National Technical University of Athens - Department of Water Resources & Environment

Course: Renewable Energy & Hydroelectric Projects

Academic year: 2023-24

Project 1: General layout design and turbine mix selection of a small hydroelectric diversion project

At a river location, in the upper reaches of the Pinios, the construction of a small hydroelectric diversion project (run-off-river) is being studied. The catchment location, hydrographic network and contours are given in shapefile (*shp) files. Also, a sample of the average daily flows for a period of 41 hydrological years (1/1/1980 to 31/12/2021) is available at the water intake site, given in an excel file. In the electromechanical (E/M) study of the project, one or two Francis-type turbines are proposed, the efficiency curve of which (efficiency degree as a function of the flow) is given by an analytical parametric relationship (see notes), while the overall efficiency of the rest E/M equipment (generators, transformers) is estimated at 95%. The minimum operating output of the specific turbines is equal to 30% of the nominal.

Figure 1: Area of interest, showing the hydrographic network, catchment location and upstream catchment boundaries.

1. Identify a suitable location of the power station and sketch all necessary project elements (inlet canal, loading tank, penstock, power station) in a Geographic Information System (GIS).

2. Estimate the environmental flow that should be channelled downstream of the water intake, based on the requirements of the Greek legislation.

3. Construct a simulation model of the daily operation of the project, applying: (a) one Francis turbine, 4.0 MW, and (b) a mixture of two Francis turbines, 3.0 and 1.0 MW.

4. Estimate the characteristic performance measures of the above two alternative layouts (average annual energy production, capacity factor, turbine uptime percentage, exploitable volume percentage).

5. Suggest an optimum mix of Francis turbines to ensure maximum annual energy production, with a capacity factor of at least 30%.

Note 1: For the hydraulic calculations, to estimate the net drop height, consider that a diameter of 3.0 m is applied to the intake pipe, and the equivalent roughness and local loss factor are taken to be k_s= 1.0 mm and k= 1.50, respectively.

Note 2: The theoretical background relevant to the simulation of small hydroelectric projects is detailed in the following publication, which we encourage you to consult when preparing the exercise:

Sakki, G.-K., I. Tsoukalas, and A. Efstratiadis, A reverse engineering approach across small hydropower plants: a hidden treasure of hydrological data?, Hydrological Sciences Journal, 67(1), 94–106, doi:10.1080/02626667.2021.2000992, 2022.