Hydropower Plants: Generating and Pumping Units
Mock exam – part 1

Duration : 45 minutes;

To indicate your answer, cross the corresponding box. Each question has **only one correct answer.**

Exam evaluation: Every correct answer gives you +1 point. A blank answer gives you 0 point, a wrong one -0.25 point. If in one question you cross more than one box, it will be considered as blank answer: 0 point.

Maximum total score: 20 points

1) What is the main difference between storage hydropower plants and run of river power plants?

- ☐ Run of river power plants have a limited storage capacity and, therefore, offer a restricted flexibility to the power system in respect to storage hydropower plants.
- ☐ Run of river power plants can be equipped only with Kaplan turbines while storage hydropower plants only with Pelton.
- ☐ Storage hydropower plants are off-river as they don't have a natural inflow.

Answers 2 and 3 are simply completely untrue, there is no type of hydropower plant which can be equipped with only one hydraulic machine type and storage hydropower plants are normally linked to a natural inflow.

2) Which parameters are important to compute the specific energy losses in the penstock by knowing the local loss coefficient?

- ☐ The diameter, the length and the flow the velocity in the penstock.
- ☐ The static pressure in the penstock.
- ☐ The discharge and the area of the penstock.

Because the losses are defined as $gH_r = \lambda \frac{L}{D_h} \frac{C^2}{2}$, *and we know the local loss coefficient, we simply need the diameter, length and velocity to compute them. Therefore, answer 1 is correct.*

3) According to the energy and discharge balance, which of the following sentence is correct?

- ☐ The specific energy of the flow at the headwater and tailwater reservoir are the same.
- ☐ The flow discharge from the headwater to the tailwater reservoir is the same if we neglect the volumetric losses.
- ☐ The specific energy of the flow increases linearly with the discharge.

First answer is not true because the turbine extracts the energy between the head and tailwater, meaning that they cannot be equal.

Answer 2 is right by conservation of mass flow rate.

Answer 3 is wrong because losses are a function of Q^2 not Q.

4) Why is it important to include the number of poles of the synchronous generator in the design of the hydroelectric unit?

- ☒ Because it defines the rotational speed of the unit.
- ☐ Because it defines the runaway condition of the unit.
- ☐ Because it allows defining the range of the variable speed of the unit with an asynchronous motor.

For a synchronous generator, the rotational speed of the unit is fixed by the number of poles, according to $n = \frac{2 f_{grid}}{z_p}$, that's why answer 1 is correct.

5) The hydraulic power in a hydropower plant operating in pumping mode is:

- ☐ Always positive.
- ☐ Always negative and the absolute value is greater than the pump power input.
- ☒ Always negative and the absolute value is smaller than the pump power input.

The hydraulic power in pumping mode is negative and smaller than the power input because the efficiency of a pump is lower than 100%. That's why answer 3 is correct.

6) The power transferred by a hydraulic turbine can be computed by knowing:

- ☒ The rotational speed and the driving torque.
- ☐ Only the absolute flow velocity at the inlet and outlet section of the hydraulic machine.
- ☐ The traversing discharge and the gross head.

Answer 1 is correct because $P_t = \omega T$

Answer 2 would only provide the discharge which is not sufficient to know the transferred power

Answer 3 would allow getting the available power, but not the transferred one

7) Which hydraulic machine type reaches the highest efficiency at BEP for generating units?

- ☒ Francis turbine.
- ☐ Pelton turbine.
- ☐ Kaplan turbine.

Francis turbines can reach ~96-97%, Pelton ~92% and Kaplan ~90%.

8) If you have a plant with a very high head (> 1000 m), you will choose for a new storage hydropower plant:

- ☐ Multiple Francis turbines.
- ☒ One or multiple Pelton turbine.
- ☐ One Kaplan turbine.

Pelton turbines are typically made for high and very high heads, that's why they will be chosen. Francis and Kaplan are suitable for lower heads.

9) The absolute flow velocity:

- ☐ Only depends on the discharge in all sections of the hydropower plants.
- ☐ Is given by the sum of the tangential velocity and the relative velocity of the flow.
- ☐ It does not depend on the specific energy losses.

Cm is equal to Q·A in all sections of the machine, therefore answer 1 is false as it does not include the tangential component of the absolute flow velocity.

Answer 2 is true by definition of $\vec{C} = \vec{U} + \vec{W}$

Answer 3 makes no sense.

10) Why are Pelton turbines defined as impulse turbines?

- ☐ Because they handle very large discharge values.
- ☐ Because the rotational speed depends on the flow velocity of the jets.
- ☐ Because the transferred energy is given by the difference in kinetic energy between the inlet and outlet section of the bucket.

Answer 1 is false, Pelton turbines do not handle large discharge in respect to other hydraulic machines.

Answer 2 is not completely wrong, but the inlet flow velocity has an impact on all turbine types, which means that it does not explain why Pelton turbines are characterized as impulse turbines.

Answer 3 is correct, because it is only the kinetic energy from the jet that participates in the energy equation for Pelton turbines, and pressure has no role, contrarily to reaction turbines.

11) The jet hits the bucket:

- ☐ Perpendicularly, i.e. absolute, relative and tangential velocity are aligned at the inlet section of the bucket.
- ☐ With an incidence which corresponds to a positive relative flow angle at the inlet section of the bucket.
- ☐ With an incidence which corresponds to a negative relative flow angle at the inlet section of the bucket.

As the inflow is a jet, all velocities are aligned at the bucket inlet, and answer 1 is correct.

12) How can you regulate the power output in a hydropower plant equipped with a Francis turbine?

- ☐ The power output cannot be regulated.
- ☐ By changing the guide vanes opening angle.
- ☐ By changing the blades pitch angle position.

Answer 2 is the only one that make sense. It is completely untrue that the power output cannot be regulated, and Francis turbines cannot change their blade angles, contrarily to Kaplan.

13) What is the role of the draft tube in a Francis turbine?

- ☑ To recover the kinetic energy by decreasing the axial velocity of the flow.
- ☐ To increase the static pressure at the runner outlet.
- ☐ To have a uniform flow velocity at the runner outlet.

Answer 1 is correct because it defines the actual purpose of the draft tube.

14) What is the phenomenon affecting Francis turbines operation which appears exclusively at partial load condition?

- ☐ Fatigue of the mechanical components.
- ☐ Development of cavitation on the runner blades.
- ☑ Development of a precession vortex rope.

Fatigue occurs for all conditions, and cavitation occurs for many regimes. Therefore answer 3 is correct.

15) For which site conditions you will likely select a bulb turbine?

- ☐ In case of very high head (> 1000 m).
- ☑ In case of low head conditions (< 5 m).
- ☐ In case of very large discharge. (> 250 m^3 s^{-1})

Very high heads are perfect for Pelton turbines, while very large discharge is ideal for Kaplan. Bulb turbines are made for very low heads, and answer 2 is correct.

16) In a generating unit equipped with a Kaplan turbine, in which conditions do you have the best efficiency?

- ☑ If the flow at the exit of the runner is fully axial, i.e. Cu = 0.
- ☐ If the tangential velocity is double the tangential component of the absolute velocity at the outlet section of the turbine.
- ☐ If the pitch of the blades is positioned at its maximum opening angle.

Answer 1 is the definition of BEP.

17) In a run of river power plant there is an important variation of the flow discharge during the year. Why is a Kaplan runner likely to be the best choice?

- ☐ Because it is a run of river power plant and the head will be the one in the range of Kaplan turbine.
- ☑ Because with a large discharge variation a Kaplan turbine is particularly suitable as it is possible to adjust guides vanes and blade angle to have good performance in the operating range.
- ☐ Because it allows avoiding cavitation for all range of flow discharge.

Answer 1 is untrue because a Francis might work for run of river. Answer 3 is wrong because cavitation is also a problem for Kaplan turbines, and there is no guarantee it can be avoided altogether.

Answer 2 is correct, as Kaplan have 2 degrees of freedom for adapting to large discharge variations: changing the guide vane angle, just like for Francis turbines, and changing the blade angle. This allows a broad range of operation.

18) What is a ternary group?

- ☑ A generating and pumping group where the electrical machine, the turbine and the pump are on the same shaft.

- ☐ A generating and pumping group with three pump-turbines in parallel.
- ☐ A generating and pumping group with one electrical machine and two pump-turbines in series.

Answer 1 is the definition of a ternary group.

19) How is the required setting level of the hydraulic machine computed in a hydropower plant?

- ☐ By knowing the minimum Net Positive Suction Head (NPSH).
- ☐ By measuring the minimum pressure in the hydraulic machine.
- ☐ By measuring the maximum discharge traversing the hydraulic machine.

The setting level is defined as $h_s = Z_{ref} - Z_{\bar{B}}$. Answer 1 is correct because knowing the NPSH provides the minimum head required to avoid cavitation, which constrains Z_{ref}.

20) If a pumping unit needs to provide frequency regulation through hydraulic bypass, how can the power input be modified at plant level?

- ☐ By shutting off the pump.
- ☐ By changing the opening of the Pelton injector if it is a ternary group.
- ☐ By changing the blade position of the pump impeller.

Simply shutting off the pump doesn't provide frequency regulation, and pumps cannot change their blades position. Therefore answers 1 and 3 are false.

Answer 2 is correct because, in a ternary group, the Pelton runner power output can be adjusted by varying the opening of its injectors, which sets the jet condition and thus the turbine rotation.