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OPTIMUM OPERATION OF HYDROUNITS

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ABSTRACT

The paper presents an automatic system for the testing of the hydro units and for their operation with the maximum efficiency.

KEYWORDS

Turbine, generator, hydro unit, efficiency, discharge, power, head, pressure, wicket gates, runner.

NOMENCLATURE

Q	*[m³/s] discharge*
D	*[m] runner diameter*
η	*[-] efficiency*
ρ	*[kg/m³] water density*
H	*[m] head*
g	*[m/s²] gravity*

Subscripts and Superscripts

m	*model*
p	*prototype*

ABBREVIATIONS

WGS wicket gates servomotor

1. INTRODUCTION

For to determine of the performances and operational parameters, a data acquisition system continuous measure and processing the following mechanical and electrical data:

- head water and tail water levels for to compute the head and the losses of the head on the trash rack;
- discharges and volumes;
- power of the generator ;
- line voltages and phase currents at the generator;
- excitation voltage and currents;
- pressures on the piston of the wicked gates servomotors;
- opening of the wicket gates and runner blades;
- optimum cam;
- efficiency of the turbines;
- efficiency of the generator.

2. MEASURED AND COMPUTED DATA

The acquisition and processing the mechanical and electrical data is made by the following block diagram.

During (on line) a measuring point the computation of the all parameters is made. These parameters are:

2.1. Head

The head is computed from head water level, tail water level and discharge.

2.2. Discharge

The discharge is obtained by two methods: from turbine prototype hill chart, from Winter-Kennedy measurements.

The turbine prototype hill chart is obtained from model measurements scale up in accordance with IEC standards, 60193/1999 [1], with 995/1991 [2].

The discharge is:

$$Q = k \cdot \Delta p^n \tag{1}$$

where

$$\Delta p = p_{CS1} - p_{CS2} \tag{2}$$

The coefficient k and the exponent n are elected in such way, that the maximum efficiency corresponds to the maximum predicted efficiency of the turbine at the best point.

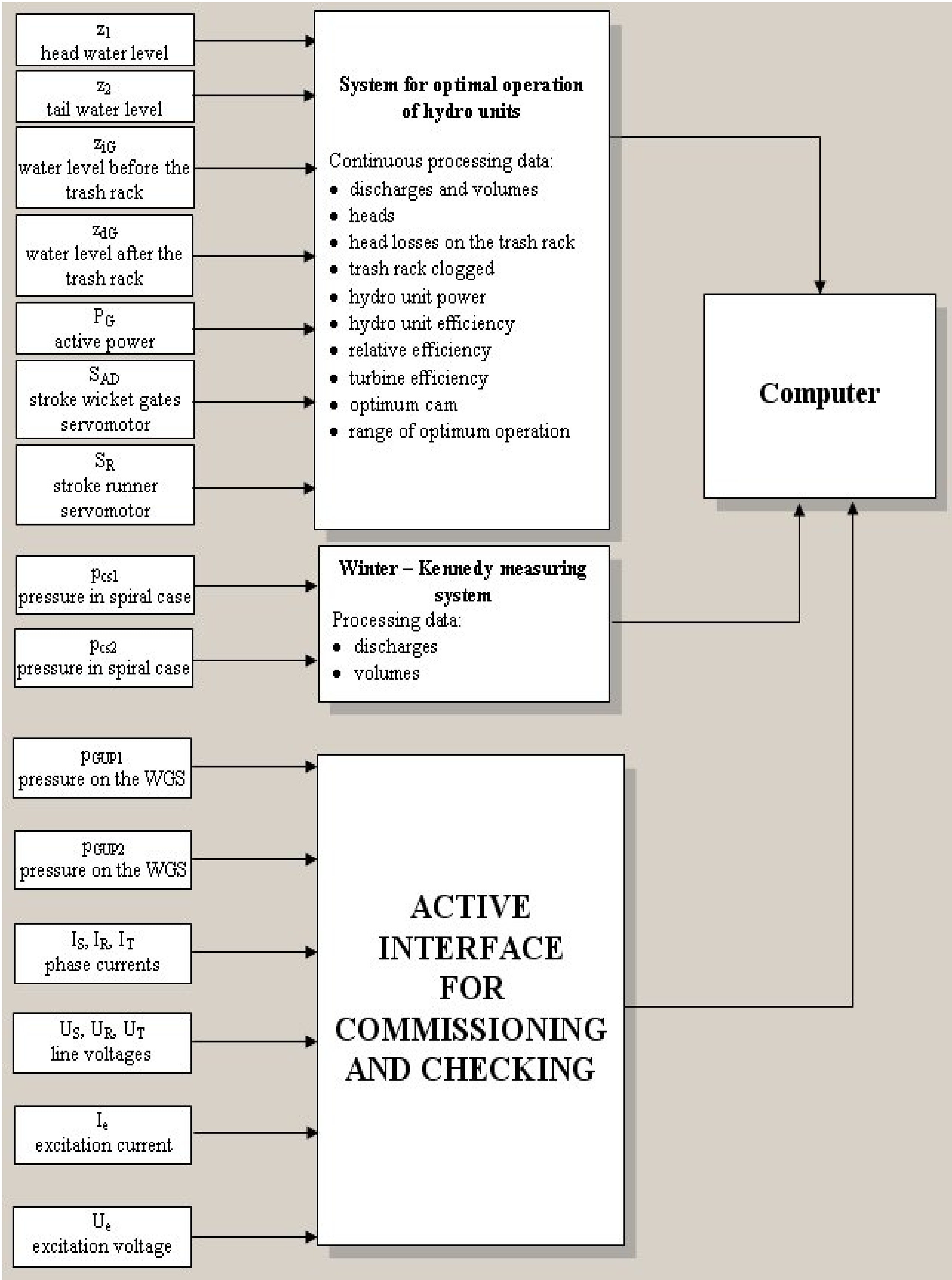

Figure 1. Block diagram.

If there are Winter-Kennedy measurements on the model, they can be used at the computation of the discharge from Winter-Kennedy measurements performed on the prototype. The scale up relation of the discharge, from the model to the prototype is obtained from Euler criteria.

$$\frac{\delta_{p_p}}{\rho_p \cdot V_p^{\ 2}} = \frac{\delta_{p_m}}{\rho_m \cdot V_m^{\ 2}} \tag{3}$$

$$\frac{V_p}{V_m} = \frac{\sqrt{\rho_m \cdot \delta_{p_p}}}{\sqrt{\rho_p \cdot \delta_{p_m}}}$$

$$\frac{Q_p}{Q_m} = \frac{V_p \cdot D_p^{\ 2}}{V_m \cdot D_m^{\ 2}} = \frac{D_p^{\ 2}}{D_m^{\ 2}} \frac{\sqrt{\rho_m \cdot \delta_{P_p}}}{\sqrt{\rho_p \cdot \delta_{P_m}}}$$

$$\delta_{P_p} = \gamma_P \cdot \Delta h_p = \rho_p \cdot g_p \cdot \Delta h_p$$

$$\delta_{P_m} = \gamma_m \cdot \Delta h_m = \rho_m \cdot g_m \cdot \Delta h_m$$

$$\frac{Q_p}{Q_m} = \frac{D_p^{\ 2}}{D_m^{\ 2}} \frac{\sqrt{\rho_m \cdot \rho_p \cdot g_p \cdot \Delta h_p}}{\sqrt{\rho_p \cdot \rho_m \cdot g_m \cdot \Delta h_m}} = \frac{D_p^{\ 2}}{D_m^{\ 2}} \frac{\sqrt{g_p \cdot \Delta h_p}}{\sqrt{g_m \cdot \Delta h_m}}$$

$$\frac{Q_p}{D_p^{\ 2}\sqrt{g_p \cdot \Delta h_p}} = \frac{Q_m}{D_m^{\ 2}\sqrt{g_m \cdot \Delta h_m}} = k \tag{4}$$

$$\begin{cases} Q_p = k \cdot D_p^{\ 2}\sqrt{g_p \cdot \Delta h_p} \\ Q_m = k \cdot D_m^{\ 2}\sqrt{g_m \cdot \Delta h_m} \end{cases} \tag{5}$$

$$Q_p = Q_m \cdot \frac{D_p^{\ 2}}{D_m^{\ 2}} \frac{\sqrt{g_p \cdot \Delta h_p}}{\sqrt{g_m \cdot \Delta h_m}} \tag{6}$$

$$Q_p = k \cdot D_p^{\ 2}\sqrt{g_p \cdot \Delta h_p} \tag{7}$$

The Reynolds and Euler criteria can not respected. Then the relation (6) and (7) will be corrected with scale up effect for efficiencies:

$$Q_p \cdot \eta_{Q_p} = Q_m \cdot \eta_{Q_m} \frac{D_p^{\ 2}}{D_m^{\ 2}} \frac{\sqrt{g_p \cdot \eta_{hp} \cdot \Delta h_p}}{\sqrt{g_m \cdot \eta_{hm} \cdot \Delta h_m}}$$

$$Q_p = Q_m \frac{D_p^{\ 2}}{D_m^{\ 2}} \frac{\sqrt{g_p \cdot \Delta h_p}}{\sqrt{g_m \cdot \Delta h_m}} \frac{\sqrt{\eta_{hp}}}{\sqrt{\eta_{hm}}} \frac{\eta_{Qm}}{\eta_{Qp}}$$

$$Q_p = k \cdot D_p^{\ 2}\sqrt{g_p \cdot \Delta h_p} \frac{\sqrt{\eta_{hp}}}{\sqrt{\eta_{hm}}} \frac{\eta_{Qm}}{\eta_{Qp}} \tag{8}$$

With assumption $\eta_{Qp} = \eta_{Qm}$ the relation (4) is:

$$Q_p = k \cdot D_p^{\ 2}\sqrt{g_p \cdot \Delta h_p} \sqrt{\frac{\eta_{hp}}{\eta_{hm}}} \tag{9}$$

2.3. Head loses on the trash rack

The head loses on the trash racks of the hydraulic turbines are computed from the level measurements and discharges. The level transducers are mounted before and after the trash rack. The formula is

$$\Delta h_G = z_{iG} - z_{dG} - k_1 \cdot Q^2 \tag{10}$$

Where, k_1 results from acceleration due to gravity and sections of hydraulic lay-out before and after trash rack.

2.4. Trash rack clogged

The trash rack clogged is:

$$\Delta h_z = \Delta h_G - \Delta h_{G0} \tag{11}$$

where, Δh_{G0} is the head loss on the clean trash rack:

$$\Delta h_{G0} = k_2 \cdot Q^2 \tag{12}$$

so:

$$\Delta h_z = z_{iG} - z_{dG} - k_3 \cdot Q^2 \tag{13}$$

where, k_3 results from k_1 and k_2.

2.5. Efficiencies of the hydro units and turbines

The efficiency of the hydro unit is:

$$\eta_A = \frac{P_G}{\rho \cdot g \cdot H \cdot Q} \tag{14}$$

The efficiency of the turbine is:

$$\eta_T = \frac{P_T}{\rho \cdot g \cdot H \cdot Q} \tag{15}$$

Where the turbine power results from:

$$P_T = \frac{P_G}{\eta_G} \tag{16}$$

The efficiency of the generator η_G is obtained from guarantee tests performed on the generator in the hydropower plant.

2.6. Openings of the wicked gates and runner blades

The openings of the wicked gates and runner blades, function of the servomotors strokes result from kinematics tests performed in the factory and in the hydropower plant

2.7. Optimal cam

The optimum connection between wicket gates opening and runner blades opening is determined from commissioning tests.

3. OPTIMUM OPERATION OF HYDRO UNIT SYSTEM

For to implement the optimum operation of hydro unit system is necessary to solve the following stages:

- calculus of the prototype hill chart according to [1] and [2];
- testing of hydro units for checking of the performances (according to fig. 1);
- optimal cam determination;
- calculus of the prototype hill chart according to [1] and [2];
- testing of hydro units for checking of the performances (according to fig. 1);
- optimal cam determination;
- optimal range of operation;
- special software for the project [3];
- connecting the system (figure 1) with the hydro unit equipments.

4. APPLICATION

The Research Centre in Hydraulics, Automation and Heat Processes from "Efitmie Murgu" University o Resita has performed such tests on the hydro units from hydro power plants on the rivers Olt, Crisu Repede, Bistra. In this year The Optimum Operation System will be implemented on the hydro units from Turnu and Ruieni hydro power plant.

From the tests performed at the Raureni hydro power plant on the river Olt, we present here the results obtained step by step.

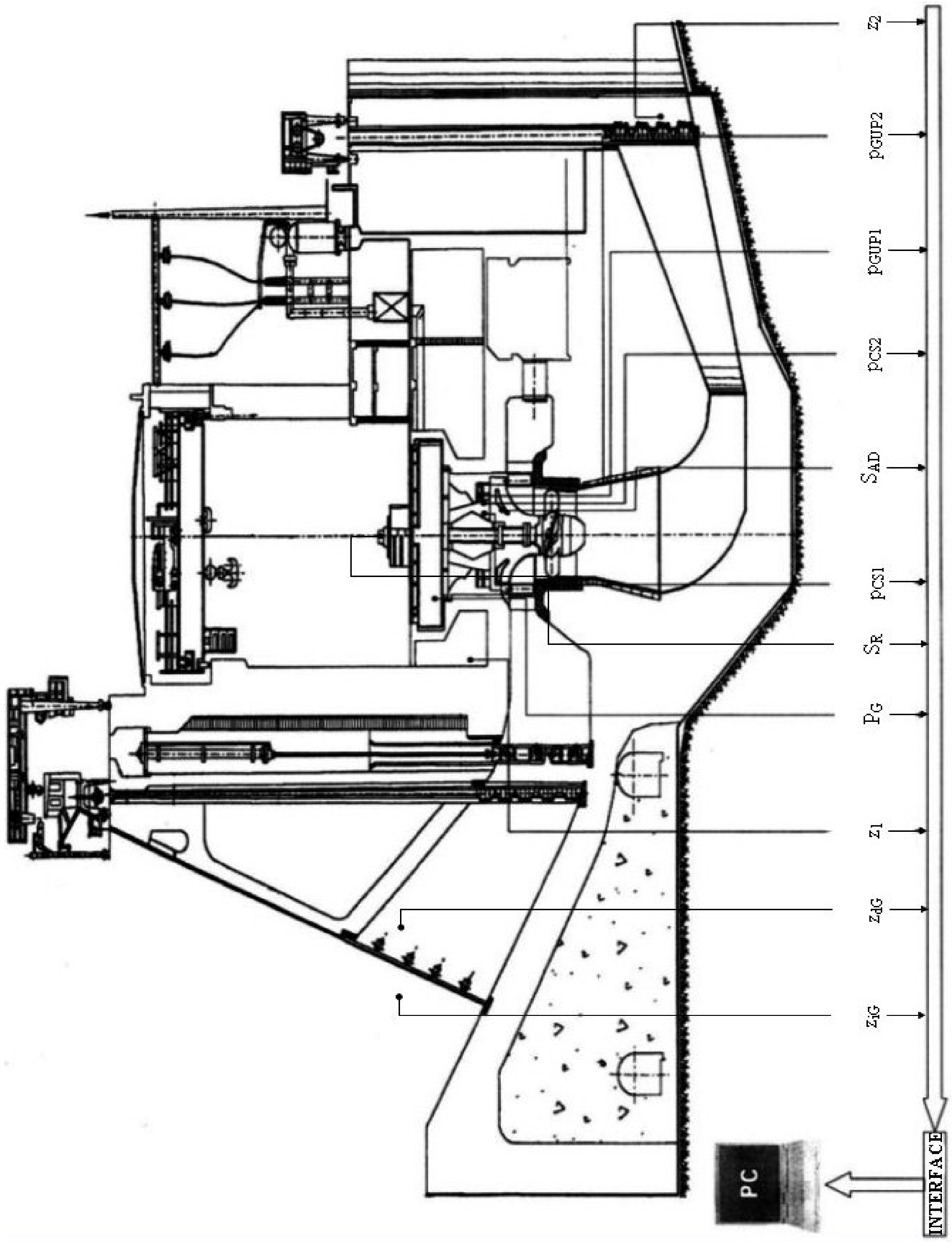

Figure 2. Hydro unit equipped with the transducers

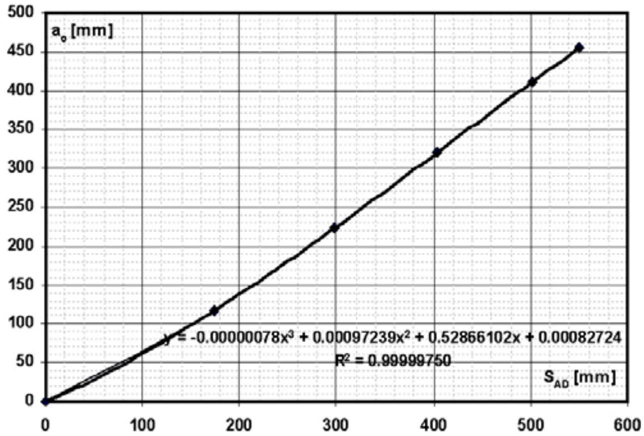

Figure 3. Wicked gates servomotor stroke

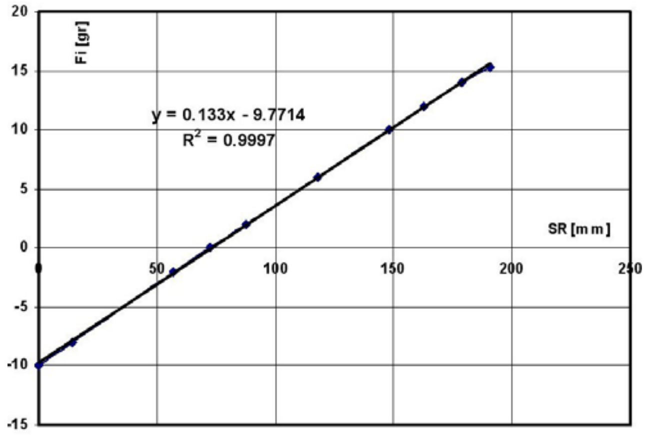

Figure 4. Runner servomotor stroke

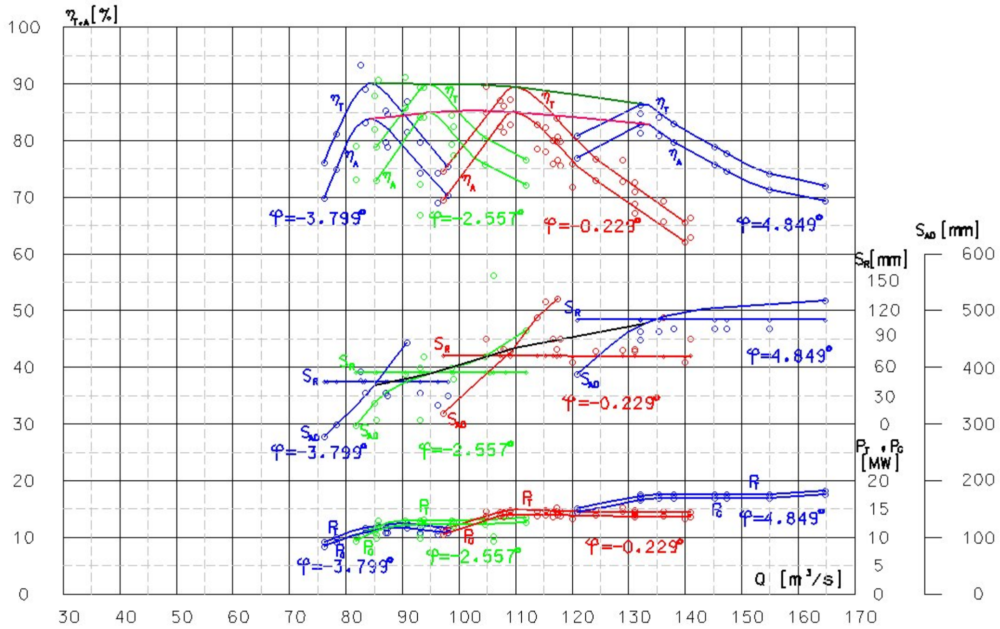

Figure 5. Efficiencies, servomotors strokes and powers for head H = 15.864 m

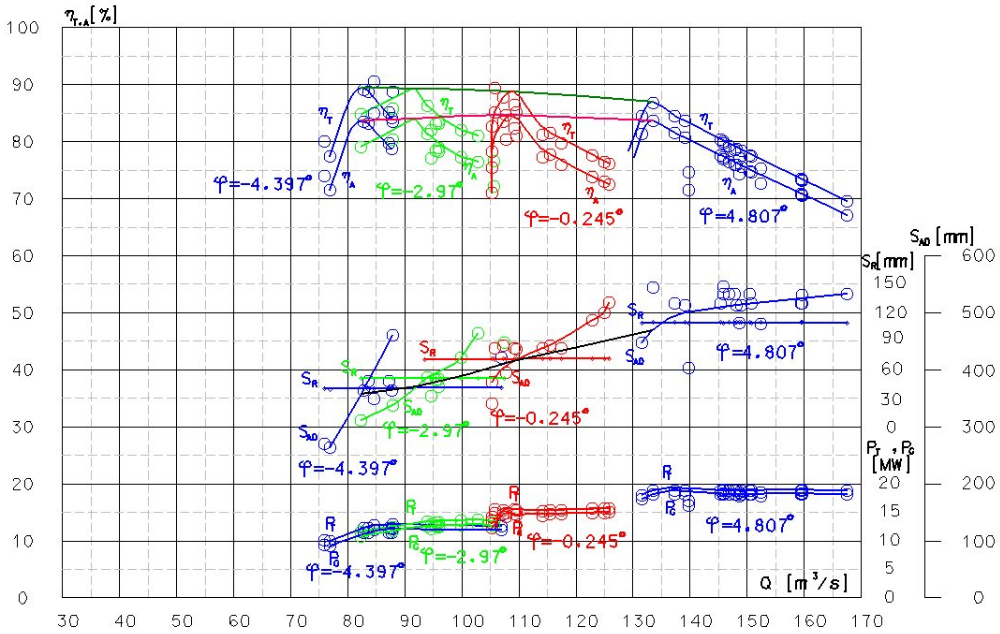

Figure 6. Efficiencies, servomotors strokes and powers for head H = 16.746 m

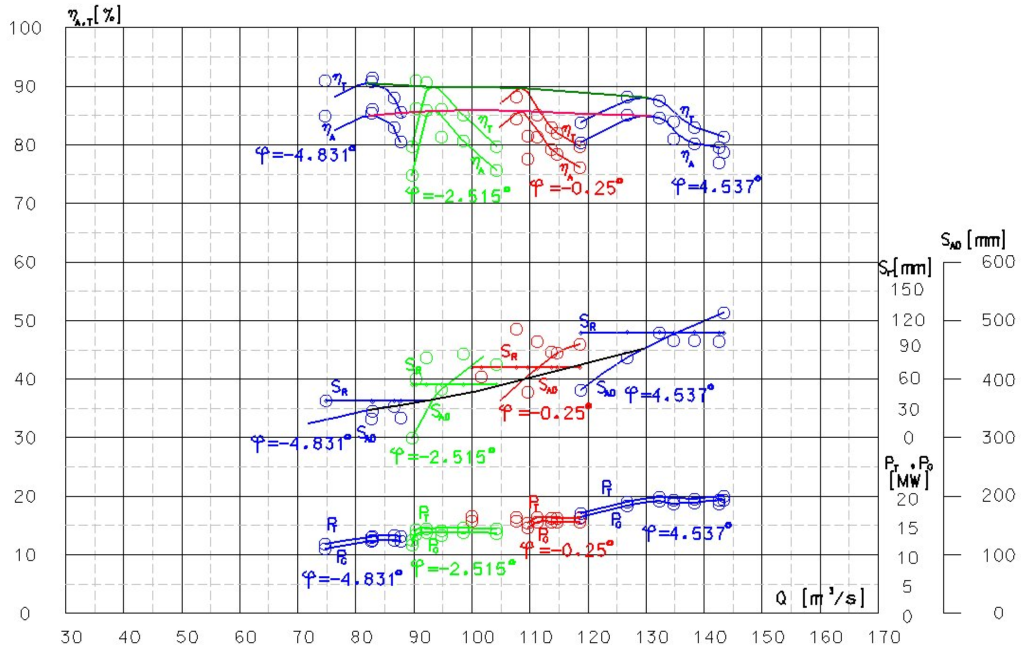

Figure 7. Efficiencies, servomotors strokes and powers for head H= 17.645 m

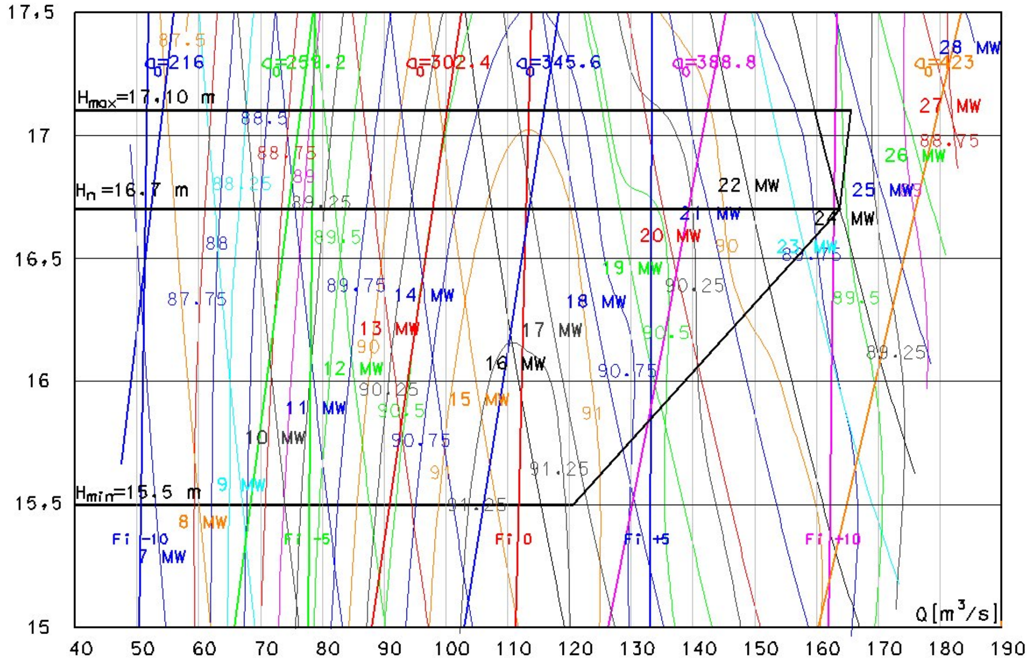

Figure. 8. Prototype hill chart

5. CONCLUSIONS

The Optimum Operation Hydro Unit system measure the main mechanical and electrical parameters and compute the performances of the turbine and the hydro unit.

The special software assures the operation of hydro units with the maximum efficiency.

REFERENCE

1. *** Hydraulic turbines, storage pumps and pump turbines. Model acceptance tests. IEC standard 60193/1999.
2. *** Determination of the prototype performance from model acceptance tests of hydraulic machines with consideration of scale effects. International Standard IEC 995. First edition 1991 – 08.
3. Campian C.V., Nedelcu D. The results from index tests performed on the Kaplan turbines. Proceedings of the International Conference, Classics and Fashion in Fluid Machinery, October 18–20, Belgrade, Yugoslavia, pp. 35–44.