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The Influence of Hydraulic lay out on the Performances of the Hydraulic Turbine from HPP Raul Alb

At the commissioning of HPP Raul Alb hydro units it has been found that the hydro units were unable to achieve the guaranteed maximum power. The present work paper presents the results of the tests performed in order to determine the maximum power it can reach these two hydro units in single and parallel operating mode.

***Keywords**: turbine, hydro unit, power, turbine power, hydraulic lay out*

1. Introduction

The HPP Raul Alb is part of hydropower development Bistra – Poiana Marului – Ruieni – Poiana Rusca that belongs to Hydropower Branch Caransebes. The hydropower plant was finalized in 2009 with commissioning of the second hydro unit. The power plant is equipped with two vertical Francis turbine type FVM 21-231. The characteristics of the power plant are the follows:

- Installed power: 41 MW
- Installed discharge: 21 m^3/s;
- Rated discharge: 10.5 m^3/s;
- Maximum gross head: 233.5 m;
- Minimum gross head: 218.5 m;
- Rated net head: 231 m;
- Turbine power: 21000 kW;
- Runner diameter: 1350 mm.

In present paper are presented the results of the index tests performed in order to determine the maximum power and efficiency which can be achieved by the both hydro units in singular and parallel operating mode considering that, at the construction of the plant, (figure 1) does not allow to achieve maximum power.

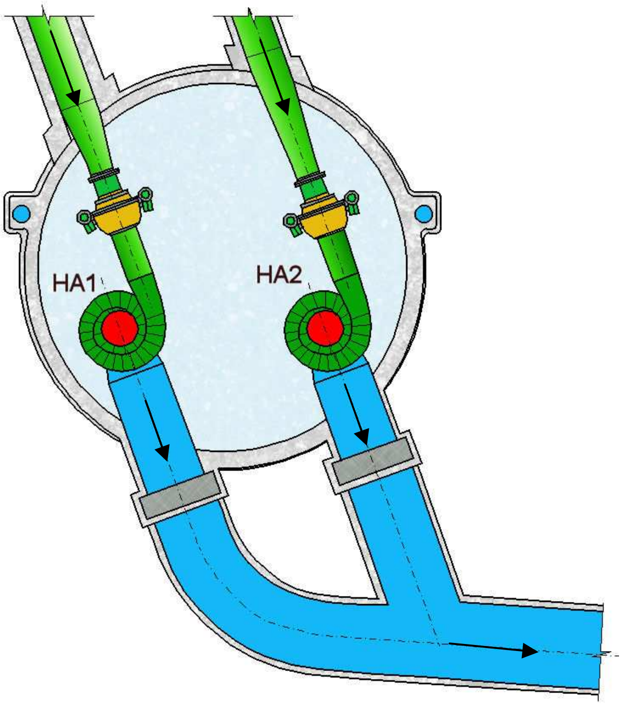

Figure 1. Horizontal section at the turbine level of HPP Raul Alb.

2. Index tests performed on hydraulic turbines

The index tests are defined [1] as all tests which are made in Hydro power plant in order to determine the discharge and efficiency in relative values. The index tests gives only relative values of the discharge and efficiency and are considered as secondary methods. They are normally used during the commissioning and operation of the machine and can be considered as a part of the field acceptance tests only when the relative discharge measuring method is calibrated by a method accepted by [1].

Form [1] an index value is an arbitrarily scaled value. Relative values are derived from index values by expressing them as a proportion of the value at an agreed condition. The index efficiency is calculated using the measured values of specific hydraulic energy and power, and the discharge, measured as an index value by an uncalibrated device. Relative efficiency is expressed as proportion of any index efficiency at reference index efficiency, for example de maximum values.

An index test may be used as a part of the field acceptance test for any of the following purposes [1]:

- to determine the correct relationship between runner/impeller blade angle and guide vane opening for most efficient operation of double-regulated machines.
- to provide additional tests data during a field efficiency test. This is particularly important if the primary method shows excessive uncertainties fall out in a certain operating range. The index discharge device in this case shall be calibrated by discharge filed measurements performed in the favorable operating range.

In additional to the field acceptance test, an index test may useful also for other purposes, such as:

- to determine the performance characteristics as expressed by the relative values of power, discharge and efficiency;
- to check the power guarantee if both parties agree;
- to extend information on performance outside the guaranteed range if the index discharge devices has been calibrated;
- to assess the change in efficiency and/or power due to the onset of cavitation resulting from a change of suction specific potential energy and/or specific hydraulic energy of the machine;
- to assess the change in efficiency and/or power of the machine resulting from wear, repair or modification. When using an index tests for this purpose it must be noted that the modification may effect flow patterns in the measuring sections;
- to obtain data for permanent discharge measuring instruments by assuming an absolute value of turbine efficiency at some operating point or by calibration with field efficiency test results;
- to optimize the operating of a power station with several units;
- to compare the index curves on the prototype with the curves expected on the basis of model tests.

2.1. Index tests performed in HPP Raul-Alb

In order to determine the turbine power and efficiency, the following measurements was performed:

- pressure at the entrance of the spiral case;
- discharge using Winter-Kennedy method;
- wicket gates servomotor stroke;
- tail water level;
- active power.

From the values recorded was computed:

- The net head:

$$H_n = \left(\frac{p_i}{\gamma} + \frac{v_i^2}{2g} + z_i \right) - \left(\frac{p_e}{\gamma} + \frac{v_e^2}{2g} + z_e \right) \tag{1}$$

$$H_n = z_i - z_e + \frac{Q^2}{2g}\left(\frac{1}{S_i^2} - \frac{1}{S_e^2}\right) + \frac{p_i}{\gamma} - \frac{p_e}{\gamma} \quad (2)$$

where: z_i is upstream elevation at the entrance section of the spiral case, z_e – downstream elevation at the exit section from the draft tube, S_i – the turbine entrance section, S_e – the turbine exit section, p_i – the pressure at the entrance in spiral case, p_e – the pressure at the exit from draft tube.

- Turbine hydraulic power

$$P_T = \rho \cdot g \cdot H_n \cdot Q \cdot \eta_h = \frac{P_A}{\eta_G} \quad (3)$$

where P_A is generator active power, η_G – generator theoretical efficiency.

- The index discharge:

$$Q_i = k_{WK} \cdot \sqrt{\Delta h} \quad (4)$$

where k_{WK} is the Winter – Kennedy coefficient and Δh is measured Winter-Kennedy differential pressure in spiral case.

- The turbine efficiency:

$$\eta_T = \eta_h = \frac{P_T}{\rho \cdot g \cdot H_n Q_i} \quad (5)$$

- The hydro unit efficiency:

$$\eta_A = \eta_T \cdot \eta_G \quad (6)$$

The measurement was begin from maximum power to minimum power, for 8 – 10 wicket gates blade positions (figure 2). At the HPP Raul – Alb turbines 24 wicket gates blade positions was measured for both hydro units.

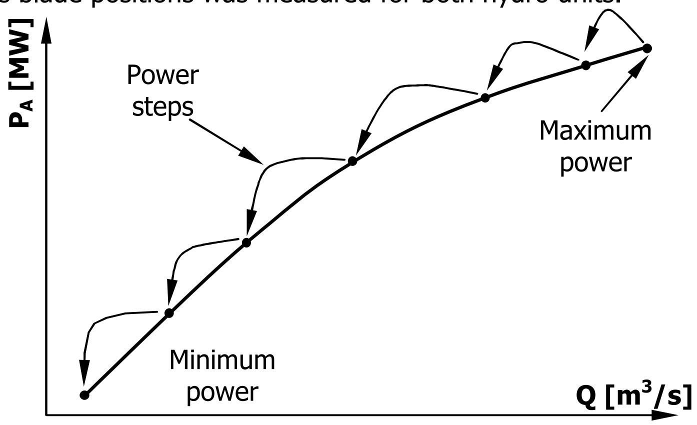

Figure 2. P_A = f(Q) for one head.

In order to determine the maximum achievable power and efficiency has proceeded has follows: the measurement was performed on hydro unit 1 (HA1) with hydro unit 2 (HA2) off, then the HA2 was started and the measurement was performed on the both hydro units and in the end the HA1 was off and the measurement performed on HA2.

3. The results obtained from index tests

3.1. Maximum power and efficiency for turbine no.1 with turbine no2 off

In table 1 are presented the results of the measurements performed on turbine no.1, using the procedure presented above, with turbine no.2 off and the figure 3 presents the comparison between measured efficiency and scaled up from model efficiency. Figure 4 shows the comparison between the turbine power measured and scaled up from model.

Table 1.

Nr. Pct.	Q_i	η_T	P_T	P_A
	[m^3/s]	[-]	[MW]	[MW]
1	10.249	88.222	20.35	19.9
2	10.277	88	20.35	19.9
3	10.29	88.103	20.4	19.95
4	10.596	84.716	20.18	19.73
5	10.824	80.318	19.53	19.09
6	8.671	92.323	18.11	17.69
7	8.658	92.201	18.05	17.63
8	7.818	91.684	16.26	15.85
9	7.793	92.228	16.29	15.88
10	6.558	90.353	13.47	13.09
11	5.721	87.573	11.4	11.03
12	4.211	80.585	7.76	7.4

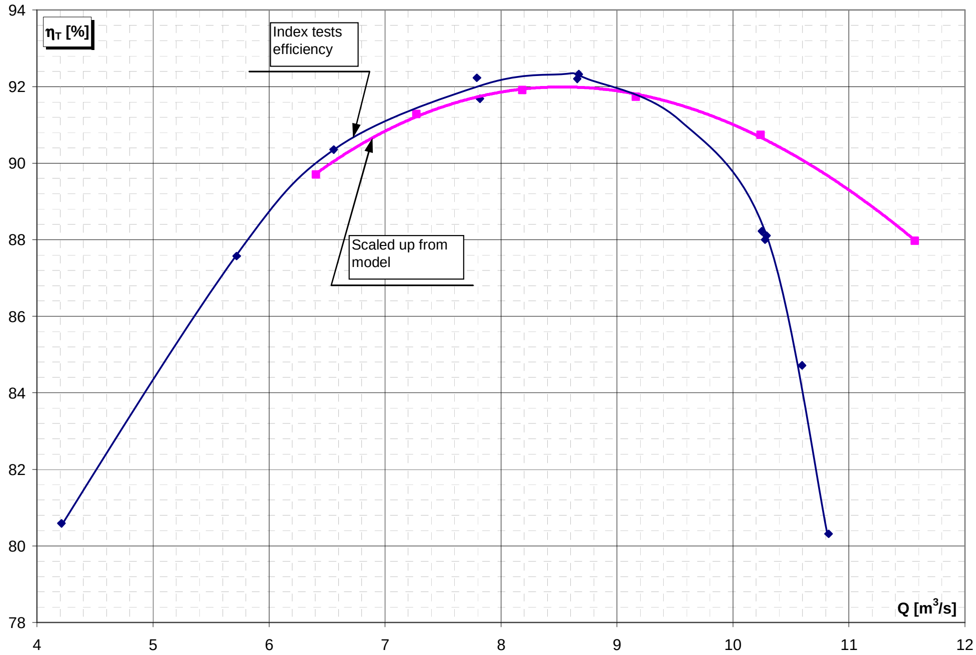

Figure 3. η_T = f(Q) for HA1 with HA2 off

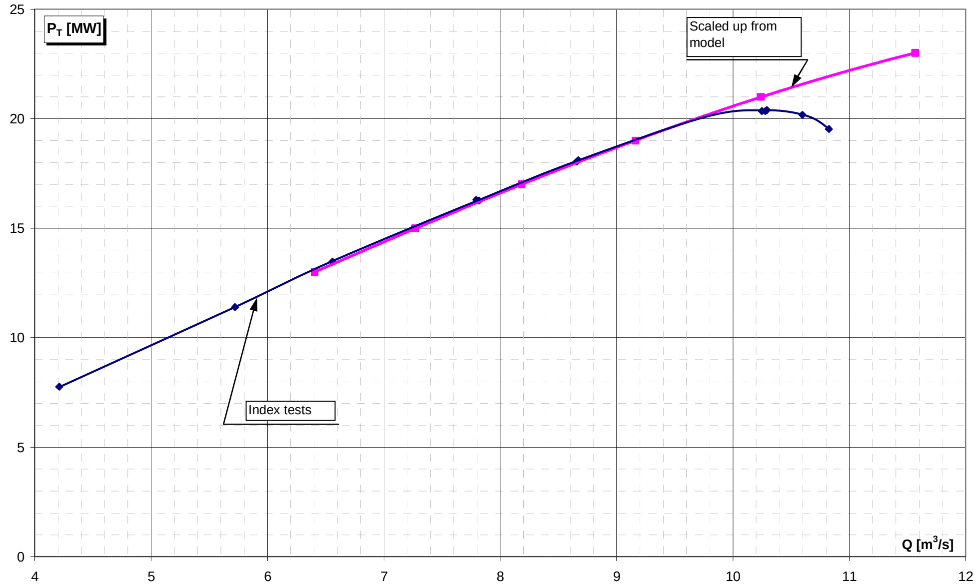

Figure 4. P_T = f(Q) for HA1 with HA2 off

3.2. Maximum power and efficiency for turbine no.1 and turbine no.2

In this case the hydro unit no. 1 was started and charged at maximum power that can be achieved and on hydro unit no. 2 was performed the index test procedure described above. Table 2 present numerical results and figures 5 and 6 the graphical ones.

Table 2.

Nr. Crt.	HA2				HA1			
	η_T	Q_i	P_A	P_T	P_A	P_T	Q	η_T
	[%]	[m^3/s]	[MW]	[MW]	[MW]	[MW]	[m^3/s]	[%]
1	89.94	9.03	17.4	17.82	18.66	19.1	10.20016	88.81568
2	89.53	9.03	17.4	17.82	18.66	19.1	10.19884	89.12969
3	73.53	10.63	16.65	17.06	17.6	18.02	11.54646	79.91516
4	90.84	7.07	14.7	15.09	19	19.44	10.24034	89.15536
5	91.5	7.07	14.7	15.09	19	19.44	10.23853	88.76499
6	89.82	5.8	11.9	12.28	19.2	19.64	10.23904	88.79719
7	87.26	4.15	8	8.36	19.21	19.65	10.2365	87.73186

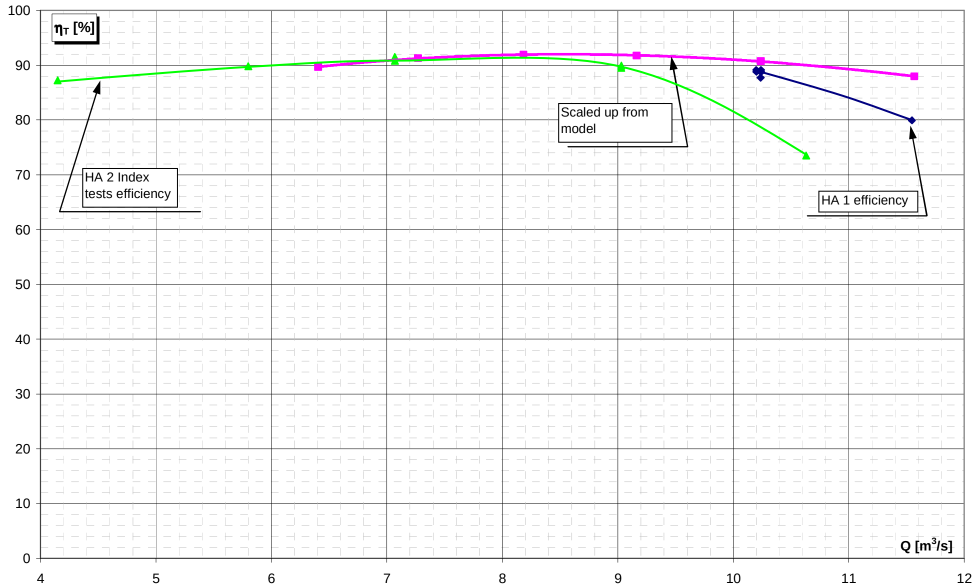

Figure 5. η_T = f(Q) for HA1 at maximum power and HA2 index tests

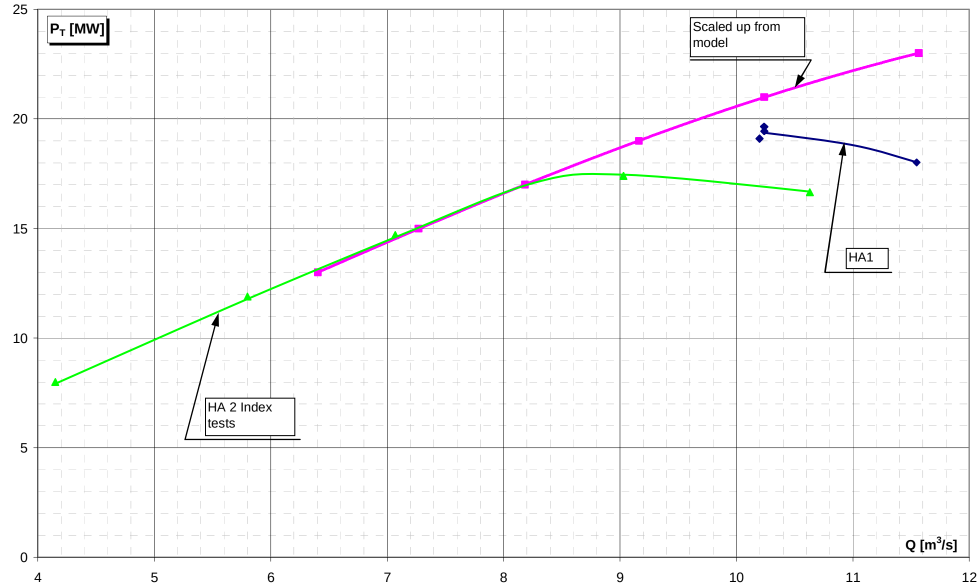

Figure 6. P_T = f(Q) for HA1 at maximum power and HA2 index tests

3.2. Maximum power and efficiency for turbine no.2 with turbine no.1 off

The final step of this index tests was to determine the maximum power and efficiency for turbine no. 2 with no. 1 off using the same procedure. The results are presented numerically in table 3 and graphic in figure 7 and 8.

Table 3.

Nr. Crt.	HA2			
	Q_i [m^3/s]	η_T [%]	P_A [MW]	P_T [MW]
1	4.55	85.42	8.46	8.83
2	6.05	88.73	11.8	12.18
3	7.55	90.73	15.2	15.6
4	9.59	87.69	18.71	19.15

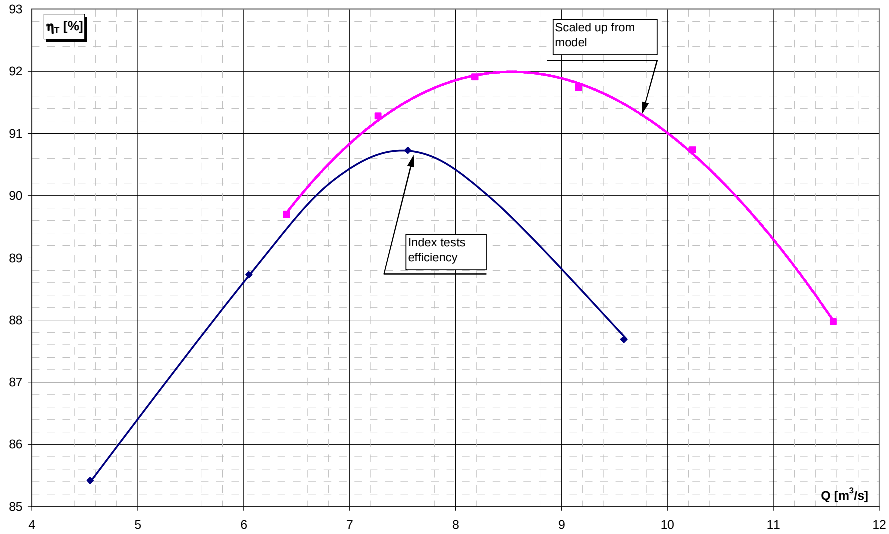

Figure 7. η_T = f(Q) for HA2 with HA1 off

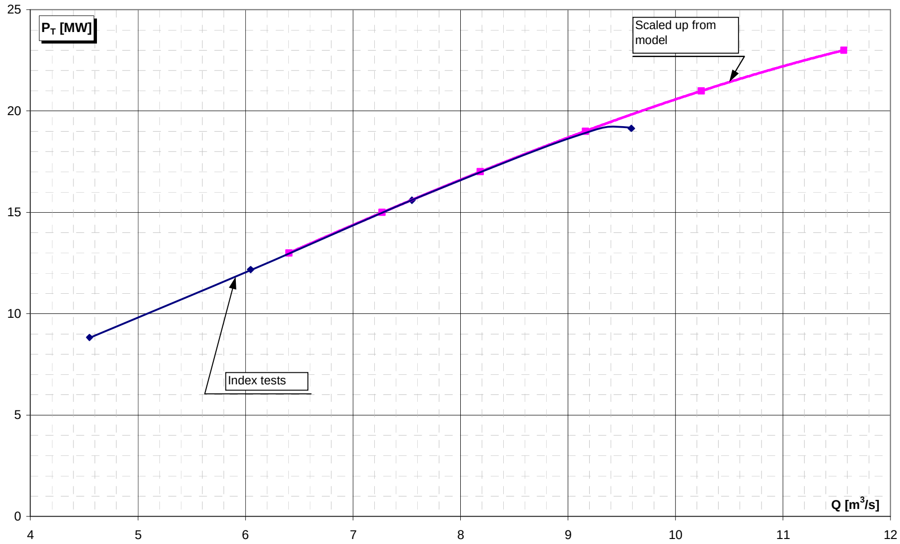

Figure 8. P_T = f(Q) for HA2 with HA1 off

4. Conclusion

From index tests performed and the results obtained, the following conclusions can be made:

- the efficiency of turbine no. 1 is higher than the no. 2 turbine, and for a discharge of 10.5 m^3/s this difference is up to 7%.
- there are differences of discharges between these two turbines working singular or in parallel;
- the maximum power of turbine no. 1 is 20.4 MW with turbine no.2 off and the maximum power for turbine no. 2 with no. 1 off is 19.14 MW;
- the maximum power that turbine no. 2 with turbine no. 1 on is 17.82 MW;
- the maximum power difference between turbine no. 1 and turbine no. 2 when the next hydro unit is off is 1.26 MW;
- the turbine no. 2 maximum power drops with 1.32 MW from 19.14 MW to 17.82 MW;

The differences between efficiency and power result from the flow conditions in the tailwater channel. The flow direction at the exit from turbine no. 2 are perpendicular to one of turbine no. 1.

References

[1] ***** *Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and bulb turbines*. International Standard IEC 41/1991-11.

[2] Winter, Ireal A., Kennedy, A.M., *Improvement Type of Flow Meter for Hydraulic Turbine*, ASCE Proceeding, Vol. 59, No.4, Part 1, April 1933, pp. 565 – 584.

[3] Câmpian C.V., *Probe index la turbinele hidraulice, Analele Universităţii „Eftimie Murgu" din Reşiţa*, Anul IV, nr.1, Reşiţa 1999, pag. 57 – 32.

[4] Câmpian C.V. ş.a., *Probe index etapa a II-a pentru trasarea diagramei reale de exploatare a hidroagregatului. Probe index la căderea H=228,04m*. Raport tehnic CCHAPT nr. U-10-400-292, martie 2010.

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