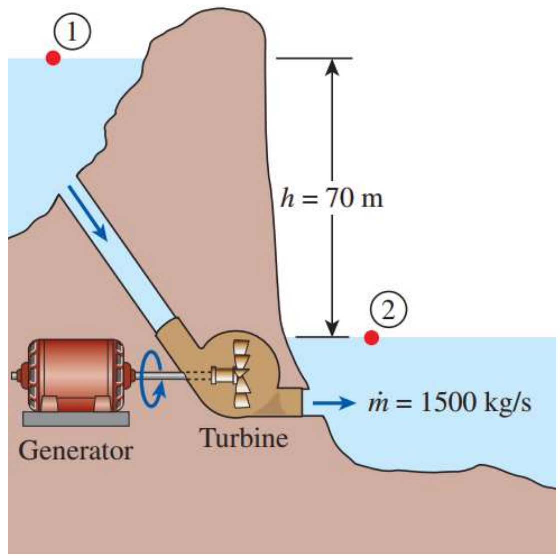
Given:

Electric power is to be generated by installing a hydraulic turbine–generator at a site 70 m below the free surface of a large water reservoir that can supply water at a rate of 1500 kg/s steadily. Neglect losses in the pipes.

Required:

If the mechanical power output of the turbine is 800 kW and the electric power generation is 750 kW, determine the turbine efficiency and the combined turbine-generator efficiency of this plant.



Solution:

The elevation change is given as

$$h := 70\text{m}$$

The mass flow rate of the water is defined as

$$m' := 1500 \frac{\text{kg}}{\text{s}}$$

The power output of the turbine is

$$E'_{turb} := 800\text{kW}$$

The power ouptut of the generator is

$$E'_{gen} := 750\text{kW}$$

The mechanical energy extracted from the fluid is given by the expression below.

$$\Delta E'_{mech} = m' \cdot \left[\frac{P_2 - P_1}{\rho} + \frac{V_2^{\,2} - V_1^{\,2}}{2} + g \cdot (z_2 - z_1) \right]$$

Recognizing that the pressure at state 1 and 2 are both at atmospheric conditions, the change in pressure term goes to zero. This is shown below.

$$\Delta E'_{mech} = m' \cdot \left[\frac{V_2^{\,2} - V_1^{\,2}}{2} + g \cdot (z_2 - z_1) \right]$$

Similarly, the velocities are state 1 and 2 are relatively low (i.e. approximately zero). So the change in the squares of the velocities goes to zero. This is shown below.

$$\Delta E'_{mech} = m' \cdot g \cdot (z_2 - z_1) = m' \cdot g \cdot h$$

$$\Delta E'_{mech} := m' \cdot g \cdot h = 1.03 \cdot \text{MW}$$

The efficiency of the turbine is then

$$\boxed{\eta_{turb} := \frac{E'_{turb}}{\Delta E'_{mech}} = 77.69 \cdot \%}$$

The efficiency of the turbine-generator system is then

$$\boxed{\eta_{turb\text{-}gen} := \frac{E'_{gen}}{\Delta E'_{mech}} = 72.84 \cdot \%}$$

Discussion:

These answers are reasonable. It is expected that the efficiency of the turbine-generator system would be less than that of just the turbine. The efficiency of just the generator could also be determined. This is shown below.

$$\eta_{gen} := \frac{E'_{gen}}{E'_{turb}} = 93.75 \cdot \%$$

The efficiency of the turbine-generator system is then found by

$$\eta_{turb\text{-}gen} := \eta_{turb} \cdot \eta_{gen} = 72.84 \cdot \%$$

This matches the previous answer.