ГІДРАВЛІКА ТА ГІДРОТЕХНІКА

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THE INFLUENCE OF TURBINE SHUTDOWN STATE IN A HYDROPOWER STATION ON THE INITIALS VALUES OF WATER HAMMER WITH THE METHOD OF CHARACTERISTIC

The studies of changes in values hammer, compared to its initial values, are a real problem for researchers hydraulics, due to complex and multi parameters that come into play, in this work we will put the fingers on a specific phenomenon operation of hydropower stations, reflecting the case of a simultaneous stopping of a turbine (valve) or other turbines are shut down for technical reasons or exploitation slump to meet a minimum requirement requiring the operation of a turbine to regulate the storage of water, the consequences resulting from such operations result in changes to local pressures and flows in the system considered, to understand the problem we will analyze with the method of characteristic.
Keywords: water hammer, hydropower station, method of characteristic.

INTRODUCTION:

Generators are the main hydroelectric energy source on the network, faults can occur on the hydraulic or the generator itself, optimal operation is expected to master as soon as possible all faults related to the operating system and water hammer that can be caused extensive damage. It poses a very important for researchers, especially in branched networks. This article will discuss a case of well-defined phenomenon which is the study of variations in pressure and flow compared to baseline at the end to reach a numerical characterization of the phenomenon.

PROBLEM:

The influence of turbine shutdown state in a hydropower station on the initial values of the hammer, in a system where a single turbine in operation, this problem specific to the operation of hydropower stations, reflecting the case a simultaneous shutdown of one or more turbines for technical reasons or exploitation slump to meet a minimum requirement requiring the operation of a turbine to regulate the water storage Designed for drinking water that for irrigation, the consequences resulting from such operations result in changes to local pressures and flows in the system under consideration:

The calculation of the variation of pressure and flow is through the graphical method Bergeron.

CALCULATION HYPOTHESES:

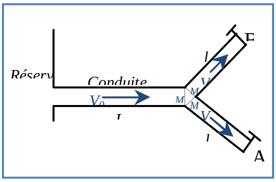


Fig. 1. Schéma 01

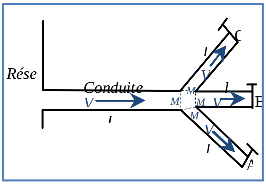


Fig. 2. Schéma 02

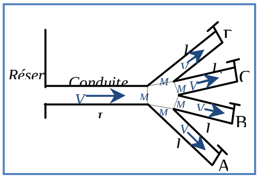


Fig. 3. Schéma 03

Assumption of the proposed system:

1. The losses are zero.
2. The lengths of secondary pipes identical.
3. Sections of the secondary lines are identical.
4. The angular coefficients of the secondary pipes are equal.
5. The length of the main pipe extremely large compared to the secondary pipes.
6. The slopes of the pipes are zero.

CALCULATION OF DATA:

Initial conditions $Q_0=5$ and $H = H_O$

$$a = \tan \alpha = (c / g.S)$$

With:

a: slope of the main duct

S: section of the main pipe;

c: the speed waveform in the main duct;

g: acceleration of gravity;

$$a_1 = a_2 = a_3 = a_4 = \alpha_1 = tg\ (c_1/g.S_1);$$

a_1, a_2, a_3 and a_4: angular coefficients of secondary lines A, B, C and D successively (in all proposed schemes).

S_1, S_2, S_3 and S_4: secondary pipes sections A, B, C and D successively (in all proposed schemes).

c_1, c_2, c_3 and c_4: wave velocities in the secondary lines A, B, C and D successively (in all proposed schemes).

DEVELOPMENT OF EQUATIONS FEATURES:

Expecting that many engineers are today, still do not know the method of characteristics as a technical solution to facilitate the discussion; we rewrite the equations of momentum and continuity as follows:

$$L_1 = \frac{\partial Q}{\partial t} + gS\frac{\partial H}{\partial x} + \frac{f}{2DS}Q\left|Q\right| = 0; \quad (1)$$

$$L_2 = c^2\frac{\partial Q}{\partial x} + gS\frac{\partial H}{\partial t} = 0. \quad (2)$$

The method of characteristics based on the successful replacement of a pair of partial differential equations, the development of the method begins by assuming that the pair of equations. (1) and (2) may be replaced by a linear combination of these two equations. Use as a constant linear scale factor, sometimes called a Lagrange multiplier. A possible combination is:

$$L = L_1 + \lambda L_1;$$

$$\left(\frac{\partial Q}{\partial t} + \lambda c^2\frac{\partial Q}{\partial x}\right) + \lambda gS\left(\frac{\partial H}{\partial t} + \frac{1}{\lambda}\frac{\partial H}{\partial x}\right) + \frac{f}{2DS}Q\left|Q\right| = 0. \quad (3)$$

If H = H (x, t) and Q = Q (x, t) are the solutions of equations (1) and (2), and the total derivatives can be written as:

$$\frac{\partial Q}{\partial t} = \frac{\partial Q}{\partial t} + \frac{\partial Q}{\partial x}\frac{\partial x}{\partial t} \quad (4)$$

and

$$\frac{\partial H}{\partial t} = \frac{\partial H}{\partial t} + \frac{\partial H}{\partial x}\frac{\partial x}{\partial t}. \quad (5)$$

Coefficient λ is defined as

$$\frac{1}{\lambda} = \frac{\partial x}{\partial t} = \lambda \quad (6)$$

Or

$$\lambda = \pm\frac{1}{c^2}. \quad (7)$$

And using equations (4) and (5), equation (3) can be written as

$$\frac{\partial Q}{\partial t} + \frac{gS}{c}\frac{dH}{dt} + \frac{f}{2DS}Q\left|Q\right| = 0 \quad (8)$$

if

$$\frac{dx}{dt} = +c \quad (9)$$

and

$$\frac{\partial Q}{\partial t} - \frac{gS}{c}\frac{dH}{dt} + \frac{f}{2DS}Q\left|Q\right| = 0. \quad (10)$$

$$\text{if} \qquad \frac{dx}{dt} = -c. \tag{11}$$

In the plane (x - t), the equations. (9) and (11) represent two straight lines having slopes These are called characteristic lines, Mathematically, these lines divide the plane (x - t) into two parts, which can be dominated by two types solution, ie, the solution may be discontinuous along these lines, they represent the path traveled by a disturbance, for example, a disturbance at point A (Fig. 1) at time t0 reach the point P after time.

Before presenting a procedure to solve the equations (8) and (10), we will first explain the physical meaning of the characteristic lines in the plane (x - t). To facilitate the discussion, we will consider a single line of (Fig. 2), compatibility equations (8) and ((10) are valid over the entire length of the pipe (ie . d, for 0 <x <l) and boundary conditions are required at the ends (ie at x = 0 and x = l) (Fig. 2) In the example considered, there is a constant-level tank to the upper end (x = 0) and a valve at the downstream end (at x = l), and the transient conditions are produced by the closing of the valve, suppose If there is a steady state at time t = 0 when the valve is closed instantaneously This reduces the flow through the valve to zero and causes a rise in pressure in the valve, due to this increased pressure, wave pressure moves in the upstream direction (towards the tank), if the path of the wave is drawn on the plane (x - t), it is represented by the line BC, as shown in (Fig. 4), it is clear from this figure that the conditions of the region I only depend on the initial conditions (steady state), as upstream boundary conditions are not changed, while in region II they depend on conditions imposed downstream (state disturbance) Thus, the characteristic BC separates the two types of solutions. Excitations if imposed simultaneously at points A and B, then the region influenced by the initial conditions as shown in (Fig. 5), the AC characteristic line separates the regions affected by the upstream boundary and initial conditions, and the BC line separates the regions affected by the downstream boundary and initial conditions. In other words, the characteristic lines on the plane (x - t) represent the paths of movement disturbances initiated at various locations in the system.

To solve the equations of (8) to (11), a number of finite difference schemes have been proposed Streeter and Wylie, using a finite difference technique first order Evangelisti suggests a method predictor-corrector and Lister employs both first and second order finite difference systems, because the time intervals used in solving these equations for practical problems are usually small, a technique first order suggested by Streeter and Wylie, is sufficiently precise. However, if friction losses are large, then a first-order approximation can produce unstable results. For such cases, a predictor-corrector method or a second-order approximation should be used to avoid the instability of systems of finite differences.

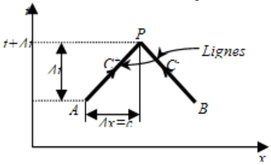


Fig. IV.1. Lignes caractéristiques dans le plan (x-t)

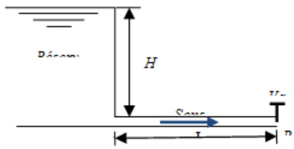
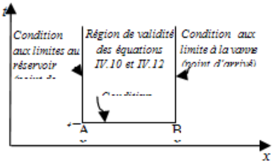


Fig. V.2. Configuration physique



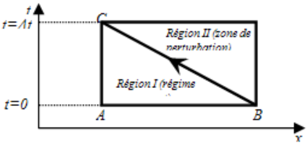


Fig. IV.3. Région de validité des équations pour une conduite simple

Fig. IV.4. L'excitation à l'extrémité avale

Referring to (Fig. 1), let conditions at time t = t0 be known. These are known initially (ie at t = 0, the initial conditions are steady) or were calculated for the previous time step. We want to calculate unknown conditions. Referring to (Fig. 1), we can write line along the positive characteristic AP:

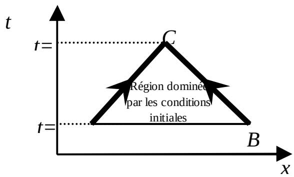


Fig. 5. The excitement upstream and downstream ends

$$dQ = Q_P - Q_A. \tag{12}$$

$$dH = H_P - H_A. \tag{13}$$

The same way, we can write the characteristic negative long line BP.

$$dQ = Q_P - Q_B. \tag{14}$$

$$dH = H_P - H_B. \tag{15}$$

Indices in equations (12), (13), (14) and (15), referenced to locations on the plane (x - t) Substituting equations. (12) and (13) in equation (8) and equations (14) and (15) in equation (10), the calculation of the friction term at the points A and B, and multiplying by the set, and replacing in the first equation and the second equation is obtained:

$$H_P - H_A + \frac{c}{Sg}(Q_P - Q_A) + \frac{f\Delta x}{2gDS^2} Q_A \left|Q_A\right| = 0 \qquad (16)$$

and $$H_P - H_B - \frac{c}{Sg}\left(Q_P - Q_B\right) - \frac{f\Delta x}{2gDS^2} Q_B \left|Q_B\right| = 0. \qquad (17)$$

We can write equation (16) and (17) as:

$$H_P = H_A - a\left(Q_P - Q_A\right) - RQ_A\left|Q_A\right| \qquad (18)$$

and $$H_P = H_B + a\left(Q_P - Q_B\right) + RQ_B\left|Q_B\right| \qquad (19)$$

with:

$$a = c/Sg \text{ et } R = \frac{f\Delta x}{2gDS^2} \qquad \text{such that,}$$

a: the angular coefficient and R: coefficient of friction (losses).
We can write equation (18) as

$$C^+:\ H_P = C_P - a\,Q_P. \qquad (20)$$

And equation (IV.19) as:

$$C^-:\ H_P = C_M - a\,Q_P \qquad (21)$$

with: $$C_P = H_{i-1} + a\,Q_{i-1} - RQ_{i-1}\left|Q_{i-1}\right|; \qquad (22)$$

$$C_M = H_{i+1} - a\,Q_{i+1} + RQ_{i+1}\left|Q_{i+1}\right|. \qquad (23)$$

Note that equation. (20) is valid along the positive characteristic line AP and equation (21) The negative characteristics along the lines BP values of constants Cp and CM are known for each time step, and the constant has depends on the properties of the pipe. We refer to the equation. (22) Since the characteristic equation and the equation positive. (23) Since the characteristic equation negative in the equations. (18) and (19), we have two unknowns, namely H_P and Q_P. The values of these unknowns can be determined by solving these equations simultaneously, that is to say:

$$Q_P = 0,5(C_P + C_M). \qquad (24)$$

Now, the value of H_P can be determined either from equation (18) or Equation (19). Thus, using equations (18) and (24), the conditions at all interior points (see Fig. 6) at the end of the time interval can be determined, however, limits, either equation (18) or (19) are available. Therefore, as discussed above, we need particular boundary conditions to determine the boundary condition at the moment $t_0 + \Delta t$.

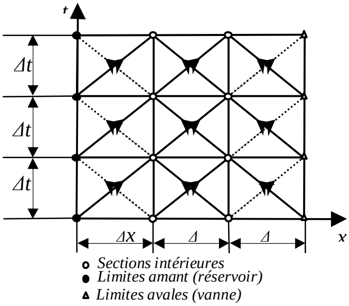


Fig.6. Features mesh

To illustrate how to use the above equations, we will consider the conduct of the single (Fig. 2) The pipe is divided into n equal segments (Fig. 6), and the conditions to state $(t = t_0 + \Delta t)$ of equilibrium points at time t = t0 are first obtained. Then, in order to determine the conditions at the time $(t = t_0 + \Delta t)$, equations (18) and (24), are used for the interior points (interior sections of schemes), and boundary conditions are used for special conditions boundary. A careful examination of (Fig. 6) shows that the boundary conditions must be known to calculate the conditions at the time $(t = t_0 + 2\Delta t)$, the interior points. The grid points, and conditions $(t = t_0 + 2\Delta t)$ are determined by following the procedure just outlined. In this way, the calculations proceed step-by-step until the conditions for the transient time are determined.

1. APPLICATION OF THE METHOD FEATURE:

In what follows we will apply the characteristic method for solving the proposed system.

BOUNDARY CONDITIONS

Based on equations (20), (21), (22) and (23), knowing that in our schemes we have neglected the pressure drop which means the friction coefficient R = 0 equations (22) and (23) becomes:

$$C_P = H_{i-1} + aQ_{i-1}; \tag{25}$$

$$C_M = H_{i+1} - aQ_{i+1}. \tag{26}$$

Applying these equations on the three schemes are:

DIAGRAM N 01 (n = 2)

Was the point M:

$$Hp = Hp_{p,n+1} = Hp_{A,1} = Hp_{B,1}\ . \tag{27}$$

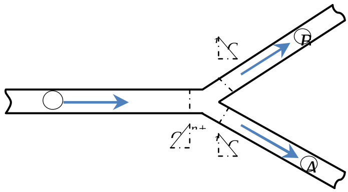


Fig. 7. Junction lines

Also applying the continuity equation at point M:

$$Qp_{p,n+1} = Qp_{A,1} + Qp_{B,1}. \tag{28}$$

We have the rates of each line:

$$Qp_{p,n+1} = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a}; \tag{29}$$

$$-Qp_{A,1} = -\frac{Hp_{A,1}}{a_1} + \frac{C_{M_1}}{a_1}; \tag{30}$$

$$-Qp_{B,1} = -\frac{Hp_{B,1}}{a_2} + \frac{C_{M_2}}{a_2}. \tag{31}$$

It replaces the three equations (29), (30) and (30) in equation (28):

$$\sum Qp = 0 = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a} - \frac{Hp_{A,1}}{a_1} + \frac{C_{M_1}}{a_1} - \frac{Hp_{B,1}}{a_2} + \frac{C_{M_2}}{a_2};$$

$$Hp = \frac{Cp_p + C_{M_1} + C_{M_2}}{\left(\frac{1}{a} + \frac{1}{a_1} + \frac{1}{a_2}\right)}. \tag{32}$$

DIAGRAM N ° 02 (n = 3)

Was the point M:

$$Hp = Hp_{p,n+1} = Hp_{A,1} = Hp_{B,1} = Hp_{C,1}. \tag{33}$$

Also applying the continuity equation at point M:

$$Qp_{p,n+1} = Qp_{A,1} + Qp_{B,1} + Qp_{C,1}. \tag{34}$$

We have the rates of each line:

$$Qp_{p,n+1} = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a}; \tag{35}$$

$$-Qp_{A,1} = -\frac{Hp_{A,1}}{a_1} + \frac{C_{M_1}}{a_1}; \tag{36}$$

$$-Qp_{B,1} = -\frac{Hp_{B,1}}{a_2} + \frac{C_{M_2}}{a_2}; \tag{37}$$

$$-Qp_{C,1} = -\frac{Hp_{C,1}}{a_3} + \frac{C_{M_3}}{a_3}. \tag{38}$$

It replaces the four equations (IV.34) (IV.35) (IV.36) and (IV.37) in equation (IV.33):

$$\sum Qp = 0 = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a} - \frac{Hp_{A,1}}{a_1} + \frac{C_{M_1}}{a_1} - \frac{Hp_{B,1}}{a_2} + \frac{C_{M_2}}{a_2};$$

$$Hp = \frac{Cp_p + C_{M_1} + C_{M_2} + C_{M_3}}{(\frac{1}{a} + \frac{1}{a_1} + \frac{1}{a_2} + \frac{1}{a_3})}. \tag{39}$$

DIAGRAM N ° 03 (n = 4)

Was the point M:

$$Hp = Hp_{p,n+1} = Hp_{A,1} = Hp_{B,1} = Hp_{C,1} = Hp_{C,1}. \tag{40}$$

Also applying the continuity equation at point M:

$$Qp_{p,n+1} = Qp_{A,1} + Qp_{B,1} + Qp_{C,1} + Qp_{D,1}. \tag{41}$$

We have the rates of each line:

$$Qp_{p,n+1} = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a}; \tag{42}$$

$$-Qp_{A,1} = -\frac{Hp_{A,1}}{a_1} + \frac{C_{M_1}}{a_1}; \tag{43}$$

$$-Qp_{B,1} = -\frac{Hp_{B,1}}{a_2} + \frac{C_{M_2}}{a_2}; \tag{44}$$

$$-Qp_{C,1} = -\frac{Hp_{C,1}}{a_3} + \frac{C_{M_3}}{a_3};. \tag{45}$$

$$-Qp_{D,1} = -\frac{Hp_{D,1}}{a_4} + \frac{C_{M_4}}{a_4}. \tag{46}$$

It replaces the five equations (41), (42), (43), (44) and (45) in equation (40):

$$\sum Qp = 0 = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a} - \frac{Hp_{A,1}}{a_1} + \frac{C_{M_1}}{a_1} - \frac{Hp_{B,1}}{a_2} + \frac{C_{M_2}}{a_2}; \qquad (47)$$

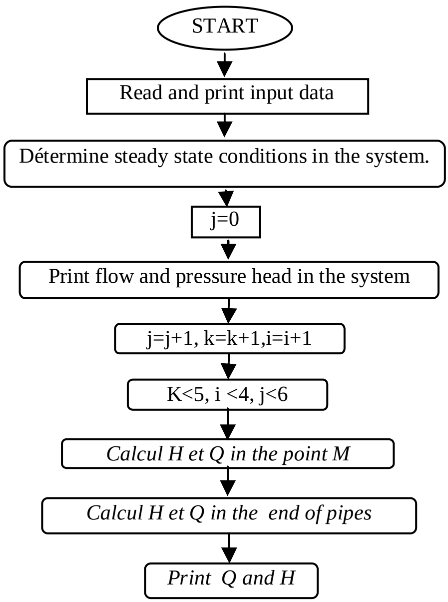
$$Hp = \frac{Cp_p + C_{M_1} + C_{M_2} + C_{M_3} + C_{M_4}}{(\frac{1}{a} + \frac{1}{a_1} + \frac{1}{a_2} + \frac{1}{a_3} + \frac{1}{a_4})}. \qquad (48)$$

General equation:

$$\sum Qp = 0 = \frac{Hp_{p,n+1}}{a} + \frac{Cp_p}{a} - \sum_1^n \left[\frac{Hp_{A,n}}{a_n} + \frac{C_{M_n}}{a_n} \right]; \qquad (49)$$

$$Hp = \frac{Cp_p + \sum_1^n C_{M_n}}{(\frac{1}{a} + \sum_1^n \frac{1}{a_n})}. \qquad (50)$$

ORGANIZATION OF CALCULATION:



CONSTRUCTION GRAPHIC OF PRESSURE AND FLOW:

To represent the variation of pressure and flow over time, we chose the results: of n=2 in the case of a = 1 and a_1 = 3,Are below the graphs for each line (A, B and the main pipe):

A. **Pipe A**: Variation of pressure and flow

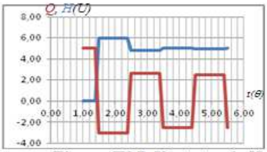


Figure. IV.7. *Variation de Het Q dans la section M1(l=0)*

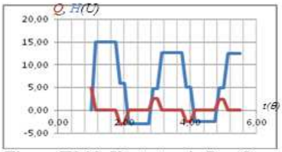


Figure IV.10. *Variation de P et Q dans la Section l=3/4*

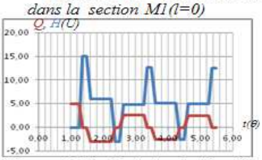


Figure. IV.8. *Variation de H et Q dans la section l=1/4*

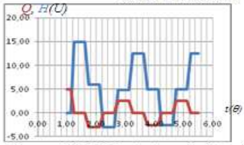


Figure IV.10. *Variation de P et Q dans la Section l=1/2*

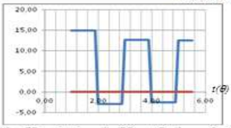


Figure IV.11. *Variation de H et Q dans la Section l=1*

A. **Pipe B**: Variation of pressure and flow:

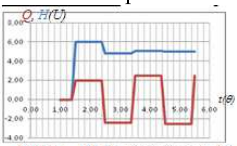


Figure. IV.12. *Variation de H et Q dans la Section M2 (l=0)*

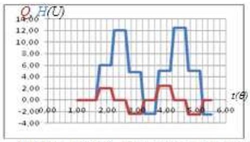


Figure IV.14. *Variation de la pression et du débit dans la Section l=1/2*

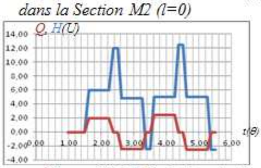


Figure IV.13. *Variation de H et Q dans la Section l=1/4*

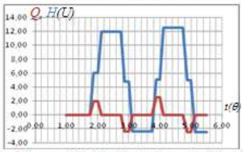


Figure IV.15. *Variation de H et Q dans la Section l= 3/4*

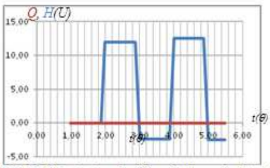


Figure IV.16. *Variation de H et Q dans la Section l=1*

B. **Principal pipe**: Variation of pressure and flow:

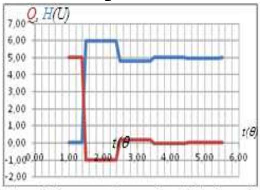


Figure V.19. Variation de la pression et du débit dans la Section M3 (L=1)

INTERPRETATION OF GRAPHIC RESULTS:

Based on the analysis of graphs, we note the following:

1. At the connection point M: the values of pressure and flow remain stable for a period *θ* (*2l/c*), the pressure wave at point *M* will travel a round trip of each section with a speed of "*c*" return to the starting point M corresponds.

2. A section ¼ *l*:

• The values of pressure and flow remain stable hang a period θ ¼(0.5l/c) in each line in the case where the pressure wave takes its departure at this section to the point M in the opposite direction flow and is reflected back to the end of a hard time (0.5l / c).

• As against these values remain stable hang a hard time 3/4θ (3/2l/c) in each line, this is the time for a return wave departed this section in the direction of the flow to reflect and reach this section.

In section 1/2 l: values of pressure and flow remain stable hang a period 1/2 θ (l / c) in each line, it is time to go and wave from this section in the flow direction (or in the opposite direction of flow) and its return to this style.

This stability, variable Q (t, x) and H (t, x) of pressure and flow that occurs in the graph in the plane (t, x) has the same explanation as the cases cited previously made the its symmetry relative to the middle of the pipe.

This stability is observed for each section and resulting in constant levels of pressure and flow that lasts a return wave and leaves from the section in question and return to the same place.

CONCLUSION:

Following the analysis of the results, we note the following points:

1. In the case where the number of branching (n) is equal to the angular coefficient of the secondary pipes (n = a1), it was found that there is a conservation of the initial values of pressure surges in the different time intervals, c. A.D. values of pressure and flow remained stable baseline (H=0)

2. In the case where the number of branching (n) is greater than the angular coefficient of secondary lines (n> a1), it was found that there is a variation in pressure and flow compared to baseline, this variation continues until 'that the system is an equilibrium state at time t = 4.5θ.

Pressures in the pipe ends (points A, B, C and D) to increase when the system is steady state ie when the value of the main duct flow approaches nearer and nearer the flow amount zero.

3. In the case where the number of branching (n) is less than the angular coefficient of the secondary pipes (n <a1), it was found that there is always a change of flow and pressure relative to the initial values, the variation continues to which the system takes its equilibrium state ie when the value of the main duct flow approaches nearer and nearer the flow amount zero.

a. Pressures in the ends of the pipe at point A to decrease when the system is steady state ie when the value of the main duct flow approaches nearer and nearer the value of the zero flow, the pressure decreases from an initial value ((A1 = (c1 / g) Vo) to a value A5 = ((c1 / g) Vo-H)

Pressures in the pipe ends (points B, C and D) to increase when the system is steady state ie when the value of the main duct flow approaches nearer and nearer the value of the zero flow, the pressure rises from an initial value ((B1 = (c2 / g) Vo) to a value B5 = ((c2 / g) Vo + H)

b. The pressures in the point (M), ie the branch point, vary with alternating (larger value to a smaller value), this variation is continued until the flow rate is zero.

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АНАЛІЗ ВПЛИВУ ЗУПИНКИ ТУРБІНИ ГЕС НА ПАРАМЕТРИ ГІДРАВЛІЧНОГО УДАРУ МЕТОДОМ ХАРАКТЕРИСТИК

Дослідження змін в значеннях параметрів гідравлічного удару, в порівнянні з їх первісними значеннями, являють собою реальну проблему для дослідників через комплексність та складність па-

раметрів, які розглядаються. Дана робота торкається специфічних явищ експлуатації гідроелектростанцій, які відображують обставини одночасної зупинки гідротурбін (закриття затворів), в той час як інші турбіни закриті з технічних причин або через експлуатаційне різке падіння до відповідного мінімального запиту на роботу турбін з метою регулювання та збереження води. В результаті таких збуджень виникають зміни локальних тисків і потоків в системі, які підлягають розгляду. Ці та інші проблеми було проаналізовано за допомогою методу характеристик.
Ключові слова: гідравлічний удар, гідроелектростанція, метод характеристик.

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АНАЛИЗ ВЛИЯНИЯ ОТКЛЮЧЕНИЯ ТУРБИНЫ ГЭС НА ПАРАМЕТРЫ ГИДРАВЛИЧЕСКОГО УДАРА МЕТОДОМ ХАРАКТЕРИСТИК

Исследование изменений в значениях параметров гидравлического удара, в сравнении с их первоначальными значениями, представляют собой реальную проблему для исследователей из-за комплексности и сложности параметров, входящих в рассмотрение. В данной работе затрагиваются специфические явления эксплуатации гидроэлектростанций, которые отражают обстоятельства одновременного отключения турбин (закрытия затворов), в то время как остальные турбины закрыты по техническим причинам или из-за эксплуатационного резкого падения до соответствующего минимума спроса на работу турбины в целях регулирования и сохранения воды. В результате таких воздействий возникают изменения локальных давлений и потоков в системе, которые подлежат рассмотрению. Эти и другие проблемы были проанализированы с помощью метода характеристик.
Ключевые слова: гидравлический удар, гидроэлектростанция, метод характеристик.