UNIVERSITY OF WEST ATTICA
FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

MSc by Research in Electrical and Electronics Engineering
Indicative homework assignment in the course: MRES.B.02.07- Small Hydro-electric power plant

Calculation of the produced energy of a small hydro-electric power plant & Examination of the investement viability
The following data are given:

- The average monthly stream flow at intake position is given for 10 consecutive years, according to the following table, in m^3/sec, if the aforementioned values are multiplied by factor α_1 :

	1	2	3	4	5	6	7	8	9	10
October	1.07	2.25	4.37	2.87	2.43	2.54	1.95	1.45	0.97	2.55
November	3.72	3.38	4.37	2.89	3.87	3.54	3.57	3.27	3.66	4.22
December	2.24	8.76	10.7	8.56	6.95	5.43	4.53	3.75	7.72	11.47
January	3.43	3.93	3.87	7.27	7.43	4.53	5.15	4.02	3.93	7.24
February	7.27	5.83	4.75	5.42	5.62	5.64	7.89	8.45	8.11	7.91
March	4.15	4.75	3.95	5.23	4.03	4.77	4.57	5.61	7.48	7.35
April	4.29	4.03	3.15	4.61	3.26	3.45	5.88	5.15	5.11	5.37
May	3.92	3.59	4.25	3.48	3.42	3.37	3.79	4.15	4.58	4.76
June	2.75	2.85	2.68	3.42	2.63	2.52	3.13	3.15	3.95	3.34
July	2.96	2.86	4.51	3.75	2.56	2.72	2.65	3.34	2.91	3.81
August	2.85	2.79	3.02	3.04	2.08	2.70	3.53	2.37	2.71	2.39
September	2.75	3.52	3.12	2.89	2.42	2.22	2.35	2.37	2.75	2.22

- The available hydraulic head is $h=130\cdot\alpha_2$ in m
- The length of the penstock is $L=1150+20\cdot\alpha_3$ in m

Factor α_1 is equal to:

$$\alpha_1=0.85+N/50$$

where *N* the order of the first letter of your surname.
Factor α_2 is equal to:

$$\alpha_2=0.75+M/40$$

where *M* the order of the first letter of your name.
Factor α_3 is equal to *N*.

The following steps should be carried out:
(a) Design the available flow duration curve (using 120 points) and calculate the average monthly available flow (from the data of 10 years). The available flow will be estimated, if the residual flow is subtracted from the stream flow. The residual flow is the maximum among: (1) the 30% of the weighted average stream flow for June, July and August (taking into consideration the different number of days for the respective months), (2) the 50% of the monthly average stream flow for September, (3) 30 lt/s.

(b) Determine the nominal operation point of the turbine so as to be equal to Q_{40}, where Q_{40} is determined by the flow duration curve as the typical value for the proportion of time 40% during which the flow exceeds or equals a certain value Q_{40}.
(c) Select the category of hydro-turbine (i.e. Pelton, Francis, Kaplan etc.) according to its nominal available flow and nominal net hydraulic head, next the model-type (from manufacturer's datasheet) and determine its nominal power, its nominal efficiency, as well as other technical specifications. Following, select the category of generator (i.e. synchronous, induction, etc.) according to its theoretical nominal active power and its theoretical nominal apparent power, next the model-type (from manufacturer's datasheet) and determine its nominal active power, its nominal apparent power and its nominal efficiency, as well as other technical specifications (i.e. frequency, rotational speed etc.). The nominal power factor for generator inductive load is 80%. Following, select the category of transformer (i.e. dry, oil-immersed, etc.), next the model-type (from manufacturer's datasheet) and determine its nominal active power, its nominal apparent power and its nominal efficiency, as well as other technical specifications (i.e. frequency, primary winding voltage, secondary winding voltage, group vector, etc.). The nominal power factor is equal to generator one.
(d) Calculate the annual produced active power and the respective capacity factor (from the data of 10 years). Design the produced active power duration curve of the small hydroelectric power plant with respect to time duration (using 120 points).
(e) Calculate the total investment costs and the respective simple payback period, where the electricity market costs are equal to 0.08 €/kWh and the annual expenses are equal to 13% of the annual revenue. Is there any difference at payback period, if the deflated payback period is used, where the constant deflated discount rate is equal to 7.5%, the construction period is 2 years and the total investment costs are splitted into two equal parts? What is the net present value after 20 years of operation? What is the internal rate of return for the investment payback period to be equal to 5 years (after the first operation)?

From the calculations the following assumptions are made:

- one hydro-turbine is used,
- the penstock is from steel,
- the water speed should be smaller than 4 m/sec,
- the total head losses should be smaller than 10% of the available hydraulic head,
- the total local resistance of all elements (valves, curves, intake point, etch.) is equal to 6,
- the efficiencies of turbine, generator and transformer remain stable and are equal to the nominal ones for different flows.