The determining of the lowest water level in a surge tank

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Abstract

This treatise solved: firstly, mathematically solved the important factor in management of the canal system hydropower plant -the lowest water level of the surge tank (or fore bay tank). Secondly, improved the former is the same as the stability condition of the water level vibration in the surge tank. Thirdly, improved the water level in the surge tank is connected with the diameter of the hydraulic tunnel and the diameter of the penstock.

Key words: hydropower plant, surge tank, lowest water level, hydraulic tunnel, penstock

1. The lowest water level of the surge tank (or fore bay tank)

In order to simplify description below named water level of the surge tank, about surge tank parameter using to index 's' is described it, also about tunnel parameter using to index 't' is described it, also about penstock parameter using to index 'p' is described it. Hydropower station output is calculated as follows:

$$N = KQH \qquad (1)$$

Where:

The variable N represents hydropower station output, kW;

K represents output factor, 9.81η (η represents total efficiency of the hydropower station);

Q represents discharge of water, m^3/s; H represents effective headwater, m.

H is calculated as follows: $$H = H_0 - \Delta h \qquad (2)$$

Where: The variable H_0 represents static headwater of the hydropower station, m ; ΔH represents loss headwater, m.

H_0 and ΔH respectively is calculated as follows:

$$H_0 = Z_{normal} - Z_{tail} \quad (3)$$

$$\Delta h = \Delta h_t + \Delta h_p \quad (4)$$

Where: Z_{normal} and Z_{tail} respectively represent normal water level and tail water level, m; Δh_t and Δh_p respectively represent loss headwater of the tunnel and penstock, m.

Also, Δh_t and Δh_p respectively is calculated as follows:

$$\Delta h_t = \alpha_t Q^2 = Z_{normal} - Z_s \quad (5)$$

$$\Delta h_p = \alpha_p Q^2 \approx Z_s - Z_{tail} \quad (6)$$

Where: α_t and α_p respectively represent coefficient of loss headwater in the tunnel and penstock, Z_s represents water level of surge tank, m.

And then α_t and α_p respectively is calculated as follows:

$$\alpha_t = 10.294 {n_t}^2 L_t {D_t}^{-5.333} \quad (7)$$

$$\alpha_p = 10.294 {n_p}^2 L_p {D_p}^{-5.333} \quad (8)$$

Where: n_t and n_p respectively represent friction coefficient of the tunnel and penstock; L_t and L_p respectively represent length of the tunnel and penstock, m; D_t and D_p respectively represent diameter of the tunnel and penstock, m. Calculation scheme shown on Fig. 1.

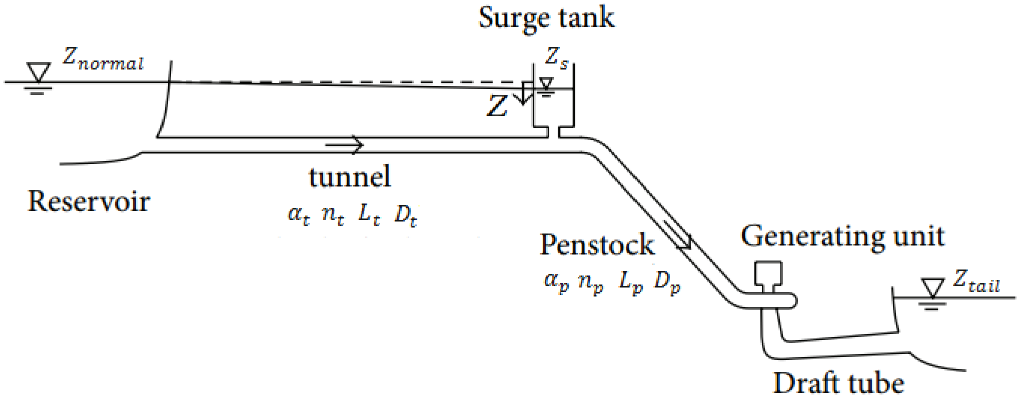

Figure 1. Power generating system with surge tank

Substitute Eq. (2) ~ (6) to Eq. (1), could see

$$N = KQ(Z_s - Z_{tail} - \alpha_p Q^2)$$

$$Q = \sqrt{\frac{Z_{normal} - Z_s}{\alpha_t}}$$

Therefore, derived output equation is obtained:

$$N = K\sqrt{\frac{Z_{normal}-Z_s}{\alpha_t}}\left(Z_s - Z_{tail} - \alpha_p \frac{Z_{normal}-Z_s}{\alpha_t}\right) \qquad (9)$$

If relative to water level of the surge tank 'Z_s' take derived function, can be obtained as a limit state equation of special case.

$$\frac{\partial N}{\partial Z_s} = 0$$

Derived limit state equation is as follows:

$$\frac{1}{2}\left[Z_s - Z_{tail} - \frac{\alpha_p}{\alpha_t}(Z_{normal} - Z_s)\right] = \left(1 + \frac{\alpha_p}{\alpha_t}\right)(Z_{normal} - Z_s) \qquad (10)$$

Based on water level of the surge tank 'Z_s', limit state equation, Eq. (10) can be rewritten as:

$$Z_s = \frac{\left(2+3\frac{\alpha_p}{\alpha_t}\right)Z_{normal}+Z_{tail}}{3(1+\frac{\alpha_p}{\alpha_t})} \qquad (11)$$

Eq. (11) is the formula that is able to determine the lowest limit of the surge tank.

Also, Eq. (11) can be rewritten as:

$$Z_{normal} - Z_s = \frac{Z_{normal}-Z_{tail}}{3(1+\frac{\alpha_p}{\alpha_t})} \qquad (12)$$

Therefore, loss headwater equation in the tunnel can be derived as:

$$\Delta h_t = \frac{H_0}{3(1+\frac{\alpha_p}{\alpha_t})} \qquad (13)$$

Here, because of $\alpha_p \neq 0$, that is

$$\Delta h_t < \frac{1}{3}H_0 \qquad (14)$$

From the above, could see that the loss of the headwater must is lower than static headwater, and then the surge tank mustn't be located at the place where is lower than 1/3 of the place of the lowest static headwater. This result is coincidence with the stability condition of the water level vibration.

2. The relationship between three parameters

To guarantee the water level of the surge tank, we have to determine the diameter of the penstock is bigger than the value of determination from below.

From Eq.(13), the diameter of the penstock can be derived as:

$$D_p = D_t \sqrt[5.333]{\frac{{n_p}^2 L_p}{C{n_t}^2 L_t}} \qquad (15)$$

Here, variable 'C' is as follows:

$$C = \frac{Z_{normal} - Z_{tail}}{3(Z_{normal} - Z_s)} = \frac{H_0}{3\Delta h_t} \qquad (16)$$

3. Conclusion

(1) The lowest water level of the surge tank (or fore bay tank) must locate at the place the total loss headwater of where is lower than 1/3 of the static headwater.

(2) The diameter of the tunnel and penstock, the water level of the surge tank have to be determined in the connection between parameters.

(3) If there are some penstocks, have to guarantee its economy, but also using to one penstock of equal in effect has to do verification its effect.

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