ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XX, NR. 1, 2013, ISSN 1453 - 7397

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Intex Tests Performed on Hydro Unit n°2 from HPP Ruieni before and after Refurbishment

The paper work presents the results of index tests performed on HPP Ruieni hydro unit n°2 before and after refurbishment, using for discharge measurements the Winter-Kennedy method.

***Keywords**: Index tests, hydro unit, hydraulic turbine, wicket gates, Winter-Kennedy method*

1. Introduction

In the year 2010 Hydropower Branch Caransebes decided to put hydro unit n°2 from HPP Ruieni in refurbishment or LN4 type works. These types of activities are done once at 25 – 30 years and their objectives are to prepare the hydro unit for a new cycle of exploitation. Shortly, for turbine, this type of works means:

- runner blade and wicket gates refurbishment;
- turbine cover and draft tube refurbishment;
- central cone replacement;
- turbine bearing refurbishment.

"Eftimie Murgu" University Research Center in Hydraulic, Automation and Heat Processes – CCHAPT carried out the index tests before and after rehabilitation.

2. Problem formulation

2.1. HPP Ruieni technical data

The HPP Ruieni is underground plant type equipped with two vertical Francis turbines and 153 MW installed power.

The technical specifications for each turbines are:

Inlet runner diameter	D_{1e} = 2,6 m
Rated speed	n = 428,6 rpm
Maximum net head	H_{max} = 350 m

Maximum power at maximum head	P_{max} = 76,5 MW
Rated net head	H_c = 326 m
Rated net head maximum power	P_{max} = 76,5 MW
Minimum net head	H_{min} = 250 m
Minimum power	P = 40 MW

Figure 1. Turbine shaft, turbine bearing and wicket gates

2.2. Index tests

The index tests performed on hydro unit n^{o}2 from HPP Ruieni was performed in accordance with [1]. One of the index test application described in [1] is the determination machine of efficiency and/or power due to wearing, after rehabilitation or a turbine constructive change and this is the purpose of this measurements.

In order to perform the tests, the maximum power corresponding to the existing head was achieved using the main command of the hydro unit, a period of time was necessary to obtain a steady state without pressure oscillation in penstock. When the above condition was obtained the first point of measurement was recorded. The period necessary to obtain a steady state after a power modification was approx. 2 minutes. The signals acquisition period has been established at 2 minutes and the sampling rate 1 Hz. 7 position of wicket gates before and 10 after was recorded, each wicket gate position representing a power step.

The index efficiency is:

$$\eta_{ix} = \frac{P_T}{\rho \cdot g \cdot H_n \cdot Q_{ix}} \tag{1}$$

where P_T is turbine power, ρ - water density, g – acceleration due to gravity, H_n – net head, Q_{ix} – index discharge measured using Winter-Kennedy method.

The turbine power was computed using the following formula:

$$P_T = \frac{P_A}{\eta_G} \tag{2}$$

where P_A – active power, η_G - generator efficiency determined using calorimetric method at the test performed after rehabilitation and the theoretical one at the tests before.

For the net head was used:

$$H_n = z_i - z_e + \frac{Q_{ix}^2}{2g}\left(\frac{1}{S_i^2} - \frac{1}{S_e^2}\right) + \frac{p_i}{\gamma} - \frac{p_e}{\gamma} \tag{3}$$

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.

Te index discharge was computed using the following formula:

$$Q_{ix} = 20{,}8 \cdot \Delta p^{0.51} \tag{4}$$

where Δp is measured Winter-Kennedy differential pressure in spiral case, 20,8 – is Winter-Kennedy coefficient determined from previous tests.

2.3. Winter-Kennedy method

The method are based on the correlation between water discharge that pass trough the turbine and the pressure measured on two pressure taps applied on the spiral case, pressure taps located on the same spiral case radial section, figure 2, the method was described for the first time in [2] and detailed in [1].

For this index tests on the hydro unit n°2 was used 1-2 pair of taps, the differential pressure was measured using a SIMEAS type differential sensor presented in figure 3.

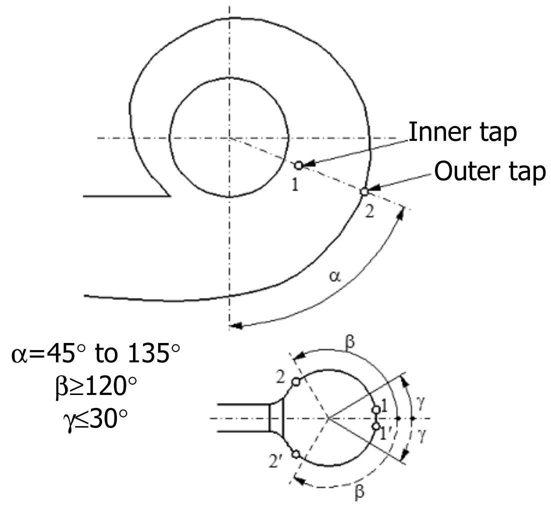

Figure 2. Location of taps for Winter-Kennedy method of discharge measurement through a turbine equipped with steel spiral case [1]

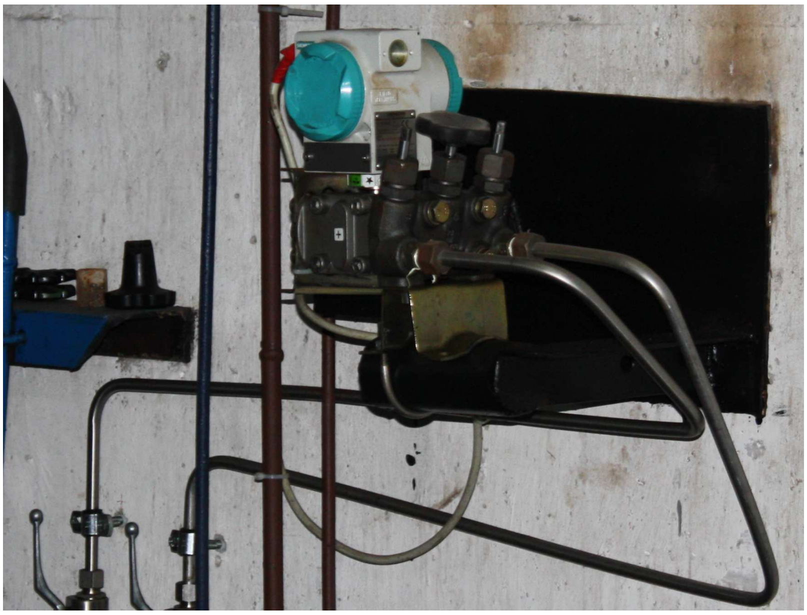

Figure 3. The transducer used for Winter-Kennedy differential pressure measurements

2.4. Measurement instruments

For index tests before and after rehabilitation, was used the same measurement instruments. In table 1 are presented type of the measurement instruments used and measured elements.

Table 1.

Data acquisition system and active power measurement	Digitline VPA 323
Wicket gates servomotor stroke	Linear transducer type Temposonics MTS G series 0 - 500 mm
Pressure at the entrance in spiral case	Pressure transducer GS 4200, 0 – 60 bar
Winter-Kennedy differential pressure	Differential pressure transducer type SITRANS P DS3
Tail water level	Level immersed transducer type MJK 7050

2.5. Measurement errors

In order to evaluate the efficiency measurement errors was taking in to account the discharge, head and power measurement errors and also the accuracy of the measurement instruments and prescribes from [1].

The global error for efficiency measurement was computed with:

$$\varepsilon_\eta = \sqrt{\varepsilon_H^2 + \varepsilon_Q^2 + \varepsilon_P^2} \tag{6}$$

where ε_H is global error for head measurements, ε_Q – global error for discharge measurements and ε_P – global error for active power measurements.

The global error for efficiency measurement both before and after rehabilitation was ε_η = 0.978%.

3. The results

The index tests were performed in two stages:

- before rehabilitation in June 2010;
- after rehabilitation in May 2012.

The power steps for tests before and after rehabilitation were approx. 5 MW and the necessary time, from maximum to minimum power, were approx. 1 hour.

Figure 4 presents the graphic results for the tests performed on the hydro unit in June 2010 and figure 5 the results obtained in May 2012. The both curves are compared with the ones obtained from the scale up from model.

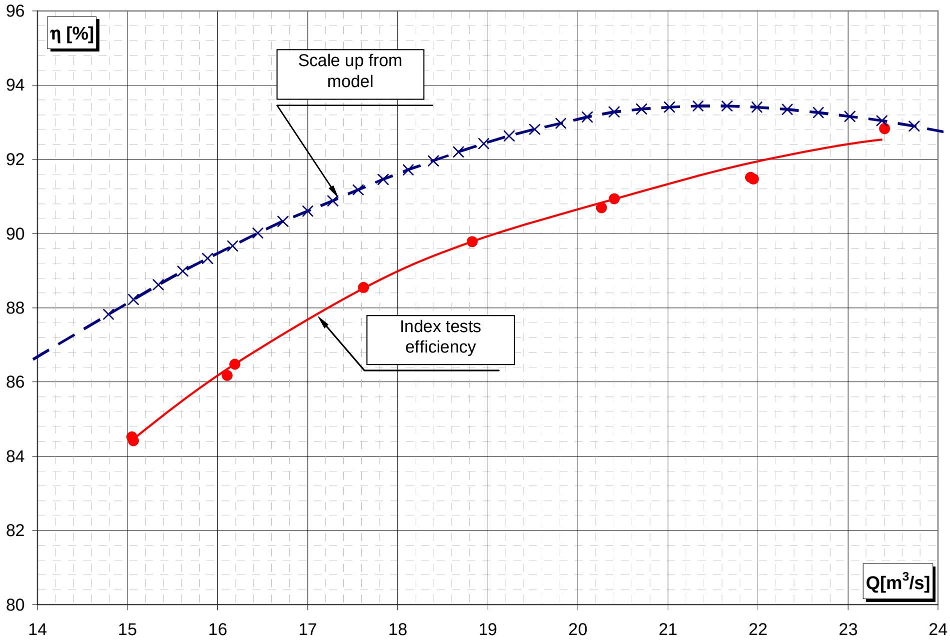

Figure 4. Graphical results from test June 2010

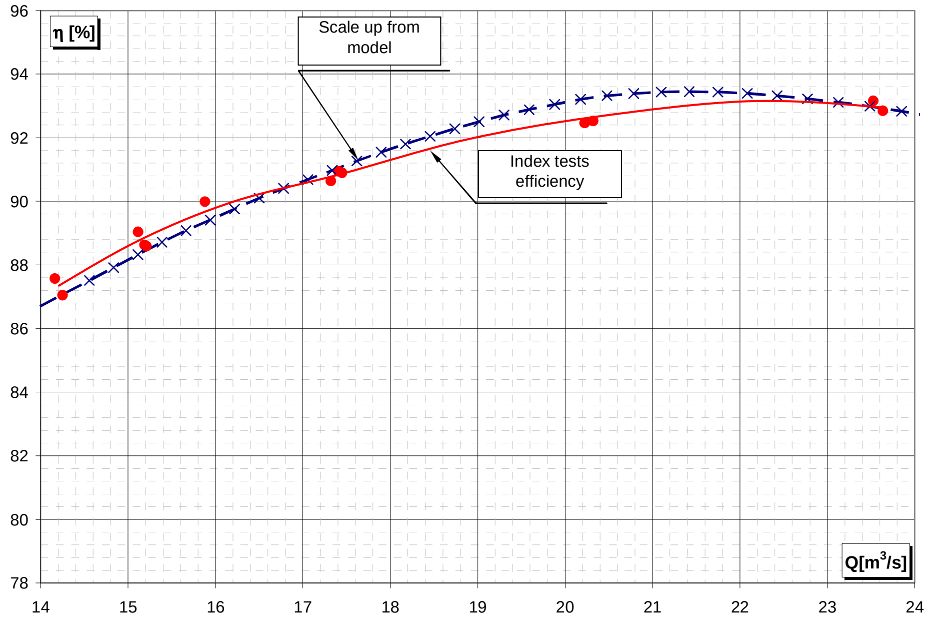

Figure 5. Graphical results from test May 2012

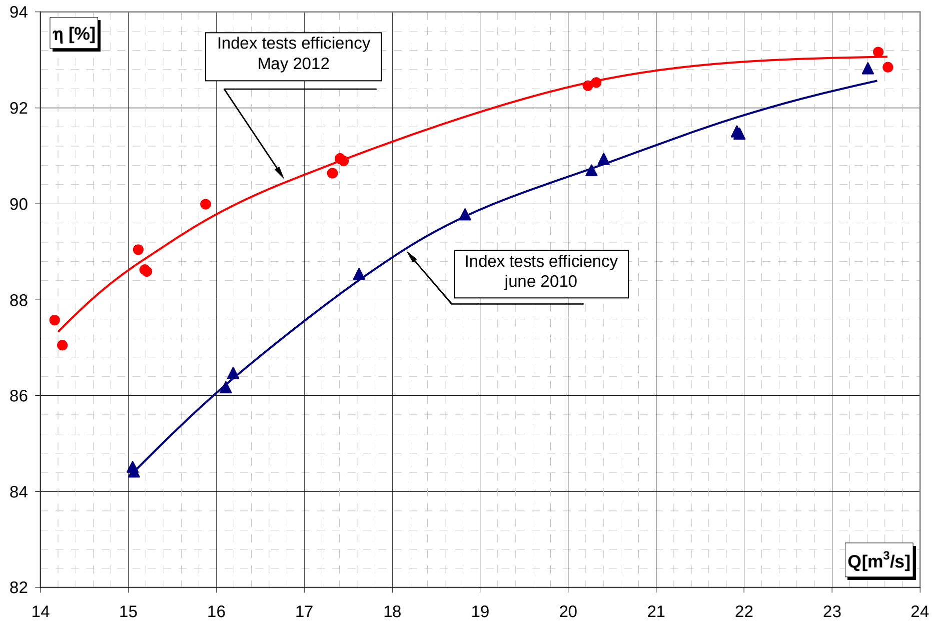

Figure 6. Comparison between the efficiency determined in June 2010 and May 2012

From figure 4 it can be seen that the turbine efficiency is lower than the scale up from model (which is considered to be optimum) with over 2% on almost all domain. Since the generator efficiency curve used in computation is the theoretical one, which corresponds to a new or refurbished generator, in reality the generator efficiency is few percent lower than the used in computation, we can say that the turbine efficiency in this case is lower at least 4 – 6 % that the optimum one.

The turbine efficiency which results from the index tests performed in May 2012 (figure 5) is very close in value of the scale up from model. The difference between them is maximum 0.3%. We have to mention that in the turbine efficiency computation for a May 2012 test was used the generator efficiency determined using the calorimetric method.

After rehabilitation, the turbine efficiency has been improved with 1 – 3.5% which leads to the conclusion that the rehabilitation works achieved his goal.

4. Conclusion

From the index test carried out and the results obtained we conclude that the rehabilitation works achieved his goal a turbine efficiency increase with 1 – 3.5%.

The owner of HPP Ruieni was obtained, after the index tests, important information which can be used for better planning of maintenance or rehabilitation interval but also a good basis to estimate de efficiency losses in time.

Also, after the index tests, the Winter-Kennedy coefficient were determined which can be used to continuous monitoring of the discharge.

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