U.P.B. Sci. Bull., Series D, Vol. 74, Iss. 1, 2012 ISSN 1454-2358

MANAGEMENT OF A HYDROELECTRIC MOBILE DAM

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The dam management system is made by measurement and control equipment to ensure the retention level used in exploitation, to control the flow rates, to ensure the net head on the hydraulic turbine, to ensure the flow rate in the turbine, to ensure the hydropower development security in the floods period. The paper presents the monitoring case of a mobile dam which has the control of the flow rate as reference. Analytically characteristics of flow rate for different retention level and gates opening are drawn. It is describe the kinematics of a segment gate with flap operated by an electro-mechanical system and the synchronizing algorithm of the gates movement.

Keywords: dam, segment gate with flap, management system, synchronizing operation

1. Introduction

A mobile dam is characterized by a small height having fixed and mobile hydro-mechanical elements. The mobile part is made by gates which are assisted on the sill and which occupies more then 75% from the overflow field. Commonly, such a dam is made by a segment gate with flap. Over the total or partial opening of the gates are discharged the flow rates, alluviums, floating and ice. When the hydroelectric power station does not work, the flow rates are transited downstream through the gate.

The dam management system is made by measurement and control equipment to ensure the retention level used in exploitation, to control the flow rates, to ensure the net head on the hydraulic turbine, to ensure the flow rate in the turbine, to ensure the hydropower development security in the floods period.

The system of automated surveillance, monitoring and control is centralized and in real time. The monitoring process of the mobile dam is part of the hydropower station management process and is in S2 class of services because of the short periods of work.

The paper presents the monitoring case of a mobile dam which has the control of the flow rate as reference. To this end the position of the segment gate with flap is changed and the overflow rate remains constantly. The case study was applied to the Ramnicu Valcea mobile dam and hydroelectric power station,

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placed on river Olt. The structure of the monitoring system block scheme is represented in Figure 1, [6].

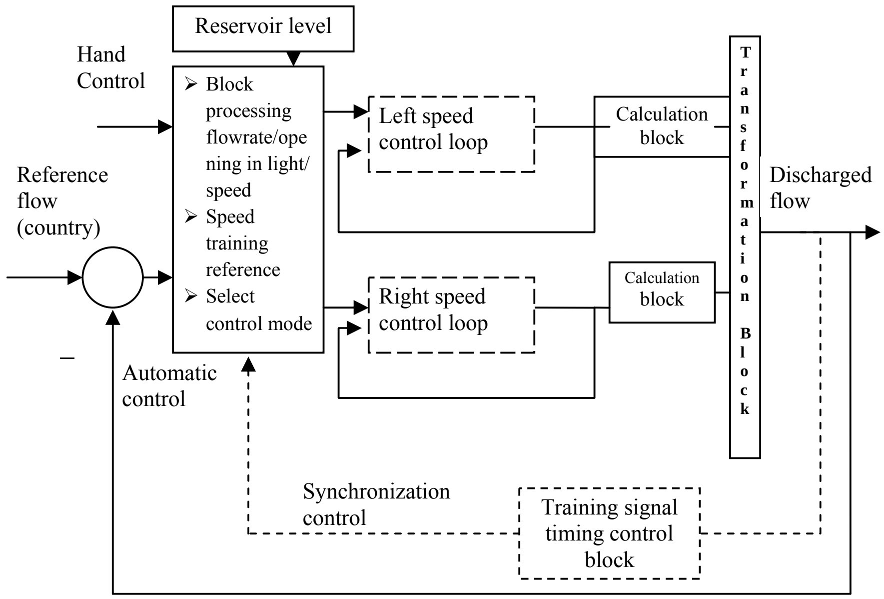

Fig. 1 Structure of the monitoring system block scheme

The flow rate discharged through the gates could be measured, or could be determinate from the flow characteristic of the gate or could be analytically calculated. Today is not used a direct measurement method for the flow rate discharged through a spillway or a gate and neither an analytically method. It is used the flow rate characteristics of a gate made it in the laboratory using a hydrodynamic similarity. But the differences between the real gate flow rate characteristics, which was working in time of years, and model gate made this method to be ineffectual.

2. Kinematical elements of a segment gate with flap

The basic components of a chain hoist are: electric motor, brake, speed reducers, sprockets, chains, position indicator, limit switches, slack chain detector and hand drive, [2]. The hoist chain of the segment gate with flap has a key electric motor drive and an auxiliary motor drive to synchronize the gates vertical lift. The auxiliary motor drives the two arms of the segment gate by using a coupling shaft.

Classical control method to achieve synchronization with electrical shaft is physically and morally obsolete. Currently, electric motor drives with frequency converters is made. Each engine will have a constant speed regardless of torque. The frequency converter will increase the value of current when the motor load increases to maintain a constant speed.

Synchronization driving of the two arms of the segment gate with flap is obtained by measuring the horizontal displacement given by the imbalance of the segment gate body panel. Maximum angle of inclination (α) agreed to the angular displacement of the left arm of the gate or right one is at most 0.1° in the case of Ramnicu Valcea Hydropower Station and could go up to ± 1 °. The segment gates with flap of the mobile dam of Ramnicu Valcea Hydropower Station have the openings and heights of 16x(8+2) m^2. Achieving synchronization driving involves measuring the angular position of the flap, β, and the angular position segment gate, α. Points that define the kinematics driving of the segment gate with flap are presented in Fig.2. In Figs. 3 and 4 are geometric elements that define the kinematics driving system of the gates, specifying the calculation for the length of the flap drive chain, l_c, and length of the segment gate drive chain, l_s.

Knowing the system of action coordinates, Fig. 2, the calculated length of chain wheel drive is:

$$l = l_c - l_0, \tag{1}$$

$$l_c{}^2 = (x_C - x_B)^2 + (z_C - z_B)^2, \tag{2}$$

$$l_0{}^2 = (x_{C0} - x_{B0})^2 + (z_{C0} - z_{B0})^2, \tag{3}$$

where l_c is given by the coordinates of contact point, C, the chain and sprocket wheel drive system, and the coordinates of point B located at a position the throttle opening angle β, [6]. Free chain length, l_0, depends on the flap position on the sill, B_0, to the point of contact of the wheel sprocket C_0.

Because propping chain sprocket wheel drive mechanism is not continuously but by bolts is found that the length of the wrapped chain is smaller than the theoretical length chain and the amplification factor used is:

$$k = \left(2\pi \frac{R_L}{n}\right) / 2R_L \sin\left(\frac{\pi}{n}\right) \tag{4}$$

where n is the number of teeth corresponding to a length of a joining chain and R_L is the radius of the sprocket wheel.

Pinion angle drive mechanism which drives the chain is calculated according to the report submission, i, between the first and last training wheel drive equipment and the number of N electric motor revolutions performed:

$$\theta = \frac{2\pi N}{i}. \tag{5}$$

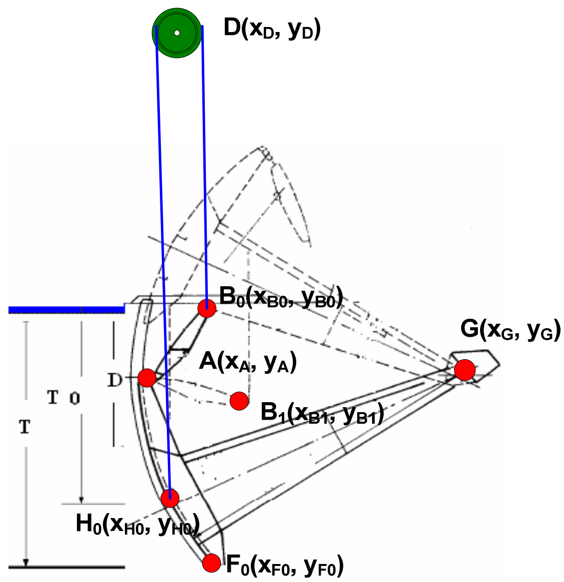

Fig. 2.Scheme of a segment gate with flap

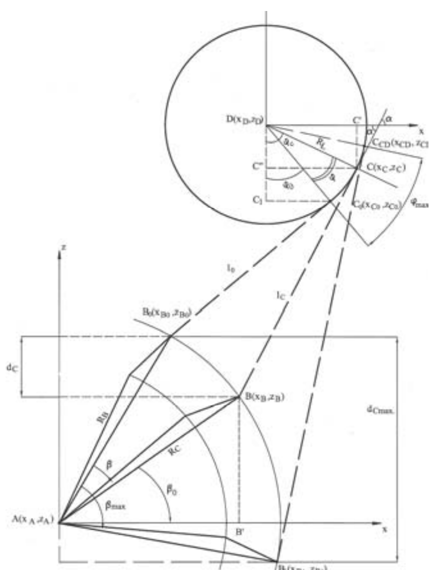

Fig. 3. Kinematics and geometrical sizes of the flap gate

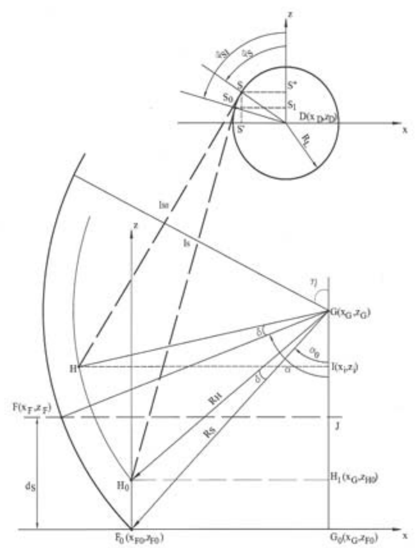

Fig. 4. Kinematics and geometrical sizes of a segment gate

Similarly, geometric considerations as shown in Fig. 3, is calculated the length of chain carried by the sprocket wheel, l, to drive segment gate when the flap is completely open and the free chain length, l_0, when the flap gate is closed:

$$l^2 = (x_{SS} - x_H)^2 + (z_S - z_i)^2 \tag{6}$$

$$l_0{}^2 = (x_{SI} - x_{H0})^2 + (z_{SI} - z_{H0})^2 . \tag{7}$$

Angle calculation θ based on the number of electric motor revolutions can be made depending on the length of drive chain and the corresponding segment gate arm radius, R_S:

$$\theta = k\frac{l - l_0}{R_S} - \varphi , \tag{8}$$

with

$$\varphi = \varphi_{Si} - \varphi_S = 2arctg\frac{-(x_{H0} - x_D) \pm \sqrt{(x_{H0} - x_D)^2 + (z_{H0} - z_D)^2 - R_L^2}}{-(z_{H0} - z_D - R_L)} -$$
$$2arctg\frac{-(x_H - x_D) \pm \sqrt{(x_H - x_D)^2 + (z_H - z_D)^2 - R_L^2}}{-(z_H - z_D - R_L)} .$$

3. Flow rates under and over the gates

During the mobile dam operation the water is discharged through the segment gate with flap. According to the rules of dam operation the flow rates are discharged firstly by opening the flap, and then, when the flap is at rest on the sill will be discharge the flow rate through the segment gate. Depending on the maximum retention level the flow rates discharged could be done above or under the gates.

Analytical formulas, well known in literature [2, 4], were used for calculation the discharge of the segment gate with flap knowing different retention levels and openings of the gates. Was considered the case of not drowned spillway with a practically WES profile.

To an opening of the flap the discharge has the flow model over a sharp-crest weir, [4]:

$$Q = \frac{2}{3}\mu \cdot b_1\sqrt{2g}H^{3/2} \tag{9}$$

where: H is the flap's head (Fig. 5) with $H = N_L - z_{nnr} - d$ and μ is considered as a coefficient of flow calculated as:

$$\mu = \left(0{,}6035 + 0{,}0813\frac{H}{P_1} + \frac{0{,}00009}{P_1}\right)\left(1 + \frac{0{,}0011}{H}\right)^{3/2} . \tag{10}$$

Flow rates characteristics are plotted in Figure 6.

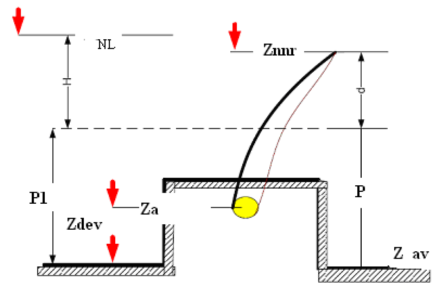

Fig. 5. Notations on the sizes involved in calculating the discharge over a flap. (*NL* - level in the lake, z_{nnr} - normal retention rate level, *d* – flap opening)

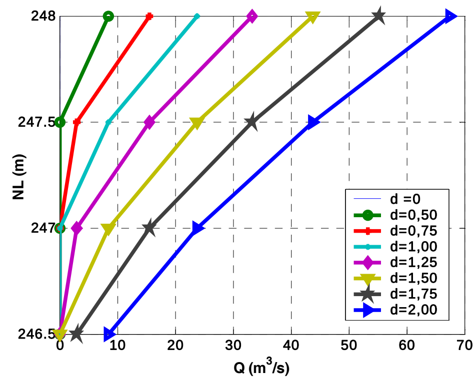

Fig. 6. Flow rates characteristics of the flap gate CHE Ramnicu Valcea

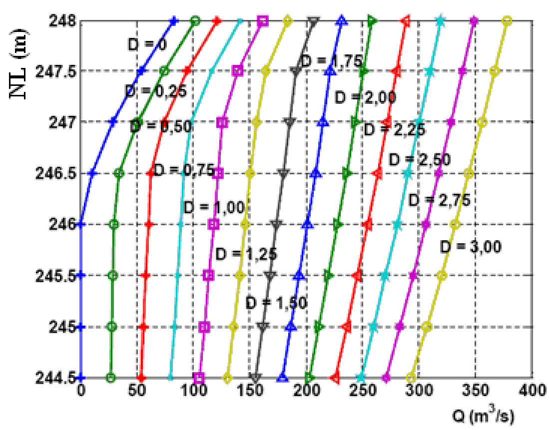

Fig. 7. Flow rates characteristics of the segment gate @ CHE Ramnicu Valcea

Flow rate discharged at a segment gate's opening is modelled by the flow through large rectangular openings, not drowned, [1]:

$$Q = \frac{\mu \tau_e T^{3/2} \sqrt{2g\left(1 - \varepsilon \tau_e\right)}}{\sqrt{1 - \alpha \mu^2 \beta^2 \tau_e^2}} \tag{11}$$

with notations from Figures 2 and 4 where the medium specific energy of the fluid in the access section of the upstream reach is a dimensionless size as a ratio between the segment gate opening and the specific energy, *T*, $T_0 = T + V_0^2 / 2g$, and $\tau_e = \frac{d_S}{T}$, with μ, discharge coefficient of an orifice given by

$\mu = 0{,}02\,\tau_e^3 + 0{,}02\,\tau_e^2 + 0{,}0038\,\tau_e + 0{,}61$, and ε is the vertical contraction coefficient of the gate in the current with $\varepsilon = 0{,}21\,\tau_e^3 - 0{,}063\,\tau_e^2 + 0{,}048\,\tau_e + 0{,}61$. In this case was considered $\alpha = \beta = 1$ and $T = N_L - Z_{F0}$. In Figure 7 the flow rates discharged to an opening D of the segment gate and different retention levels are plotted.

4. Synchronising process of the gates mechanisms

Synchronization system uses three-phase AC electric motor with frequency converter and speed control is achieved by vector control method. When the imbalance, Δ, between the two arms exceeds the allowable value, c, the frequency will be changed until the imbalance is cancelled.

Achieving synchronization is done via a system of tracking having as the input the speeds of both auxiliary electric motors [6]. Speeds are measured on-line through speed transducers. Achieving synchronization algorithm is implemented numerically using a PLC (Programmable Logic Controller). After accepting the order of action and determination of imbalance, the engines receive commands to speed or slow the drive with a percentage value, *a*, until the rotation speed becomes equal but without exceed the speed of synchronism. The synchronization algorithm is detailed in Figure 8. Figure 9 presents Image from the ALUTUS monitoring system of CHE Ramnicu Valcea mobile dam. For each of the segment gate with flap is made a synchronization system that can be connected in a general management system of a hydroelectric power station.

5. Conclusions

The management of a mobile dam which operates in a flow rate reference is the subject of this paper. As an important part of management process is developed the monitoring system of overflows above and below the gates of a mobile dam and gates movement synchronizing process, too. Analytically characteristics of flow rate for different retention level and gates opening are drawn. It is describe the kinematics of a segment gate with flap operated by an electro-mechanical system and the synchronizing algorithm of the gates movement. The system presented in the paper was implemented on the hydroelectric power station of Olt river and is part of the hydropower system management control ALUTUS.

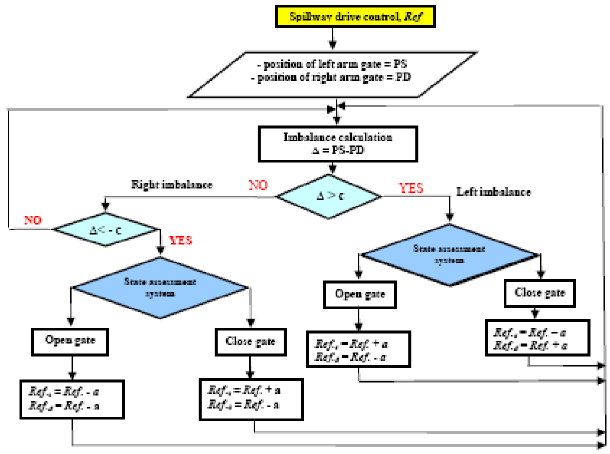

Fig. 8. Algorithm to achieve synchronization with reference $Ref._s$ = left reference, $Ref._d$ = right reference, *a* is a figure of 10% of the working current rotation speed

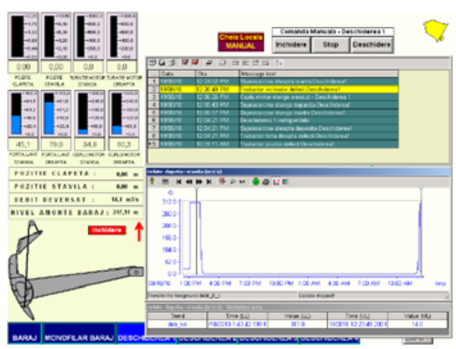

Fig. 9 Image from the ALUTUS monitoring system of CHE Ramnicu Valcea

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