by comparing following variations, included in table 1;

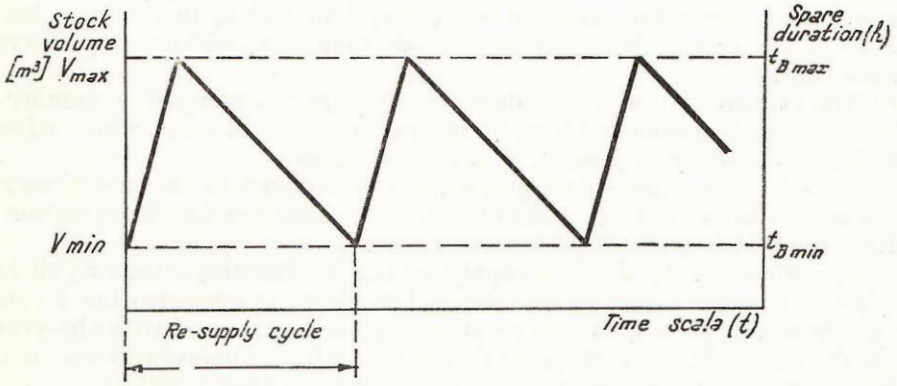


Fig. 2 - Stock variation in bunker

f) from the safety viewpoint, since all failure stoppages practically occur with pumps, each pump in the naphtha pumping station is assimilated to a supply line;

g) cost of damages for not satisfying consumers was supposed as being directly proportional to the non-delivered energy amount.

Two possible values were taken into account for the non-delivery of electric energy, and two possible values, for the non-delivery of heat. These values were considered as equiprobable.

Table 1

Amounts	Amounts			
	j	j^*	l	l^*
I	2 × 100%	1 × 100%	2 × 100%	1 × 100%
II	2 × 100%	1 × 100%	1 × 100%	1 × 100%
III	1 × 100%	1 × 100%	2 × 100%	1 × 100%
IV	1 × 100%	1 × 100%	1 × 100%	1 × 100%
V	2 × 50%	2 × 50%	1 × 100%	1 × 100%
VI	1 × 100%	1 × 100%	3 × 100%	1 × 100%

Note: In table 1 the columns have following meanings:

j is the total number of solid-fuel transport lines;
j^* — active elements of j;
l — total number of auxiliary-fuel transport lines;
l^* — active elements of l at full load.

For the consumers' electric-power supply, it was supposed that the power-station was interconnected with a system which, in its turn, has a certain failure degree. Heat supply is made isolatedly, without any external replacement.

The heating station is considered as a system consisting of a number of subsystems, series connected (Fig. 6), independent of each other, which achieve also, from the safety viewpoint, a series connection.

In order to compute damages, a quota is assigned to the fuel economy, which results from applying a calculation of probabilities for the operation of series-connected systems [3].

Specification: As the fuel supply system is a function attending all boilers in the power-station (general internal service), its operation has a continuous character. Its scheduled operating time is hence equal with the yearly calendar time (T_{an}), which justifies the use, within the calculation, of the disponibility notion, related to the yearly calendar time (8760 h).

2. OPERATION SAFETY OF THE FUEL PLANT

The solid-fuel supply system is made up of a number of belt conveyers, operating in series and in parallel, which discharge in intermediary bunkers. These have a fuel stock ensuring the boiler operation during t_{max} (hours) and each of them supplies a particular boiler (Fig. 2).

Sizing of bunkers and transport system must be done in such a way that, when the power station is continuously operating at full load, the resupplying of each bunker be done, when the stock reaches the critical value,

i.e. the one corresponding to time $t_{B\,min}$ [2]. This minimal value must be selected in such a way that, for faults of a shorter duration than the stock duration ($t_{B\,min}$), the re-supplying of all bunkers be made without perturbing the boiler operation. We suppose in this paper that this condition is fulfilled.

From the viewpoint of safety calculation, we hence propose a simplified equivalent diagram, in which a single consumer and a single bunker appear, the consumer being equivalent with the total of all maximal consumptions, and the bunker, with the sum of all power-station bunkers' volume. The effect of the bunker upon the operation safety of the consumers depends on the number and duration of breakdowns in the supply system.

The probability that the bunker replace a breakdown of a duration t_{Rj}, which fulfils condition $t_{B\,min} < t_{Rj} < t_{B\,max}$ (in the hypothesis of a linear emptyng of bunker), is

$$p = 1 - \frac{t_{Rj} - t_{B\,min}}{t_{B\,max} - t_{B\,min}} \tag{1}$$

Coal stock in bunkers is periodically restored, its magnitude being represented by a saw-tooth curve, comprised between maximal volume V_{max} and re-supplying volume V_{min} (Fig. 2).

The probability that in the stock be a lesser volume than V, is given by the linear relation:

$$x = \frac{V_{max} - V}{V_{max} - V_{min}} \tag{2}$$

By dividing numerator and denominator by maximal fuel consumption per hour, it results that magnitude x can also be expressed by the time ratio:

$$x = \frac{t_{max} - t}{t_{max} - t_{min}} \tag{3}$$

The coal bunker will be able to replace the fuel supply line, stopped for a breakdown of a duration t, with a probability $(1 - x)$.

The hystogram of breakdowns in the belt conveyer supply system has a given distribution.

Since the belt conveyer consists of a great number of elements, with a short replacement duration (rollers, etc.), and of a limited number of elements with a replacement duration superior to $t_{B\,min}$, it is possible to make a hypothesis of faults as in Fig. 3. At present a statistic of these distributions is not available, and in this calculations we took into consideration the situation in Fig. 3.

We admit, however, that the operation of a fuel supply line, consisting of several series-connected belt conveyers, is statistically known, and that the number of stoppages is classified according to their duration; hence we deduce the total stoppage time during a year, by relation:

$$t^{l}_{0,\,year} = \sum_{1}^{n} Z_j t_j^{med} \tag{4}$$

where: n is the total number of time classes;

Z_j — the number of breakdowns in time class j;

t_j^{med} — mean duration of a breakdown of time class j;

$$t_j^{med} = \frac{t_{j-1} - t_j}{2} = \left(j - \frac{1}{2}\right) \Delta t : \tag{5}$$

where: Δt is the magnitude of a time class.

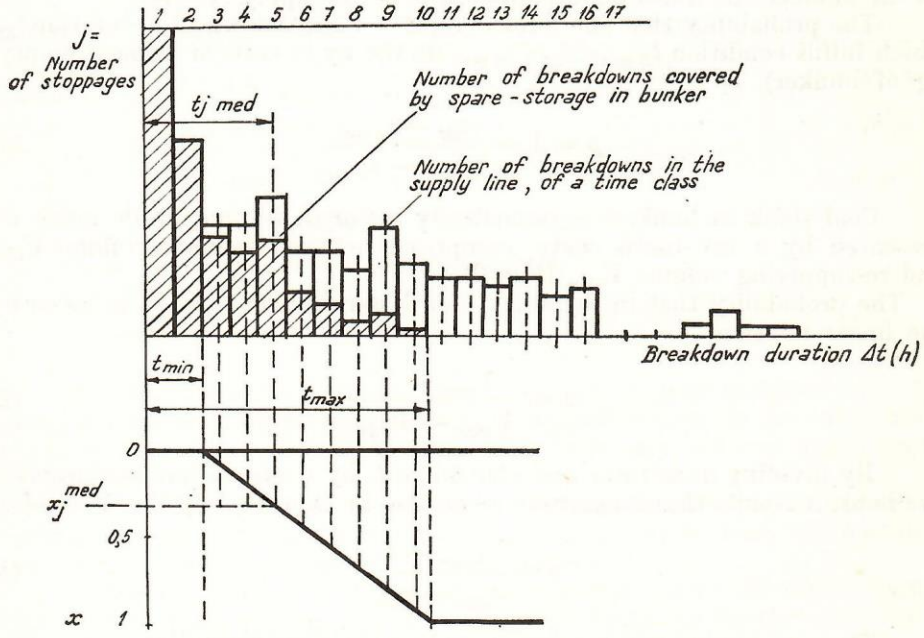


Fig. 3 - Distribution of stoppages according to stoppage duration (hatched surface, number of stoppages replaced by stock in bunker)

The total yearly stoppage time of the supply system, including also the effect of the invariable bunker stock (t_0^s, *year*) will be given by relation:

$$t^s_{0,\,year} = \sum_{1}^{m} x_j^{med} z_j t_j^{med} + \sum_{m}^{n} z_j t_j^{med} \tag{6}$$

where m represents the integer for which the time class fulfils condition

$$m\Delta t \leqslant t_{max}. \tag{7}$$

The graphic representation of the bunker influence upon the fuel system safety is presented in the hystogram in Fig. 3.

During the operation of the fuel plant subsystem, restoring stages alternate with success stages (Fig. 4)

For a rigorous sizing, it is necessary that statistical data be available, which are connected with the previous operation of this subsystem: the mean

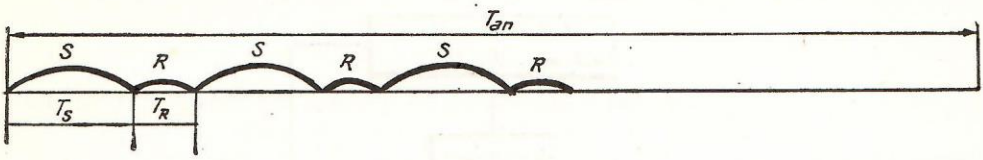


Fig. 4

number of breakdowns α, the inspection duration t_{rev_i}, the frequency of cases ν_i. The mean inspection duration is determined by means of expression:

$$t_R = \alpha \sum_i t_{rev_i} \nu_i. \tag{8}$$

The mean duration of a restoring stage is:

$$T_R = \frac{t_R}{\alpha} \tag{9}$$

For subsequent calculation, the synthetical coefficient X [4], [5] is adopted, which is defined by

$$X = \frac{T_R}{T_S} \tag{10}$$

where Ts is the mean duration of a success stage.

Following coefficients are deduced [5]:

— success coefficient

$$k_\Sigma^b = \Sigma [\Pi k_i \prod_{i \neq j} \cdot q_j], \tag{11}$$

where

$$k_i = \frac{1}{1 + X_i}, \tag{12}$$

and

$$q_j = \frac{X_j}{1 + X_j}, \tag{13}$$

— failure coefficient

$$C_\Sigma^b = 1 - k_\Sigma^b. \tag{14}$$

The correlation between coefficient X and availability coefficient d can be expressed by

$$d = \frac{T_s}{T_{year}} = \frac{T_s}{T_s + T_R} = \frac{1}{1 + X}. \tag{15}$$

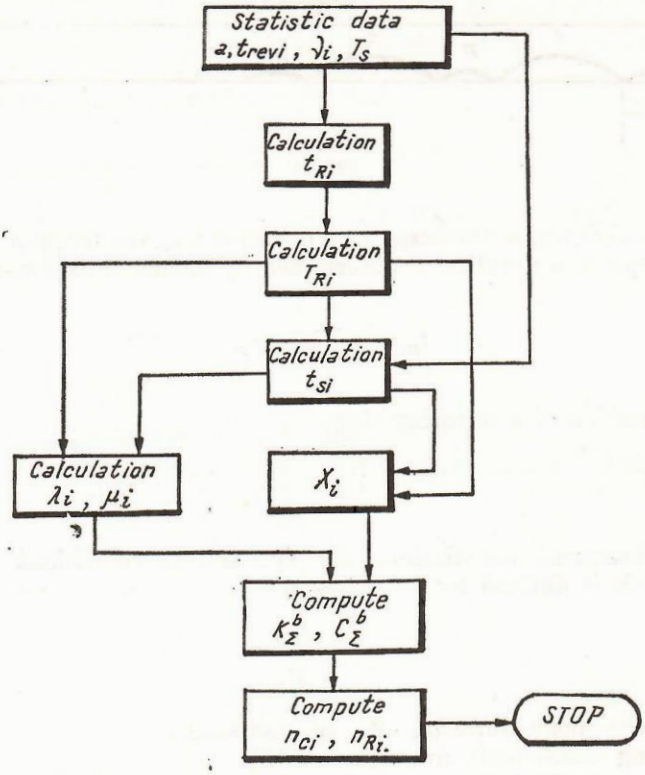


Fig. 5

The flow diagram of indices characterizing the fuel-supply system safety is presented in Fig. 5

3. OPERATING SAFETY OF THE ELECTRIC AND HEAT POWER STATION

We consider the fuel plant as being integrated within the sequence of operation of the District-heating power-station [1], as presented in Fig. 6.

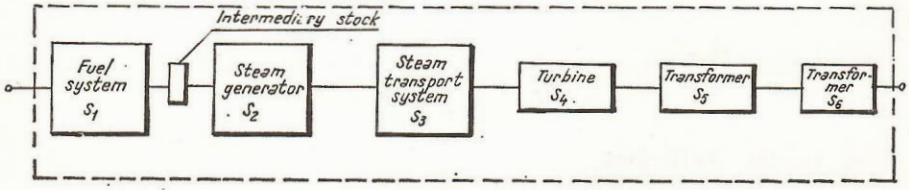


Fig. 6 Power - plant as a whole

S_1, S_2, ..., S_6 represent distinct subsystems, series connected, of the system determined by the power-station. The working hypothesis is that the component subsystems S_i do not depend one on the other, i.e. the failure of one of them does not imply the failure of another one [3].

In this case:

$$P_{(B)} = P_{B_1 \cup B_2 \cup \ldots \cup B_6} \tag{16}$$

where $P_{(B)}$ is the probability of connection interruption;

B_k — the event of getting out of action of a subsystem.

On denoting by $\bar{B}_k$ the event contrary to B_k and which expresses the operation without interruption of subsystem S_k in the observation interval T, taken as a basis, one obtains:

$$P_{(B)} = 1 - P_{(\bar{B})} \tag{17}$$

where

$$\bar{B} = \bar{B}_1 \cap \bar{B}_2 \cap \ldots \cap \bar{B}_6 \tag{18}$$

But, as $\bar{B}_k$ is independent:

$$P_{(\bar{B})} = P_{(\bar{B}_1)} \cap P_{(\bar{B}_1)} \cap \ldots \cap P_{(\bar{B}_6)} \tag{19}$$

or

$$P_{(\bar{B}_k)} = 1 - P_{(B_p)} = 1 - p_k \tag{20}$$

hence

$$P_{(B)} = 1 - \prod_{i=1}^{6} (1 - p_i). \tag{21}$$

4. ECONOMIC CRITERION OF ANALYSIS

We use, for economic computations, as a comparison criterion, an expression of the type of yearly computation costs, which takes into account investments, direct costs, and damages determined within each version, in terms of its safety.

With a view to generalizing the problem, relative magnitudes of these values are used.

One takes into consideration as follows:

a) The total investment in the final plant I^b depends on the power P_i of the station, and of the heating power of the fuel, H_i, or the maximal yearly output B_h, respectively,

$$I^b = f_1(P_i, H_i) = f_2(B_h). \tag{22}$$

For the two-fuel plant, this investment can be written:

$$I^b = f_{\mathrm{I}}(B_{h\mathrm{I}}, j) + f_{\mathrm{II}}(B_{h\mathrm{II}}, l). \tag{23}$$

This investment value for concrete application has to be computed for each case separately.

b) The value of 'total production required by consumer:

$$V_t = p_e E^{year} + p_q Q^{year} = E^{year}\left(p_e + \frac{p_q}{y_t}\right) \tag{24}$$

where p_e is the cost of the electric energy (lei/kWh)

p_q — cost of heat (lei/Gcal);

E^{year} — yearly produced energy (kWh/year);

Q^{year} — yearly delivered heat (Gcal/year);

y_t — total district-heating index (Gcal/kWh).

c) Value of damages by lack of production, imputable to the fuel system

$$V_n = (p_e^* E^{year} C_\Sigma^s + p_q^* Q^{year}) C_\Sigma^b \text{ [lei]}, \tag{25}$$

where p_e^*, p_q^*, represent the specific damage by not-delivering to consumer electric energy, and heat, respectively [lei/kWh]; [lei/Gcal].

C_Σ^s — failure probability of the supplying connection of the system;

C_Σ^b — failure probability imputable to the fuel plant.

We obtain, by successive transformations:

$$V_n = C_\Sigma^b E^{year}\left(p_e^* C_\Sigma^s + \frac{p_q^*}{y_t}\right) \text{ [lei]}. \tag{26}$$

d) The efficiency function:

Criterion Z has, in the analysed case, the expression:

$$Z = \frac{I^b}{n} + V_n + V_n' - V_b' + \Delta V_b + C_{year} \text{ [lei]}. \tag{27}$$

where: n is the normed investment efficiency ($n = 10$ years);

V_n' — the non-cashed value, due to undelivered production ($V_n' = C_\Sigma^b V_t$);

V_b' — the value of the non-consumed fuel, due to the non-operation;

ΔV_b — difference between the value of the primary fuel and the value of the auxiliary fuel, for the auxiliary fuel amount which replaces, during breakdowns, the primary fuel;

C_{year} — yearly costs, differentiated between versions.

From the differentiated yearly costs we retain only the depreciation costs, and those for maintenance and repairs, all percentually assigned to investment. I^b. The other costs (fuel, staff, overhead and auxiliary) are considered as not differing in the versions taken for analysis, hence they do not occur within the calculation.

We admit 7% depreciation and 2% maintenance and repair costs:

$$C_{year} = 0.09\, I\,.$$

Note: Value ΔV_b has an economic sense in the calculation, in case the auxiliary fuel cost p^b_{II} is higher than the primary fuel's one, p^b_I. If the auxiliary fuel has a more reduced price than the primary one, but in the general balance sheet the fuel quotas are fixed and fuel I is the marginal one, $\Delta V_b = 0$, since fuel II must be considered as having marginal fuel's price.

The expression of the efficiency function is:

$$z = 0.19\, I^b + C^b_\Sigma E^{year}\left[(p^*_e + p_e)\, C^s_\Sigma + \frac{p^*_q + p_q}{y_t}\right] - \\ - C^b_\Sigma Q^{year}_{tot}\frac{P_{b\,med}}{7000} + 10^{-3} Q^{year}_{tot}(K^b_\Sigma - K^b_{\Sigma I})\frac{p^b_{II} - p^b_I}{7\,000} \tag{28}$$

where $K^b_{\Sigma I}$ is the success coefficient of the main fuel plant.

$$Q^{year}_{tot} = \frac{860\, E^{year}}{\eta_{tot}} + \frac{Q_t\, 10^6}{\eta_c} = E^{year}\left(\frac{860}{\eta_t} + \frac{10^6}{y_t \eta_c}\right) \tag{29}$$

where η_{tot} is the net total efficiency of the electric and heat power station for electric energy production,

η_c — boiler efficiency.

For the sake of simplicity, since damages value is much higher than the selling price $p^*_e \gg p_e$ and $p^*_q \gg p_q$, we disregard p_e and p_q. We approximate that $p_{b\,med} = p^b_I$, as the main fuel has a higher quota than the secondary one.

Finally, it results:

$$z = 0.19\, I^b + C^b_\Sigma E^{year}\left[p^*_e C^s_\Sigma + \frac{p^*_q}{y_t}\right] + \\ + \frac{E^{year}}{7 \times 10^6}\left(\frac{860}{\eta_t} + \frac{10^6}{y_t \eta_c}\right) \times [(k^b_\Sigma - k^b_{\Sigma I})(p^b_{II} - p^b_I) - C^b_\Sigma p^b_I]. \tag{30}$$

The logical diagram, for the general case is shown in Fig. 7.

5. APPLICATION

The calculation has been applied to a electric and heat power station with two turbo-generator units, with the unit power $P_i = 50$[MW], with three boilers of 400 [t/h], with a heat output $Q_T = 1{,}1 \times 10^6$ [Goal/year], and an electric energy production corresponding to the utilization of 6000 h/year. The power-stations uses coal as main fuel, and naphtha as auxiliary fuel. Boiler's efficiency is $\eta_c = 0.90$.

Considering in the present-day conjuncture in the S.R. of Romania, that coal is the marginal fuel, we shall use as unique fuel price $p^b_I = p^b_{II} = 400$ [lei/t]. The failure index of connection to the system was selected with the covering value $C^s_\Sigma = 2 \cdot 10^{-4}$.

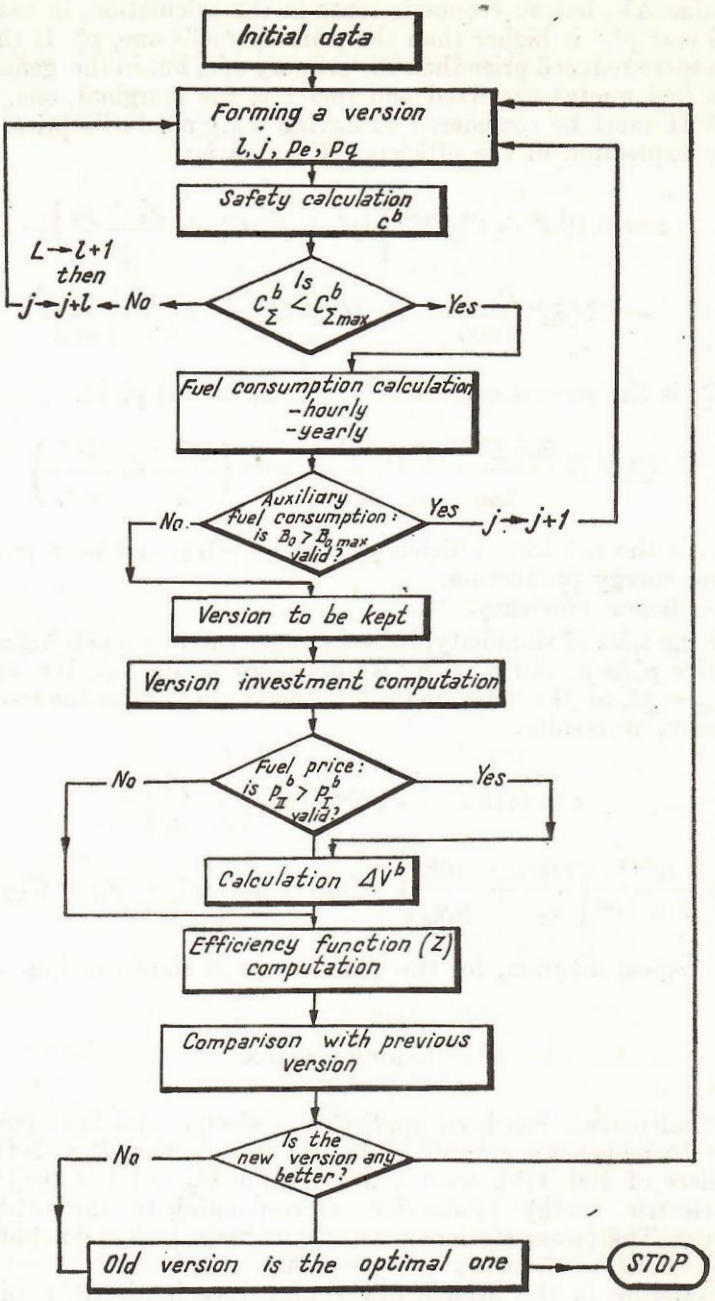

Initial data
Forming a version
l, j, pe, pq
Safety calculation
c^b
L→l+1
then
j→j+1
No
Is
C^b_Σ < C^b_Σmax
Yes
Fuel consumption calculation
-hourly
-yearly
Auxiliary
fuel consumption:
is B_0 > B_0 max
valid?
Yes
j→j+1
No
Version to be kept
Version investment computation
Fuel price:
is p^b_I > P^b_I
valid?
No
Yes
Calculation ΔV^b
Efficiency function (Z)
computation
Comparison with previous
version
Is the
new version any
better?
No
Old version is the optimal one
STOP

Fig. 7

Basic data of application are presented in table 2.

Table 2

Magnitude	Unit of measure	Value
Heat-supplying turbine PT-50	MW	50
Rated boiler output	t/h	400
Steam parameters of boiler — steam pressure — steam temperature	 atm °C	 140 570
Specific heat consumption — for the back-pressure side — for the condensation tail — mean yearly value	 kcal/kWh	 1020 2480 1750
Fuel caloric power — main fuel (coal) — auxiliary fuel (naphtha)	 kcal/kWh	 1800 9125
Power-station's total fuel consumption — main fuel (coal) — auxiliary fuel (naphtha)	 t/h t/h	 500 100

We used, for investment evaluation, correlations from fuel plant designs worked out by I.S.P.E. during the period 1967—1970.

The total investment I_t is deduced from the mechanical plant investment I_m, through the proportionality relation:

$$I_t = mI_m. \tag{31}$$

Coefficient m has the values in table 3.

The relationship between fuel-economy mechanical plants and the hourly transport capacity B_h is given, with a sufficient accuracy, by expression

$$\frac{I_{mI}}{I_{mII}} \parallel \left(\frac{B_{hI}}{B_{hII}}\right)^i. \tag{32}$$

Index i takes values:
$i = 0.4$ in coal plants;
$i = 1$ in liquid fuel plants.

With these elements, the investments assignable to the various versions of the electric and heat power station in this application are given in table 4.

Table 3

Fuel type	Line number	m
Coal	$j = 1$	1.5
Liquid fuel	$j = 2$	1.25
Liquid fuel	$l = 1$	1.4

Table 4

Fuel type	Line number	Output per hour		Total investment mill. lei
		t/h	%	
Coal	$j = 1$	500	1 × 100	6.4
	$j = 2$	500	2 × 100	10.65
	$j = 2$	250	2 × 50	8.5
Liquid fuel	$l = 1$	100	1 × 100	2.1
	$l = 2$	100	2 × 100	3.9
	$l = 3$	100	3 × 100	4.75

The success and unsuccess (failure) coefficients are determined by means of relations (11) and (12), and their values are given in table 5.

Table 5

Version	Magnitudes				Values of success and failure coefficients			
	j	j^*	l	l^*	C_Σ^b	K_Σ^b	C_Σ^b	K_Σ^b
					$d_1 = 0.92,\ 0.95$		$d_2 = 0.80,\ 0.90$	
I	2×100%	1×100%	2×100%	1×100%	0.000394	0.999706	0.000016	0.999984
II	2×100%	1×100%	1×100%	1×100%	0.00498	0.99511	0.000323	0.999677
III	1×100%	1×100%	2×100%	1×100%	0.00196	0.99904	0.0002	0.9998
IV	1×100%	1×100%	1×100%	1×100%	0.01985	0.98105	0.00362	0.99638
V	2×50%	2×50%	1×100%	1×100%	0.0357	0.9643	0.00773	0.99227
VI	1×100%	1×100%	3×100%	1×100%	0.000196	0.999904	0.000009	0.999991

For the case analysis we consider following values of maximal and minimal availabilities (synthetised in table 6).

Table 6

Availability (d) in the version	Supply system with a coal line and bunker	Liquid fuel line
maximal	0.92	0.95
minimal	0.80	0.90

The results of computing Z are presented in table 7.

With a view to establishing the optimal version to make the sizing decision, we use Savage's criterion in the strategic-game theory [6], since all versions are equally possible to be achieved in practice.

The decision matrix [M] is as follows:

million lei

[M] =

Version \ Nature's stages	Z_{11}	Z_{12}	Z_{13}	Z_{22}	Z_{22}	Z_{23}
I	3.15	4.0583	4.7	2.7755	2.8115	2.8385
II	7.18	18.25	26.5	2.7042	3.4592	4.1008
III	3.85	8.252	11.639	2.1546	2.6046	2.9386
IV	20.81	65.515	100.5	5.125	13.245	19.395
V	36.8	117.39	177.37	9.54	27	28.92
VI	2.36	3.07	3.16	2.48	2.5	2.51603

Each element a_{ij} in the matrix $[M] = [a_{ij}$ actually represents costs; as such, terms b_{ij} of regrets matrix will be formed according to the following equation:

$$b_{ij} = a_{ij} - \min_k [a_{kj}]. \tag{33}$$

We apply, for decision making, to the regrets matrix the *min-max* criterion, and obtain results in matrix $[MC]$ underneath:

It results, from this analysis, that the version VI is the optimal one:

$j = 1 \times 100\%$ $\quad$ $j^* = 1 \times 100\%$

$l = 3 \times 100\%$ $\quad$ $l^* = 1 \times 100\%$

— million lei —

Table 7

	Costs Z	Damages' value	Versions					
			I	II	III	IV	V	VI
Z_1 $d_1=0.992,0.95$	$p_e^* = 50\ p_e$ $p_q^* = 1\ 000 \frac{\text{lei}}{\text{Gcal}}$	Z_{11} $\ln Z_{11}$	3.15 0.498	7.81 0.855	3.85 0.584	20.81 1.217	3.68 1.565	2.36 0.42325
	$p_e^* = 50\ p_e$ $p_q^* = 3\ 000 \frac{\text{lei}}{\text{Gcal}}$	Z_{12} $\ln Z_{12}$	4.0583 0.60831	18.25 1.26126	8.252 0.91656	65.515 1.816326	117.39 2.06987	3.07 0.49136
	$p_e^* = 80\ p_e$ $p_q^* = 4\ 500 \frac{\text{lei}}{\text{Gcal}}$	Z_{13} $\ln Z_{13}$	4.7 0.67210	26.5 1.423425	11.693 1.06781	100.5 2.00217	177.37 2.24895	3.16 0.84407
Z_2 $d_2 = 0.80,\ 0.90$	$p_q^* = 50\ p_e$ $p_q^* = 1\ 000 \frac{\text{lei}}{\text{Gcal}}$	Z_{21} $\ln Z_{21}$	2.7755 0.44330	2.7042 0.43208	2.1546 0.33330	5.125 0.70969	9.54 0.97955	2.48 0.39445
	$p_e^* = 50\ p_e$ $p_q^* = 3\ 000 \frac{\text{lei}}{\text{Gcal}}$	Z_{22} $\ln Z_{22}$	2.8115 0.44894	3.4592 0.53900	2.6046 0.41570	13.245 1.12200	27 1.43136	2.5 0.39794
	$p_e^* = 80\ p_e$ $p_q^* = 4\ 500 \frac{\text{lei}}{\text{Gcal}}$	Z_{23} $\ln Z_{23}$	2.8385 0.45301	4.1008 0.61285	2.9386 0.46810	19.395 1.28770	28.92 1.46120	2.51603 0.4000

— million lei —

$[M'] =$

Versions \ Nature's stage	Z_{11}	Z_{12}	Z_{13}	Z_{21}	Z_{22}	Z_{33}
I	0.79	0.9883	1.54	0.2955	0.3115	0.3225
II	4.82	15.18	23.34	0.2242	0.9592	1.5848
III	1.49	5.182	8.533	0	0.1046	0.4226
IV	18.45	62.415	97.34	2.645	10.745	16.879
V	34.44	114.32	174.32	7.06	24.5	26.404
VI	0	0	0	0.3254	0	0

Small availability Big availability

max
154
min max 23.34
8.533
⇒ 97.34
174.21
0.3254 *min* ←

Conclusions

The conclusions are as follows:

a) The looked-for optimum for sizing the fuel plant is valid only when there are not restrictions concerning the consumed fuel amount. The ratio between the liquid fuel amount and that of solid fuel, due to the operation unsafety of the fuel plant system, is given by relation:

$$\alpha = k \frac{C^c_{\Sigma} - C_{\Sigma}}{1 - C^c_{\Sigma}} 100[\%] \tag{34}$$

where k is the ratio between the hourly consumed naphtha and coal rates

$$\left(\frac{B_{hp}}{B_{hc}}\right);$$

C^c_{Σ} — failure coefficient of the coal transport plant,
C_{Σ} — failure coefficient of the fuel plant system

The value of α for the various versions of the investigated case results from table 8.

Table 8

Magnitude		Versions					
		I	II	III	IV	V	VI
		$j = 2 \times 100\%$ $j^* = 1 \times 100\%$ $l = 2 \times 100\%$ $l^* = 1 \times 100\%$	$j = 2 \times 100\%$ $j^* = 1 \times 100\%$ $l = 1 \times 100\%$ $l^* = 1 \times 100\%$	$j = 1 \times 100\%$ $j^* = 1 \times 100\%$ $l = 2 \times 100\%$ $l^* = 1 \times 100\%$	$j = 1 \times 100\%$ $j^* = 1 \times 100\%$ $l = 1 \times 100\%$ $l^* = 1 = 100\%$	$j = 2 \times 50\%$ $j^* = 2 \times 50\%$ $l = 1 \times 100\%$ $l^* = 1 \times 100\%$	$j = 1 \times 100\%$ $j^* = 1 \times 100\%$ $l = 3 \times 100\%$ $l^* = 1 \times 100\%$
k		0.2	0.2	0.2	0.2	0.2	0.2
C_Σ	d_1	0.000016	0.000323	0.0002	0.00362	0.00773	0.00000935
	d_2	0.000394	0.00489	0.00196	0.01985	0.0357	0.00196
C_Σ^c	d_1	0.0064	0.0064	0.08	0.08	0.0064	0.08
	d_2	0.04	0.04	0.20	0.20	0.04	0.20
$\alpha\%$	d_1	0.256	0.256	1.74	1.74	0.256	1.74
	d_2	0.83	0.83	5	5	0.83	5

b) It does not seem convenient to independently make the sizing of the two fuel plant types, primary and auxiliary ones, by using the criterion in the regulations in force; it is rather necessary to consider them as being associated, within a combined supply system.

c) When accepting the most optimistic and pessimistic hypotheses (maxima and minima), and an arbitrary structure, theoretically deduced, on taking into account the nature of plants, we arrived at the conclusion that the yearly computed costs converge to the same optimum, independently of the hypothesis made.

The optimal pointed out version makes provision for limiting the solid fuel supply to a transport line (without any spare line) and the carrying out of the auxiliary fuel line with two spare lines.

d) When the power-station operates in a more reduced number of hours the equipping level of the spare plant can be also more limited.

e) It results, from the effected calculations, that the damage level does not modify the spare; there appear, as main component, damages due to not-delivery of heat.

f) The stock in bunker has a great influence upon the supply layout, as concerns the safety.

The carried out computations have a sense only for the hypothesis that the marginal fuel price is greater than or equal with the main fuel (coal) price.

This calculation methodology can be developed, in case a certain investment is assigned to the bunker's volume, and the relationship between transport capacity and the necessary investment for the relevant plant is known.

Thus it seems also possible to define, besides the optimal diagram, the following parameters: maximal bunker stocking time; ratio between conveyer transport capacity and the maximal consumption of boiler unit.

REFERENCES

1. MOȚOIU C., GHEORGHE A.: *Analiza dimensionării sistemului de alimentare cu combustibil la o centrală de termoficare, legat de siguranța cerută de consumatori și de prezența combustibilului auxiliar* (Analysis of sizing the fuel supply system in a heating station, in connection with the reliability required by consumers and the presence of an auxiliary fuel). Energetica, nr. 4, 1971.
2. MOȚOIU C., GHEORGHE A.: *Schemele de alimentare cu combustibil la o C.E.T. și echivalarea lor din punct de vedere al siguranței* (Fuel supply diagrams in a District-heating power-station and their equalization from the safety viewpoint). Energetica, nr. 71, 1971.
3. SPĂTARU AL.: *Teoria transmisiunii informației* (Information transmission theory). Editura tehnică, Bucharest, 1966.
4. BUHUȘ P.: *Siguranța sistemelor tehnice complexe cu aplicații la sisteme electroenergetice* (Safety of complex technical systems with applications to electroenergetical systems) Doctor's thesis, 1967.
5. DINCULESCU C., BUHUȘ P.: *O metodă pentru studiul siguranței în funcționarea sistemelor tehnice* (A method for studying technical systems operation safety). Buletinul Institutului Politehnic „Gheorghe Gheorghiu-Dej", Bucharest, tome 32, nr. 1, 1970.
6. ROȘU AL.: *Teoria jocurilor strategice* (Theory of strategic games), Editura militară, 1967.

CRITERES ECONOMIQUES POUR LA DETERMINATION OPTIMALE DES DIMENSIONS DES INSTALLATIONS D'ALIMENTATION EN COMBUSTIBLE DE LA CENTRALE ELECTRIQUE A THERMOFICATION (CET)

On analyse la corrélation entre la perturbation chez le consommateur, la sûreté de l'ensemble des installations CET et la sûreté de l'installation pour combustible, prises séparément, et on calcule la valeur des pertes, fonction de la non-livraison du combustible aux chaudières.

On étudie comparativement les dimensions de l'installation pour combustible, compte tenu de la présence de deux combustibles, de la limitation de l'appel à l'une des sources, du risque de l'interruption de la livraison des deux combustibles et de la sûreté des installations.

La décision finale est adoptée à la suite de l'application du critère de Savage, de la théorie des jeux, de la recherche opérationnelle.

Au défaut de valeurs statistiques certaines pour la sûreté des éléments on prend des valeurs informatives.

ЭКОНОМИЧЕСКИЕ КРИТЕРИИ УСТАНОВЛЕНИЯ ОПТИМАЛЬНОЙ ВЕЛИЧИНЫ УСТАНОВОК ПИТАНИЯ ТОПЛИВОМ НА ТЕПЛОФИКАЦИОННОЙ ЭЛЕКТРОСТАНЦИИ

Рассматривается соотношение между пертурбациями у потребителей, надежностью совокупности установок ТЭЦ и надежностью отдельно взятой топливной установки и рассчитывается стоимость потерь вследствие непоставки топлива котлам.

Проводится сравнительный анализ установления величины топливной установки с учетом наличия двух видов топлива, ограничения использования одного из источников, риска прекращения поставки обоих видов топлива и надежности установок.

Окончательное решение при установлении величины принимается в результате применения критерия Саважа из теории игр путем операционного исследования.

В случае отсутствия достоверных статистических величин для надежности элементов берутся информационные величины.