CONTRIBUTIONS AS FOR THE OPTIMIZATION OF THE PUMPING STATIONS UNDER PRESSURE

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The paper follows the analyze of the connections between the constructive, working parameters, the annual energy consumptions and the energy quantity included in fitting out; it is formulated a methodology of establishment of the optimum values of the parameters of admeasurements of the pumping stations for the setting under pressure, of pipes networks, what ensure an optimum consumption of energy during of duty of the fitting out (the operational energy and the included energy in the networks, equipment and constructions), of the conditions after that it can be obtained.

Keywords: Pumping station, pipe network, economic efficiency, optimization, optimum piezometer slope

1. Introduction

The optimum irrigation plots through pipes under pressure can be defined theoretic for any area and in any climatically conditions. The technique of irrigation limits this theoretical possibility. The technical principal restriction is the maximum diameter’s value that can be used on antennas, respective principled pipes. These considerations reduce the area that can be covered by a optimum plot $S_{max} = f(q, q_d, T_o)$. The all specific consumption of energy generated by the

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network, while optimum at the plot level, have values breeder with $S$ and $n$. It is prefer the variants of optimum plot with $S$ and $n$ lesser.

It is necessary an optimization of ensemble at the level of the big irrigation systems, arises from the analysis of more variants organised through the combination of the infrastructures with network’s densities different, with the optimum plots. The optimum solution of ensemble corresponds with the variant that have the total specific consumption of energy minimum on ensemble.

The optimization of the technique of wetting visa the choice of the best technology of administration of the wettings what, respecting the restrictions imposed by the necessity of the medium’s protection, ensure a social level of work acceptable for the personnel of execution in the conditions of the minimization of the specific consumption total average annual of energy CSTMAE associated to the achievement of the respective function of water’s distribution at plot’s level.

2. Nomenclature

Latin symbols:

- $a$: Relative spore of debit pumped in gap hours
- $APSP$: Average overall quota in pumping station
- $ANP$: Average overall quota in pipe
- $C$: Annual average specific consumption of energy generated by the water’s transport in plot’s network
- $d$: Pipe’s rated diameter
- $ER$: Unitary energy involved in the fixed network
- $EWI$: Unitary energy involved in pipes
- $g$: Gravitational acceleration
- $H$: Load
- $Hg$: Static pressure load
- $Ht$: Head loss in discharge pipes
- $IWIo$: Investment in pipes installations
- $Jo$: Hydraulic slope
- $Jo^*$: Optimum average piezometer slope
- $k$: Knot’s number
- $Kj$: Hydraulic slope parameter
- $kS$: number of served networks by the pumping station under pressure
- $LCP$: Principled pipe’s length
- $LCS$: Secondary pipe’s length
- $LH$: section’s length of admeasurements
- $lWI$: wetting installations’ length
- $Mc$: Deficit of calculation with a frequency commensurate to the fitting out’s
3. Problem definition

It is calculate the following parameters for the determination of the structure and of the functional, energetic and economic specific features of the optimum plot:
1. for the determination of the geometry in plane of the optimum plot:
   - the length wetted of secondary pipe (antenna) $L_{cs}$; the length wetted of principled pipes $L_{cp}$ (number of secondary pipe):
     \[ L_{CP} = n.L. \]  \hfill (1)
   - The really length of the principled pipes $L_{cpref}$; the factor of shape of the sector wetted of antenna $l$:
     \[ l = \frac{L}{L_{CS}}. \]  \hfill (2)
   - The factor of shape of the plot $f$; the unitary length of the secondary pipes $L_{cs1}$; the unitary length of the principled pipes $L_{cp1}$; the section’s length of admeasurements $L_H$:
     \[ L_H = L_{CPef} + L_{CS} = \frac{(n-1)l+1}{l}. \]  \hfill (3)
2. For the determination of the functional and power specific features of the plot with the optimum geometry by the $s$ area it is established the following parameters:
a. the debit of admeasurements of the ensemble pumping station under pressure – network is a multiple of the modulus debit \( Q_i \) and depend on the size of the area served \( S \) and the specific debit of admeasurements \( q_d \), the debit of section \( j \) of the antenna \( j = 1, 2, \ldots, n_t \), the debit of the \( k \) section of principled pipes, \( k = 1, 2, \ldots, n/2 \), \((k_S - \text{number of served networks by the pumping station under pressure, } k_S = \{1, 2\})\), figure 1):

\[
S_o = \frac{L^2}{5000.1}; \quad S = \frac{k_S.n.L^2}{5000.1}.
\] (4)

Fig.1. The scheme of the irrigation system under pressure with networks:

a) \( k = 1 \); b) \( k = 2 \).

In the irrigation season, the ensemble PSP – network – installations of wetting distributes a water volume \( W \) covering a water deficit \( M \leq M_c \) on the section of area \( S \) and the water wastage with output of water’s usage \( \eta_u \):

\[
W = \frac{10.M.S}{\eta_u}.
\] (5)

\( M_c \) (mm) represents the deficit of calculation with a frequency commensurate to the fitting out’s category of importance; it value can be established through to take into account the relations water – production and water – energy, determined in the conditions of the system. This service is ensured through the management, on each position of waiting of wetting installations, of a number humectation \( n_u \) with an average doze \( m_o \) (mm):

\[
m_o \leq 10.\gamma_v.H_d.(W_c-W_m); \quad M = n_u.m_o.
\] (6)

Depending on the distance between the positions of waiting of the wetting installations \( l_{WI} \) it is wet at a waiting a section of area \( s_{io} \) and it has to effectuate a number \( n_m \) of moves:

\[
s_{io} = Ll_{WI}; \quad n_m = \frac{n_u.10^4.S}{Ll_{WI}}.
\] (7)
Contributions concerning the optimization of the pumping stations under pressure

It is calculated the specific debit of admeasurements of the ISP’s elements \( q_d \) (l/s.ha) adequate to the deficit of calculus from top month of the irrigation season \( m_v \) that has to cover through the operating of the irrigation system under pressure ISP in \( t_z \) (days), time by \( t_h \) (hours/day) with an gross output of the water’s usage \( \eta_u \):

\[
q_d = \frac{2.78. m_v}{\eta_u t_z t_h}.
\]  

b. Optimum average piezometer slope \( \text{PPMO} \) \( J_o * \) proper of the debit’s transport of admeasurements section by optimum diameter.

c. Average piezometer slope \( \text{PPM} \) \( J_o \) of admeasurements of the antennas from the nodes \( k \neq 0 \).

d. The load necessary at pumping station PS for the water’s transport in network will be established by the section’s length of admeasurements \( L_h \) and \( J_o * \).

e. The power fitted in the pumping station for the water’s transport in the network it is established of the debit of admeasurements of plot and by the load necessary for the water’s transport in network. Also it is important the reservation of power necessary in the working of the aggregates of pumping \( k_M \) and the average output of the water’s pumping \( \eta_p \).

f. The average power absorbed by the PS for the water’s transport in the network on the period of existence of the irrigation system.

3. For the determination specific consumption of energy generated by the water’s transport through network of the irrigation plots it calculate the following parameters:

- the unitary energy involved in the fixed network:

\[
E_R = \frac{5000}{n.L} \left\{ \left[ L(n-1) + n - 2 \right] J_o + \left[ (n-1) L \phi(n) + n \psi(n) \right] \right\} \frac{K^\alpha/\beta}{J_o^\alpha/\beta} \left( \eta_l Q_{IU} \right);
\]

\[
\phi(n) = \frac{\sum_{i=0}^{n-1} (2i)^{\alpha/\beta} + n^{\alpha/\beta}}{n-1} ; \quad \psi(n) = \frac{\sum_{i=0}^{n-1} \left( 1 + 2i \right)^{\alpha/\beta} \sum_{j=1}^{n} \left( j/n \right)^{\alpha/\beta}}{n.n_l}.
\]

- The unitary energy involved in the PS for the water’s transport in network:

\[
E_{PS} = \frac{5000 L \eta_{PS_o}}{k_S n.L^2} + \frac{K_i K_N}{\eta_p} q_d \left( H_g + H_H + H_t \right).
\]

- It is established the unitary energy involved in pipes (wetting installations):
- Annual average specific consumption of energy generated by the water’s transport in plot’s network:

\[
C = \frac{K_N \cdot q_d \cdot T_o}{k \cdot \eta_p} \left( \frac{\bar{q}}{q_d} \right)^2 + \frac{\bar{q}}{q_d}.
\] (12)

- Annual average specific consumption of energy generated by the service and the exploitation of the transport system under pressure of the water, \((k_{re} - coefficient wages)\):

\[
C_f = C_{IPS} + C_{NP} + C_{WI} + k_{re} \cdot C_p ;
\]

\[
C_{ij} = a_j \cdot E_j ; \ j \in \{PS, NP, WI\} .
\] (13)

- It is established the annual average specific consumption of energy for the WI’s move:

\[
C_m = \frac{M_o \cdot r_m \cdot 10^4}{m_o \cdot J_{WI} \cdot L}.
\] (14)

- CSTMAE generated by the water’s transport in the irrigation plot with the pipes under pressure, [4]:

\[
C = \frac{5000}{n \cdot L} \left( \frac{a_p \cdot E_{PS} \cdot P_{SP_0}}{k_s \cdot L} + a_{NP} \cdot T_o \cdot \left( (n-1)l + n - 2 \right) \right) + a_{WT} \cdot \frac{q_d}{Q_{WI}}.
\]

\[
(E_{WIo} + J_{WT} \cdot L) + \frac{M_o \cdot r_m \cdot 10^4}{m_o \cdot J_{WT} \cdot L} + \frac{Y_{1} \cdot q_d \cdot K_{N} \cdot K_{I} \cdot a_{PS} \cdot P_{SP}}{\eta_p}.
\]

\[
H_g + H_o + h_{r, WI} + \left( (n-1)l + 1 \right) L J_o +
\]

\[
5000 \cdot a \cdot a_{NP} \cdot \left( (n-1)l \cdot \varphi(n) + n \cdot \psi(n) \right) K_{J} \left( n \cdot J_{WI} \right) \frac{a \cdot \alpha}{\beta}.
\]

\[
\frac{a}{n \cdot L \cdot J_o \cdot \beta}
\]

The optimisation problem OP matters in the minimization of the CSTMAE demanded by irrigation through pipes under pressure of the relation climate ground – plant. It must be respected the restrictions of functional order and it were adopted the standardized dimensions.

It must be found size’s values \(J_o, l, L\) what, depending on the equipment’s category of wetting used \((Q_{WI}, H_o, d_o, K_p)\) lead at the minimum of CSTMAE, equation (15):
\[ \min C = \min C (J_o, l, L, Q_{WI}, H_o); Q_{WI} = \frac{K_{WI}.K_Q.d_o^\beta \cdot L'}{K_p^2}; \]

\[ H_o = \frac{d_o}{K_p}; \quad h_{WI} = \frac{k_{hr}.d_o^\beta \cdot L''}{K_p}. \]

From the condition of the minimum CSTMAE generated by the wetting’s realization is established the structure of the wetting installations used and the charge necessary at hydrant.

The piezometer slope is expressed depending on depending on the length \( l \) and the specific debit of admeasurements, \([4]\):

\[ J_o = \left[ \frac{l.(n-1).\phi(n) + n.\psi(n)}{n.(n-1).J+1} \right]^{\frac{\beta}{\alpha+\beta}} \cdot \frac{\alpha}{K^a_J} \cdot \frac{\beta}{K^{a+\beta}_J} \cdot \frac{\beta}{K^{\alpha+\beta}_N} \cdot \frac{\beta}{a \cdot a_{NP} \cdot \alpha} \]

\[ \cdot \left( \frac{5000.J}{L^2.d_d} \right)^{\frac{\beta-\alpha \gamma}{\alpha+\beta}} \cdot \left( \frac{\gamma}{\eta_p} \right)^{\frac{\beta}{\alpha+\beta}}. \]

The reduction of PPM \( J_o \) has like effect a decrease of the operational consumption of energy for pumping and an enlargement of the energy included in the network. The admeasurements of the SPP – network ensemble is effected for an optimum average piezometer slope \( PPM_0 \), established from the minimum’s condition of the CSTMAE established of water’s transport in the plot’s network analysed.

### 4. The experimental results

The constants for the calculation of the CSTMAE are the following values: \( a_{PSP} = 0.105; \ a_{NP} = 0.075; \ a_{WI} = 0.175; \ k_{re} = 0.06; \ k_m = 1.05; \ k_S = 1; \ n = 4; \)
\( \eta_{PS} = 0.65 \%; \ a = 1140; \ \alpha = 1.53; \ K_J = 1100; \ K_N = 0.0103; \ i_o = 70; \) if \( Q \) is express in l/s \( K_J = 1.89.10^{-9} \); if \( Q \) is express in m\(^3\)/s \( K_J = 1.56.10^{-3} \); \( \beta = 5.08; \ \gamma = 1.97; \ m_o = 60 \text{ mm}; \ t_e = 30 \text{ days}; \ t_h = 20 \text{ hours}, \) (figure 2 for \( H = 40 \text{ m} \) and figure 3 for \( H = 75 \text{ m} \)).

Depending on the type of irrigation it is used the following values:
Fig. 2. The energy involved in PSP depending on the power fitted for load $H = 40$ m.

Fig. 3. The energy involved in PSP depending on the power fitted for load $H = 75$ m.

- In the case of aspersion installations: $l_{WI} = 18$ m; $k_i = 2; H_g = 4$ m; $r_m = 23$ for moves mechanized of wetting installations and $r_m = 52$ for hand moves; $i_{WI} = 68,4$ for moves mechanized of wetting installations and $i_{WI} = 73,1$ for hand moves; $E_{WIo} = 4200$.

- In the case of EUBA installations: $l_{WI} = 144$ m; $k_i = 1; H_g = 7$ m; $r_m = 275; i_{WI} = 106; E_{WIo} = 1712$.

The wetting installations are the constants:
- In the case of aspersion installations: $k_Q = 2.43.10^{-4}; \beta_Q = 2.52; \gamma_Q = 0.95; k_{hr} = 5.06.10^{-11}; \beta_H = 5.07; \gamma_H = 2.49$.
- In the case of EUBA installations: $k_{hr} = 4.22.10^{-5}; \beta_H = 1.84$.

Proper to the mathematical model it is worked out the logical scheme of an automat calculus programme, which will be used at the elaboration of many calculus programmes.
The optimization model it is applied at the optimum admeasurements of rectangular studs for irrigation through aspersion, respective for the irrigation – in the same conditions of water need – through EUBA installations, analysing the influence to the restrictions considered acceptable concerning of the technical features and of the specific consumption energy. The optimum values established through the method of optimization for the irrigation through aspersion and through EUBA installations in different conditions are presented in table 1.

5. Conclusions

It is strong interactions between the hydro technical systems, surrounding environment and the social – economic conditions; it exist relative indicators in the structure of the consumption energy that defer to the mode how the surrounding environment it is affected by the hidrotechnics fitting out. The operational consumption of energy for working grows up from minimum values in the case of the gravitation solutions, unto maximum values adequate to the installation with pumping.

The operational consumption of energy for service and guidance of the fittings up’s exploitation represents annual a fraction from the energy involved but, on the standardised duration of existence of the workings it has same order of the size with it.

CSTMAE has relative values elevated in the case of the systems of gravitation irrigation (because of the involved energy’s peculiarities that prevail in the structure and present a minimum, proper to the mixed solution with a special index of pumping). For to ensure the fitting out’s profitableness, the system ought to present a period of existence least equal with the necessary to the recovery of the resources anticipated consumed.

The intensive application of the irrigation matters economic through the following indicators: the time of system’s reply, the stability on operating and reability.

<table>
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<th>Parameters assessed</th>
<th>Values</th>
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<tr>
<td>$m_v$ (mm)</td>
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<tr>
<td>$\eta_u$ (%) Aspersion installations</td>
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<td>$\eta_u$ (%)EUBA installations</td>
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<table>
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<th>$T_o$ (hours)</th>
<th>$q_e$ (l/s.ha)</th>
<th>$d_p$ (mm)</th>
<th>$K_p$ (mm/m)</th>
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Table 1.
The efficient working of irrigation systems establishes a strong growth economic through the increase of the productivity at hectare of the irrigated crops.

The hydro technical fittings out for irrigation ought to present a great adaptability at technological changes that facilitate the productivity’s maintenance and of the unitary consumptions in the contiguously to the values ensured by the best technologies. The results of researches serve at the optimum designing of point of view energetic of the fittings out for irrigations in the zones with plan relief and in steep, the methods proposed allow a reduction with 20 ÷ 25 % of the consumption of energy generated by the irrigation through aspersion.

**REFERENCES**


