# Hydropower Plants: Generating and Pumping Units
# Solved Problems: Series 5

**Reversible Pump-turbine power plant**

1) What is the role of the draft tube in a Francis-type reversible pump-turbine?
2) What are the advantages of having a variable speed unit?
3) In Figure 1, identify the components of the reversible pump-turbine listed in Table 1.

*Table 1: Components to identify*

| | |
|---|---|
| 1 | Impeller |
| 2 | Guide vanes |
| 3 | Blade |
| 4 | Draft tube cone |
| 5 | Shaft |
| 6 | Stay vanes |
| 7 | Spiral case |

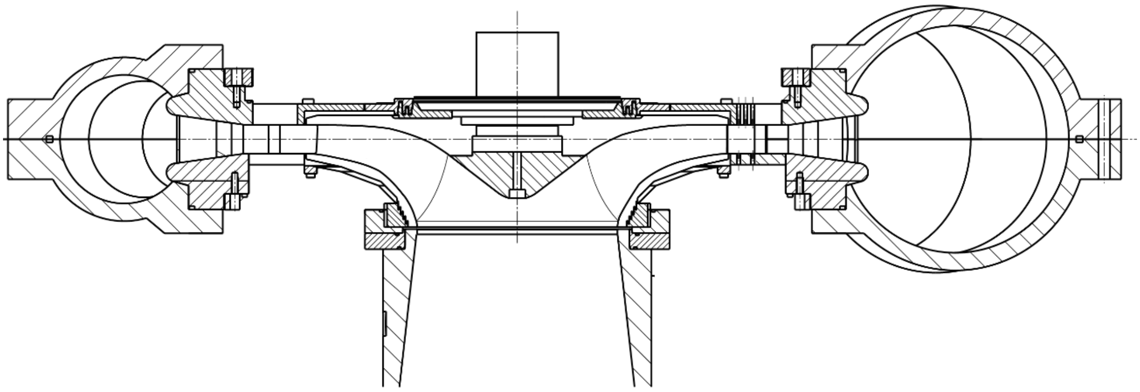

*Figure 1: Cutview of the reversible pump-turbine*

In the following questions, we are interested in the best efficiency point (BEP) of the reversible pump-turbine. The corresponding parameters of the power plant at BEP are given in Table 2.

*Table 2: Parameters of the power plant at BEP*

| Variable | Unit | Value |
|---|---|---|
| $Q$ | ($m^3 \cdot s^{-1}$) | 235 |
| $\eta_e$ | (-) | 0.95 |
| $Z_B$ | (m) | 750 |
| $Z_{\bar{B}}$ | (m) | 573 |
| $N$ | ($min^{-1}$) | 128.6 |
| $D_{1e}$ | (m) | 7.4 |
| $D_{\bar{1}e}$ | (m) | 5.4 |
| $B$ | (m) | 1 |

| Variable | Unit | Value |
|---|---|---|
| $\rho$ | $(kg \cdot m^{-3})$ | 1000 |
| $g$ | $(m \cdot s^{-2})$ | 9.81 |

4) Compute the potential hydraulic energy of the hydropower plant.
5) For the rated discharge, the specific energy losses in the complete hydraulic circuit are estimated to $gH_r = 9.5\ J \cdot kg^{-1}$. Compute the available specific energy $E$.
6) Compute the hydraulic power $P_h$.
7) Neglecting the mechanical losses and introducing the energy efficiency $\eta_e$, derive a relation between the final supplied power $P$ and the hydraulic power $P_h$.
8) Determine the final supplied power $P$ and the torque $T$.
9) Compute the external runner rotating velocity at the runner inlet and outlet, respectively $U_{1e}$ and $U_{\bar{1}e}$.
10) Compute the meridional component of the absolute flow velocity at the runner inlet and outlet, respectively $Cm_{1e}$ and $Cm_{\bar{1}e}$.
11) Compute the transformed specific energy $E_t$.
12) Compute the peripheral component of the absolute flow velocity at the runner inlet and outlet, respectively $Cu_{1e}$ and $Cu_{\bar{1}e}$.
13) Compute the absolute and relative flow angles at the runner inlet, $\alpha_{1e}$ and $\beta_{1e}$ respectively, and sketch qualitatively the velocity triangle at the runner inlet.
14) Now sketch qualitatively the velocity triangle at the runner outlet at the BEP.

For the last part of this exercise, we want to study the pump-turbine at off-design conditions.

15) The operator wants to operate the machine at off-design conditions with a lower discharge to adjust the output power of the machine. How can he do that?
16) The discharge value is now lower than the value at the Best Efficiency Point. Illustrate qualitatively the new situation with the velocity triangle at the runner outlet.
17) What phenomenon can occur in the draft tube in this case?