

HYDRAULIC TURBOMACHINES

Exercises 6

Francis Turbines

Hydropower plant equipped with Francis turbines

La Grande III power plant is located in Northern Québec on La Grande river. LG III power plant features 12 units of 200 MW capacity each. Their main characteristics at the best efficiency point are listed in Table 1.

Table 1 LG III Francis main characteristics at BEP

Parameter	Definition
$E = 780 \text{ J} \cdot \text{kg}^{-1}$	Available specific energy
$Q = 275 \text{ m}^3 \cdot \text{s}^{-1}$	Discharge
$N = 112.5 \text{ min}^{-1}$	Rotating speed
$Z_B = 175.6 \text{ m}$	Elevation of the tailrace free surface
$C_T = 0.86 \text{ m} \cdot \text{s}^{-1}$	Flow velocity at the draft tube outlet
$D_{le} = 5.484 \text{ m}$	Diameter at the leading edge - shroud intersection
$D_{te} = 5.240 \text{ m}$	Diameter at the trailing edge - shroud intersection
$D_o = 6.680 \text{ m}$	Diameter at the guide vane axis
$B_o = 1.397 \text{ m}$	Inlet channel height
$\eta_{elec} = 99.3\%$	Generator efficiency
$\eta_m = 98.8\%$	Mechanical efficiency
$\eta_q = 99.6\%$	Volumetric efficiency

- 1) Compute the torque T at the turbine-generator coupling.
- 2) Calculate η , the global efficiency of the turbine.
- 3) Neglecting the disc friction power losses, compute the discharge traversing through the turbine runner, Q_t , and the transformed specific energy, E_t .
- 4) Calculate the meridional component of the absolute flow velocity at the runner inlet and at the runner outlet, C_{m_i} and C_{m_T} , respectively.
- 5) Calculate the blade angle at the shroud, β_{Te} .
- 6) Calculate the blade angle at the shroud, β_{le} .

- 7) Estimate the guide vane opening, α_0 , by assuming that it is equal to the absolute flow angle at the guide vane axis location. It can be assumed that the flow angular momentum is conserved between the guide vane and the runner inlet.
- 8) Sketch properly the inlet and outlet velocity diagrams. Use the grid provided in Figure 1.

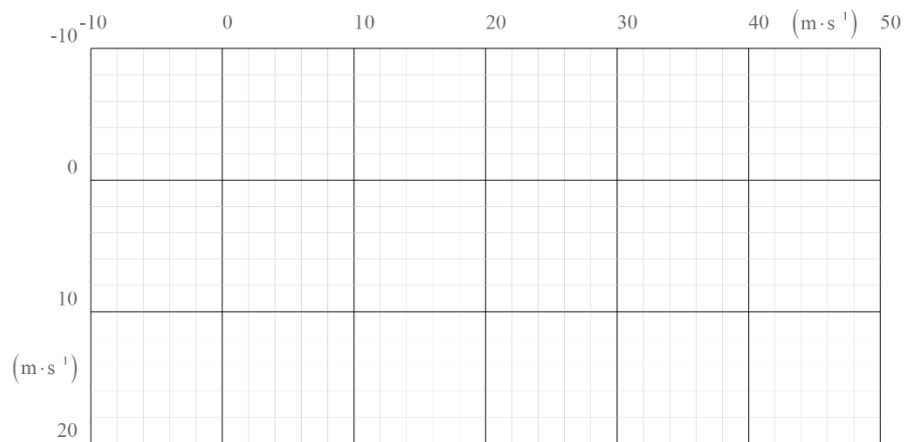


Figure 1: Velocity diagram at the turbine inlet (top) and outlet (bottom).

- 9) How to operate the machine with a lower discharge to decrease the power output, the head being constant?
- 10) The machine is now operating at partial load. Illustrate qualitatively the new situation with the velocity triangle at the runner outlet.