Exercise 3

Transient Analysis of a Hydroelectric Scheme

Introduction

You need to model the hydraulic system of a high head hydroelectric scheme with a surge shaft (Fig. 1). We suggest you use *Hydraulic System* software. Calculations are to be carried out to simulate the behavior of the water level in the surge shaft and the local pressure at a reference junction for different turbine maneuvers.

Data

- The upstream reservoir is modelled with a constant head of 1350 m a.s.l.
- The headrace tunnel is inclined from an altitude of 1340 m a.s.l. to 1327 m a.s.l. and is 2900 m long.
- Surge shaft with expansions.
- The surge shaft is located between 1327 m a.s.l. and 1369 m a.s.l.
- Head losses at the inlet to the surge shaft are symmetrical and represented by a head loss coefficient K_{ss} = 4, for a cross-section of 2.0 m².
- The 600 m-long steel penstock runs from the headrace tunnel (1327 m a.s.l.) to the turbine at 877 m a.s.l. The thickness of the steel is 25 mm.

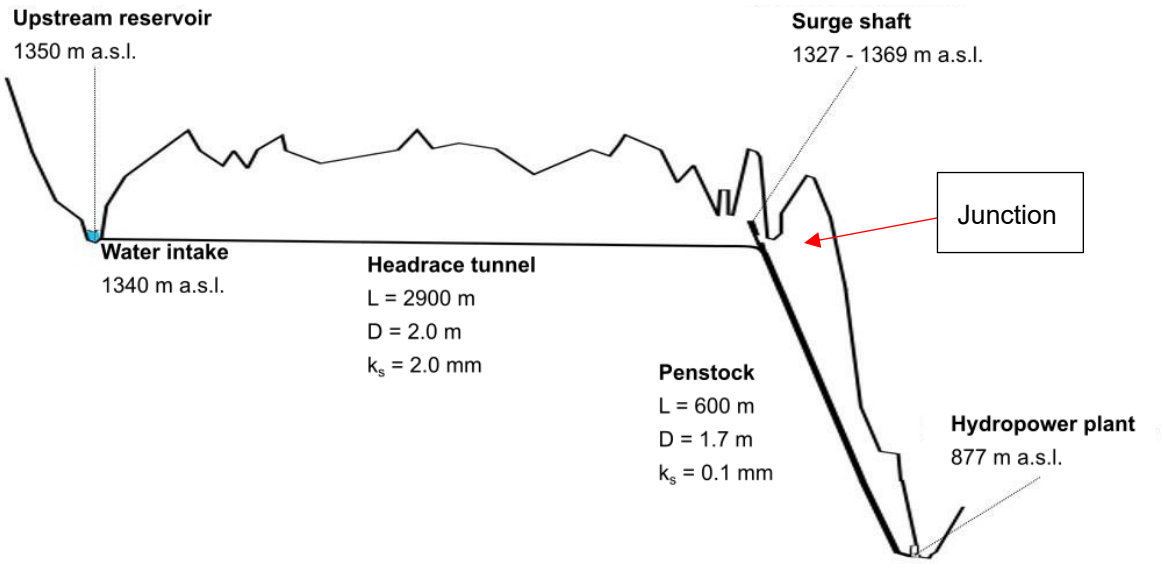

Figure 1: Hydroelectric scheme

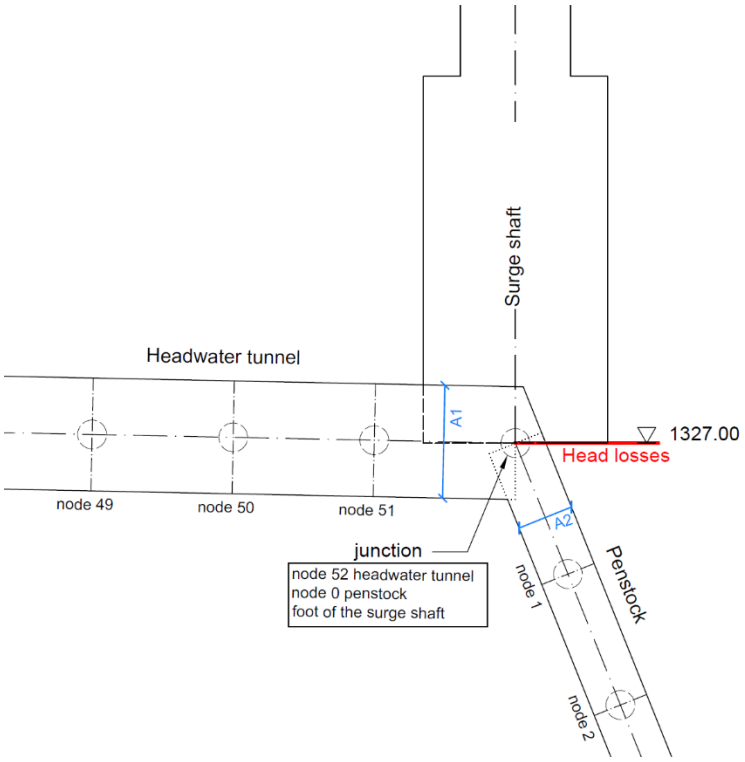

Figure 2 : Junction

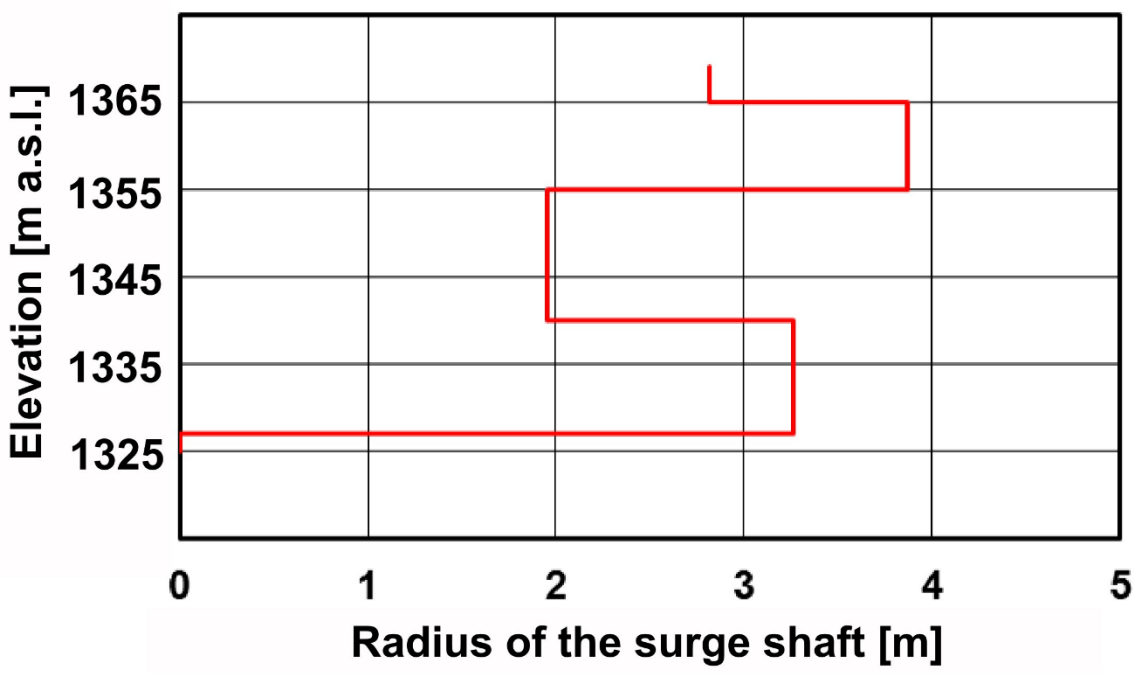

Figure 3: Surge shaft with expansions and variation of radius with altitude:
$R_{1327\text{-}1340}$ = 3.26 m, $R_{1340\text{-}1355}$ = 1.95 m, $R_{1355\text{-}1365}$ = 3.86 m, $R_{>1365}$ = 2.82 m

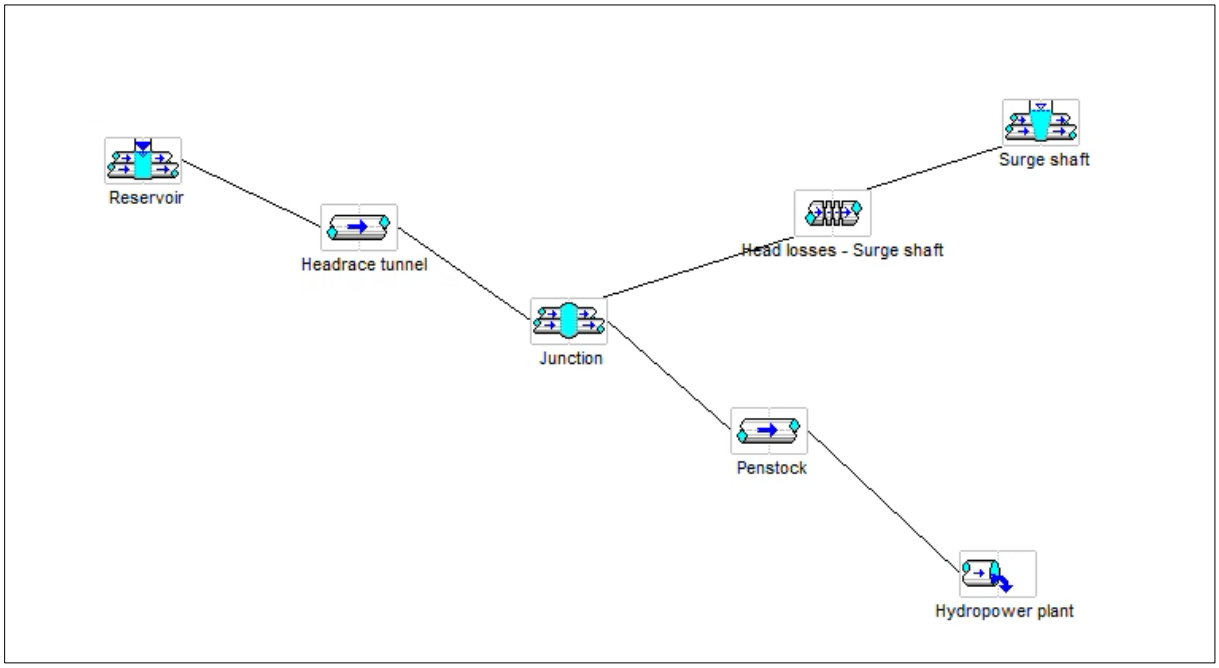

Figure 4: *Hydraulic System* model

Assumptions

- Head losses are determined at the junction (Figure 2) between the headrace tunnel, the penstock and the surge shaft.
- The volume of the reservoir can be assumed to be much larger than that of the system, including the surge shaft.

Questions

The operator of the hydropower plant shown in Figure 1 wants to increase its flexibility and efficiency. To achieve this, they aims to increase the turbining discharge from 10 m^3/s to 12 m^3/s. On the other hand, the operator would like to install a pump to exploit the volume available in the downstream reservoir with a flow rate of 10 m^3/s.

For all questions (except 3.1), simulate (i) the behavior of the water level in the surge shaft and (ii) the local pressure at the reference junction, and interpret your results.

Increasing turbining discharge

1. Simulate the initial turbining situation (Q = 10 m^3/s) for both linear opening and closing operations of 15 seconds. (2)
2. Study the situation for the two maneuvers following the discharge increase (Q = 12 m^3/s) and compare it with the original situation. (2)
3. For safety reasons, the minimum level in the surge shaft must be greater than 1328 m a.s.l.
   - 3.1. What are the potential consequences if this lower limit is exceeded? (1)
   - 3.2. What changes can be made to meet this safety requirement as a result of the increased flow rate? If possible, give numerical values. (2)

Pumping - Turbining

4. Study the situation following the decision to install a pump. Simulate the pumping situation ($Q = 10\ m^3/s$) for both 15-second linear opening and closing operations. Compare with corresponding turbining maneuvers. (2)

Checking combined modifications

5. Following the two load cases tested, we need to determine whether the hydraulic scheme is appropriately designed.

   5.1. Testing a case of transition from pumping to turbining. (1)

   5.2. Is the hydraulic scheme appropriately designed? What other, potentially more critical, cases should be tested? Test one of these cases. (1)

Water hammer

6. Compute the pressure surge with Joukowsi Formula or Michaud-Allievi Formula for:

   6.1. A 15-second linear closing operation. (0.5)

   6.2. An emergency stop in 0.5 second. (0.5)

Report

- Introduce the numerical model and give a brief conclusion of the results at the end.
- Make sure your figures are legible and try to use as few as possible.
- The maximum length is 12 pages, excluding title page and appendices.
- The report formatting will be included in the evaluation.