Scientific Bulletin of the
Politehnica University of Timisoara
Transactions on Mechanics Special issue

The International Conference on
Hydraulic Machinery and Equipments
Timisoara, Romania, October 16-17, 2008

EFFICIENCY MEASUREMENTS ON HYDROUNITS NO. 1 IN REMETI HYDRO POWER PLANT

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ABSTRACT

According IEC standard 60041/1999, before and after refurbishment performance measurements are required. In this paper performance measurements made by CCHAPT Resita before refurbishment on hydro units no. 1 in Remeti hydro power plant will be presented. The discharge, the head, the power and efficiency turbine parameters were obtained by evaluating results of index tests. Prototype hill chart of the turbine was determined by scale-up from the model, according to the IEC 60193 standards. The hydro generator efficiency was measured by thermodynamic method.

KEYWORDS

Hydro power plant, turbine, refurbishment, index tests.

INTRODUCTION

Hydro power plants Remeţi and Munteni are designated to adjust the energetic system during peaks load. Together with the Leşu hydro power plant, they form a local energetic complex, included in a unique program of exploitation, to assure the discharge regulation for Crişul Repede area.

Hydro power plant Remeţi is equipped with 2 vertical Francis turbine type FVM 54,3 – 305, with metallic spiral casing. The hydro generator is of vertical type HVS 430/125-14.

The purpose of measurements conducted on Remeti hydro power plant was to determine the functional parameters and performances of the hydro unit no. 1, before the main rehabilitation, according to the standard IEC no. 41 from 1991 (EN 60041-2003) [1]. The following parameters were measured and calculated:

- the turbine power;
- the hydro unit power;
- the turbine efficiency;
- the hydro unit efficiency;
- electrical parameters;
- the hydro unit operation in transitory regime;
- the hydro unit operation in stabilized conditions.

DETERMINE THE HYDRO GENERATOR EFFICIENCY THROUGH THERMODYNAMIC METHOD

This method is applied when thermal stabilized regimes of nominal parameters cannot be achieved. The method gives the sum of losses for multiple operating regimes of the hydro generator, which means that this method is indirect. The measured agent is the cooling air. The velocities, temperatures, surface areas are measured at different levels of the hydro generator.

The conditions during measurement are as following:

- the hydro generator must operate under the same technical conditions for the entire period of measurements;
- the temperature of the environment and the hydro generator vicinity must be less variable;
- the cooling air discharge must be less variable.

The measurements devices are:

- anemometer type YK 2005AM;
- device for temperature measurement type Optris Lasersight XTemp LS;
- temperature transducer type HBS 1/6000/3 with display LEDD-01;
- 2 ultrasonic flow meter type Siemens-Controlotron FUS1010;
- electrical transducers for P, U, I.

For temperature measurements of radiant surfaces the thermal resistances were placed at the following locations:

- on the superior cover of the hydro generator, figure 1;
- in the machine room, for the environment temperature;
- the exterior and interior walls of the hydro generator, figure 2;
- in the interior of the hydro generator for the environment temperature, figure 3;
- in a rectangular pattern with 49 measurements points, mounted on every cooler at about 200 mm from surface, figure 4, for the temperature of the cooler air speed;
- in the environment of the turbine;
- on the inferior cover of the hydro generator;
- in the entrance and exit area of the axial bearing cooling.

For discharge measurement of the cooling water of the axial and radial bearing, two measurement ultrasonic devices, placed on the linear part of the entrance pipe, were used, figure 5.

A transducer connected to a computer for electrical parameters measurement of the hydro generator was also used, figure 6.

The hydro unit efficiency for different active loads and at nominal power factor is calculated by using the following formula:

$$\eta = P/\left[P + \sum p\right] \qquad (1)$$

where:

- P – the active power at the hydro generator connectors;
- Σ p – the sum of power losses.

Figure 1 The temperature transducer mounted on the superior cover of the hydro generator

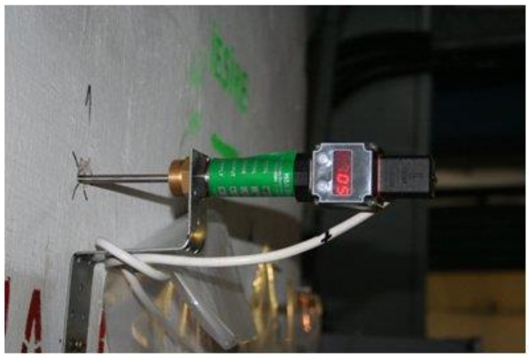

Figure 2 The temperature transducer mounted on the hydro generator wall

Figure 3 The environment temperature transducer mounted in the interior of the hydro generator

Figure 4 The rectangular pattern for cooler temperature measurements

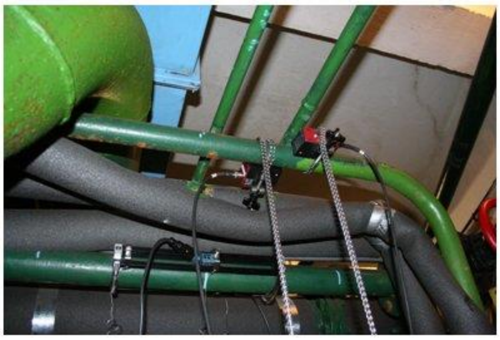

Figure 5 The ultrasonic devices for measurement of the cooling water discharge on the entrance in axial and radial bearing cooling

Figure 6 The transducer for electrical parameters measurement at the hydro generator

The discharge of the cooler is calculated using the following formula:

$$Q_A = \frac{\sum V_i}{n} \times A \qquad (m^3/sec) \qquad (2)$$

where:

- V_i – the air speed in point no. "i" (m/sec);
- n – total number of measure points;
- A – the cooling surface (m^2).

The total heat of the air passing through the cooler, transformed in power loss is:

$$P_{1A} = \sum \left(Q_A \times \Delta T \times \rho_A \times c_{pA} \right), \qquad (3)$$

where:

- Q_A – the cooler air discharge;
- ΔT – the difference between medium temperature of the warm and cold air of the cooler (degrees);
- ρ_A – the cooling air density;
- c_{pA} – the specific heat of the air.

The radiation and convection losses are algebraic added using the following formula:

$$P_2 = \sum \left(h_i \times A_i \times \Delta T_i \right) \qquad (4)$$

where:

- h_i – the heat transfer coefficient of the following surfaces: the superior and inferior cover of the hydro generator, the surface of axial bearing.

The thermal conduction losses through the generator wall were calculated through the following formula:

$$P_3 = \frac{\lambda \times A \times \Delta T}{d} \qquad (5)$$

where:

- P_3 – the thermal conduction losses;
- λ – the coefficient of thermal conductivity;
- A – the hydro generator area;
- d – the hydro generator wall thickness;
- ΔT – the temperature difference between exterior and interior hydro generator wall.

The measured efficiency of the hydro generator is shown in figure 7.

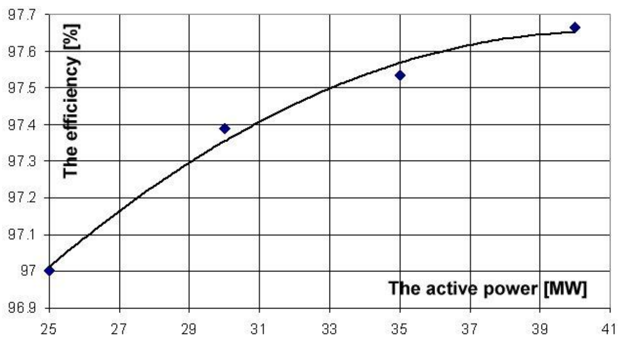

Figure 7 The measured efficiency of the hydro generator

The measured air velocity and temperature distribution on cooler 1 are shown in figure 8 and 9.

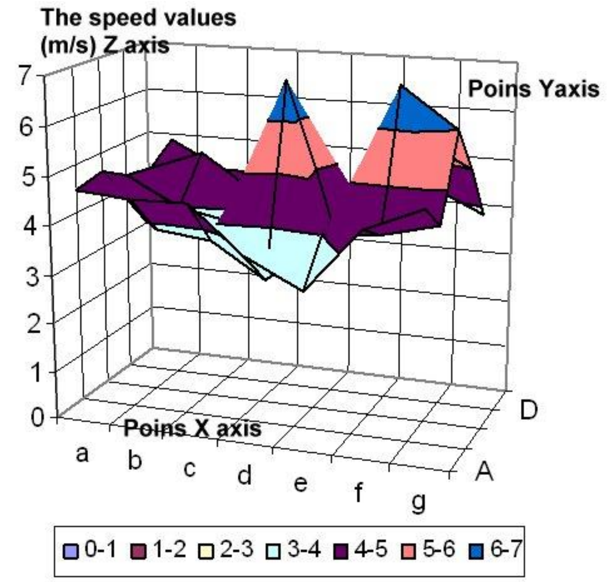

Figure 8 The measured velocity distribution on cooler 1

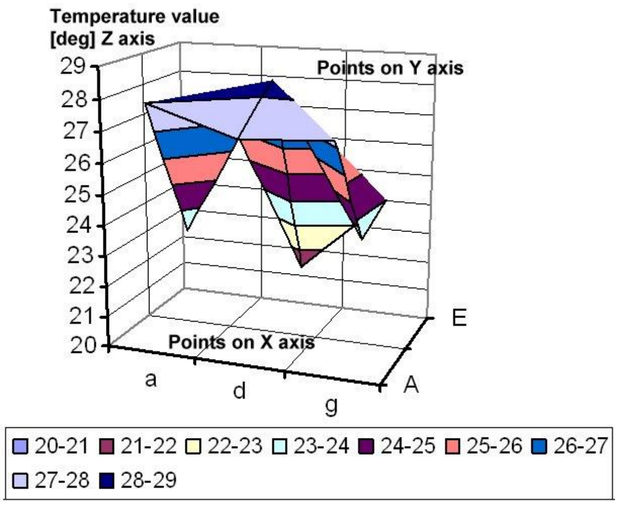

Figure 9 The measured temperature distribution on cooler 1

INDEX TESTS FOR THE HYDRO UNIT NO. 1 OF REMETI POWER PLANT

The procedure of the index tests are presented in [2]. The measured parameters are:

- electrical parameters of the hydro generator;
- wicket gates servomotor stroke – measured with a displacement transducer; the transducer is fixed on one of the control drive servomotor of the adjusting ring, figure 10;
- the pressure in the wicket gates servomotor, figure 11;

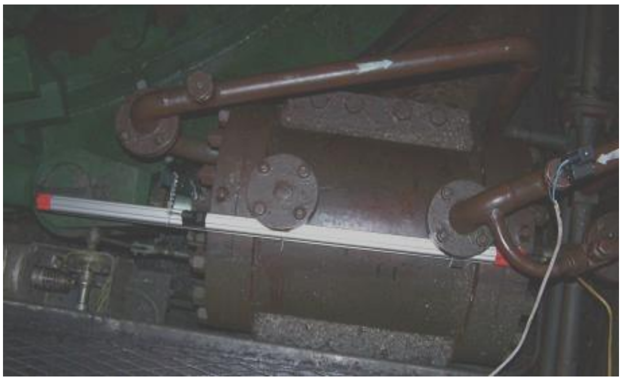

Figure 10 The device for wicket gates servomotor stroke measurement

- the pressure difference Δh – measured with a transducer Siemens SITRANS 7MF4433-1DA02-1AA1-Z according to Winter-Kennedy; the discharge is calculated through the formula:

$$Q = k_{WK} \cdot \Delta h^{n} \qquad (6)$$

The Winter-Kennedy methodology is presented in [3].

- the spiral casing pressure – measured with pressure transducer;
- head water level – measured before spiral casing with level transducer.

Figure 11 The device for pressure measurement on wicket gates servomotor

The index measurement schema for Remeti Hydro Power Plant is presented in figure 12.

The following constant parameters, reference levels and control surfaces were used:

- water density **ρ** – the constant value is calculated based of water temperature;
- gravitational acceleration **g** - the constant corresponds to the geographical location of the Remeti Power Plant;
- upstream turbine level $\mathbf{z_i}$ – corresponding to the entering level of the spiral casing, where the pressure transducer is placed;
- downstream turbine level $\mathbf{z_e}$ – at the exit of the draft tube, where the level transducer is placed; $z_e = f(\mathbf{z_{av}})$ where $\mathbf{z_{av}}$ is the transducer value;
- the input turbine section (spiral casing input section) $\mathbf{S_i}$;
- the output draft tube $\mathbf{S_e}$.

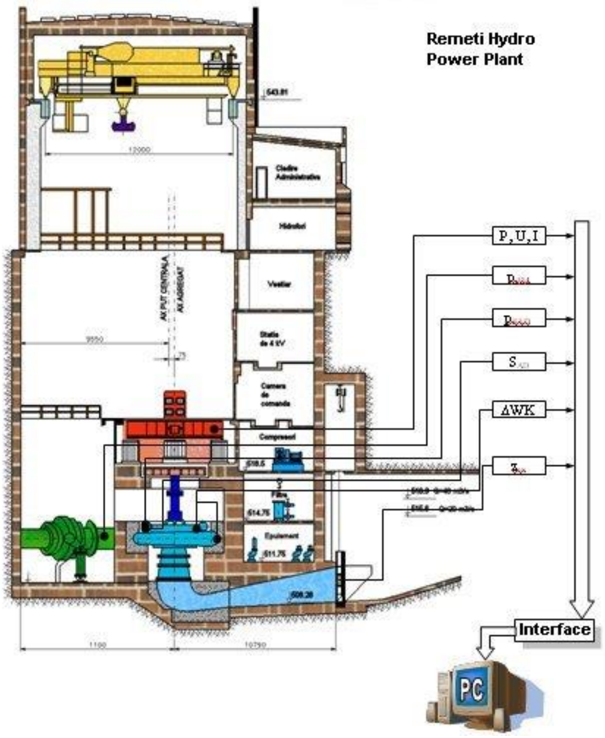

Figure 12 The index measurement schema for Remeti hydro power plant

The following relations are used for calculated parameters:

- the net head of turbine:

$$H_n = \left(\frac{p_i}{\gamma} + \frac{v_i^2}{2g} + z_i\right) - \left(\frac{p_e}{\gamma} + \frac{v_e^2}{2g} + z_e\right) \quad (7)$$

$$H_n = z_i - z_e + \frac{Q^2}{2g}\left(\frac{1}{S_i^2} - \frac{1}{S_e^2}\right) + \frac{p_i}{\gamma} - \frac{p_e}{\gamma} \quad (8)$$

- the head loss due to the trash rack:

$$\Delta h_R = z_{am} - \frac{v_{dg}^2}{2g} - z_{dg} = \sum hp_{am-dg} \quad (9)$$

where: $\mathbf{z_{am}}$ is the upstream level far before the trash rack; $\sum hp_{am-dg}$ are hydraulic losses between upstream and downstream area of the trash rack, $\mathbf{z_{dg}}$ the level in measuring section after trash rack;

- the head loss due to the trash rack clogging:

$$\Delta h_z = \Delta h_R - \Delta h_{RC} \quad (10)$$

where: $\mathbf{\Delta h_{RC}}$ is the head loss corresponding to a clean trash rack.

- the hydraulic turbine power (with mechanical losses neglected):

$$P_T = \rho \cdot g \cdot H_n \cdot Q \cdot \eta_T = \frac{P_a}{\eta_G} \quad (11)$$

- the turbine efficiency:

$$\eta_T = \eta_h = \frac{P_T}{\rho \cdot g \cdot H_n Q} \quad (12)$$

- the hydro unit efficiency:

$$\eta_A = \eta_T \cdot \eta_G \quad (13)$$

- the wicket gates opening $\mathbf{a_o}$ is correlated with the wicket gates servomotor stroke $\mathbf{S_{AD}}$ by a polynomial function, calculated from measurement of the two parameters for an imposed number of points.

Figure 13 presents the characteristics curves measured for a constant head value.

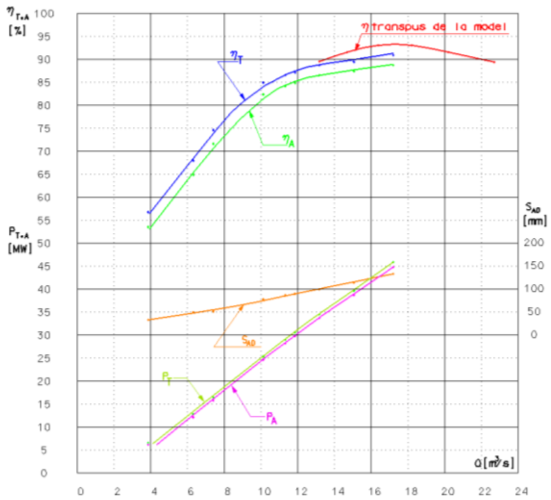

Figure 13 $\eta_T = f(Q)$, $\eta_A = f(Q)$, $S_{AD} = f(Q)$, $P_T = f(Q)$, $P_A = f(Q)$ for H = const.

From all transient regimes measured, figure 14 and 15 presents start up and hold-up tests, where the following parameters are represented as time function: the hydro generator power, voltage, current, wicket gates servomotor stroke and the pressure on a single face of the servomotor, the Winter-Kennedy pressure difference, the input pressure in the spiral casing.

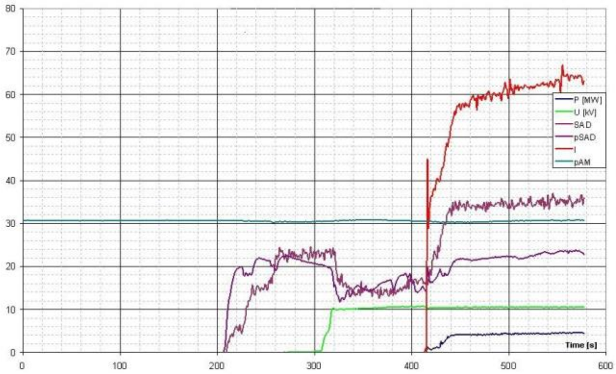

Figure 14 The start up test

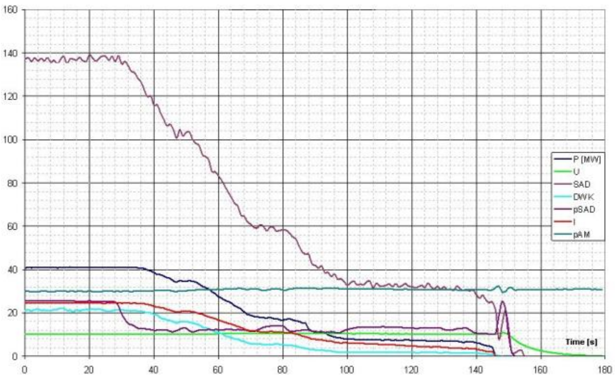

Figure 15 The hold-up test

Figure 16 presents the final prototype hill chart, calculated by model to prototype scale-up procedure using the standards IEC 60193 /1999 and 995 /1991 [4].

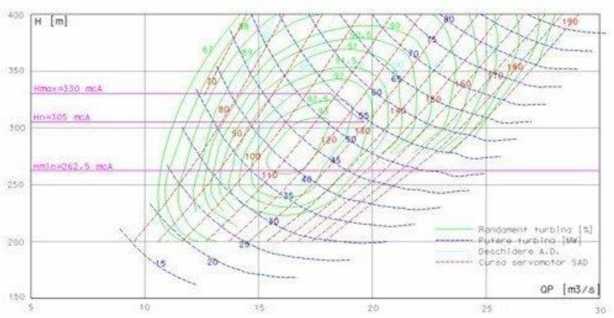

Figure 16 The calculated prototype hill chart
for Remeti Hydro Power Plant

CONCLUSIONS

This paper presents the methodology for efficiency measurement of the hydro generator and turbine, applied to the Remeti hydro power plant. The results of this diagnosis will be used for the actual and future rehabilitation of the Remeti hydro power plant.

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