



Adrian Cuzmoș, Cosmin Dumbravă, Constantin Viorel Câmpian, Dorian Nedelcu

Index Tests Performed on a Francis Turbine from HPP Ruieni

Index test are a set of measurements performed on hydro units in order to determine the relative flow and the relative efficiency. This method is usually used on refurbished hydro units, before and after rehabilitation. [1]

Key words *Index tests, Francis turbine, hydro unit, wicket gates, relative efficiency*

1. Introduction

From 2003 to 2007, on HPP Ruieni HA1 a set o test (index test) was performed, in order to determine the turbine efficiency for three different heads. The final application that results from this test are to implement a system for optimal exploitation of these hydro units [2]. This paper work presents only the methodology used for tests and some results.

2. Test method

The methodology for index tests on hydro units are present in IEC 60041 – "Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines" and this tests are performed in accordance with this international standard.

After the tests the follow operation was performed:

- Winter-Kennedy pressure taps was cleaned in accordance with IEC 60041;
- The trash rack was cleaned;
- The "on line" acquisition system and transducers are mounted and calibrated.

Usually, the tests are performed as follows:

- The hydro unit is started at the maximum power and first point of measure is recorded;
- The wicket gates are closed in steps, and for each step a point of measure are recorded;
- The last point of measure is at the minimum power that can be obtained.

For one head 8 -10 position of wicket gates opening are recorded and in this case, for this hydro unit, 8 positions was recorded.

Graphically, the measurement method is presented in figure 1.

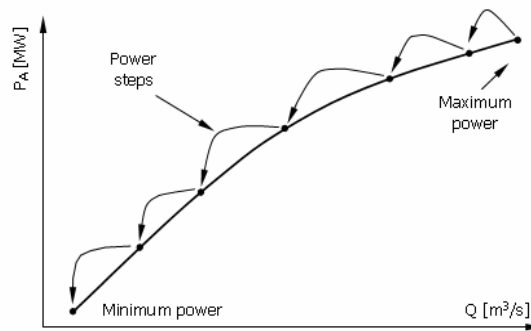


Figure 1

2. Measurement instruments

The measurement was performed by CCHAPT Resita and all the instrument are property of CCHAPT.

The measuring system is in accordance with IEC 60041 and is composed by:

- Transducers for electrical, mechanical and hydraulic process;
- Data acquisition system;
- Computer;
- Software - developed by CCHAPT.

Figure 1 presented a section from HPP Ruienii and the location for transducers that was mounted on hydro unit for tests.

The signification for symbols presented in figure 2 is:

P [MW] – generator active power;

p_{cs} [bar] – pressure at the entrance of spiral case;

S_{AD} – wicket gates opening;

p_{sad} – pressure in wicket gates servomotor;

Δ_{WK} – Winter – Kennedy differential pressure;

z_{av} – tail water level.

All this measures values are computed "on line" and were stored on PC.

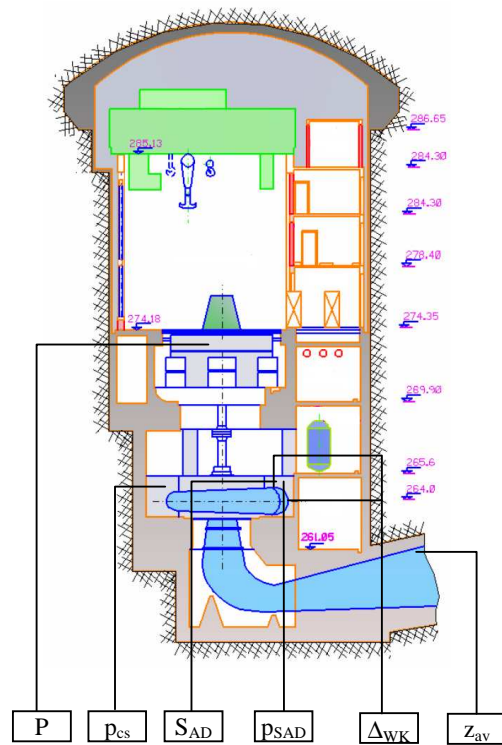


Figure 2

3. Computed values

From the values recorded the follow values was calculated:

- Net head H_n [m]:

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

where:

z_i is head water level measured at the entrance of spiral case;

z_e – tail water level;

Q – discharge;

g – acceleration due to gravity;

S_i – section at the entrance in spiral case (inlet section);

S_e – section at the exit of draft tube (outlet section);
 P_i – pressure measured in inlet section;
 P_e – pressure measured in outlet section.

- Turbine hydraulic power P_t [MW]:

$$P_T = \rho \cdot g \cdot H_n \cdot Q \cdot \eta_h = \frac{P_A}{\eta_G} \quad (2)$$

where:

P_A – active power measured;

η_G – generator efficiency.

The turbine mechanical losses are neglected.

- Turbine efficiency η_t :

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

- Hydro unit efficiency η_A :

$$\eta_A = \eta_T \cdot \eta_G \quad (4)$$

Knowing the water density, acceleration due gravity, reference levels, control surface and the correspondence between wicket gate blade opening and stroke of servomotor and the model hill chart three heads was measured in three years.

4. Results of measurements

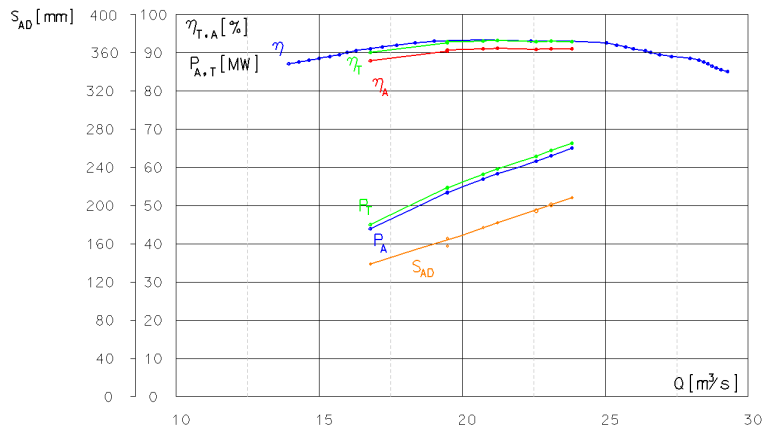


Figure 3 Results of index test for head $H = 306,5$ m

In year 2003 the test was performed at the head $H = 306,5$ m, and the result, are presented in figure 3.

The significations of notation made in figure 3 are the follow: η is turbine efficiency determined from the model hill chart for head $H = 306,5$ m; η_t – turbine

efficiency determined from index tests; η_A – hydro unit efficiency determined from index tests; P_T – turbine power calculated; P_A – generator power measured, S_{AD} – wicket gate servomotor stroke.

The next heat measured was $H = 317,5$ m and the tests were performed in 2004, in the same condition with the first one. The results are presented in figure 4 with the same signification of notation.

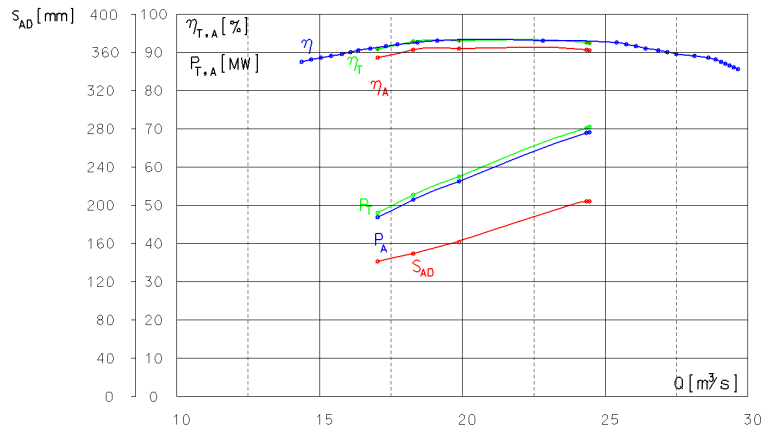


Figure 4 Results of index test for head $H = 317,5$ m

Last head $H = 325,6$ m was measured in 2006 and the results are presented in figure 5.

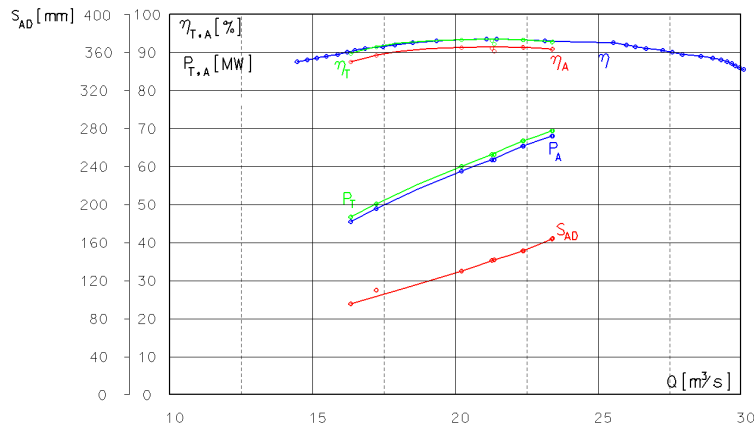


Figure 5 Results of index test for head $H = 325,6$ m

5. Conclusion

The index tests performed on this hydro unit shows that the turbine operate very good. The difference between measured turbine efficiency and efficiency determined from the model hill chart are small, 0,41% for low discharge and 0,14% for high discharge.

These sets of tests validate the prototype hill chart developed by CCHAPT which is integrated in a monitoring system for hydro unit optimization that is functional in HPP Rueni

References

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Addresses:

- Eng. Adrian Cuzmos "Eftimie Murgu" University of Reșița, Piața Traian Vuia, nr. 1-4, 320085, Reșița, a.cuzmos@uem.ro
- Eng. Cosmin Dumbrava "Eftimie Murgu" University of Reșița, Piața Traian Vuia, nr. 1-4, 320085, Reșița, cosmin.d@uem.ro
- Prof. Dr. Eng. Constantin Viorel Câmpian, "Eftimie Murgu" University of Reșița, Piața Traian Vuia, nr. 1-4, 320085, Reșița, v.campianu@uem.ro
- Prof. Dr. Eng. Dorian Nedelcu, "Eftimie Murgu" University of Reșița, Piața Traian Vuia, nr. 1-4, 320085, Reșița, d.nedelcu@uem.ro