# OPTIMIZE SYSTEM OF THE HYDRO UNITS OPERATION FOR HPP RUENI

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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, applied to the Rueni HPP [1], [2], [3].

## 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*

## ABBREVIATIONS

*C.C.H.A.P.T.* - The Research Centre in Hydraulics, Automation and Heat Processes from "Eftimie Murgu" University of Resita

## 1. INTRODUCTION

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 [4] and [5];
- testing of hydro units for checking of the performances;
- calculus of the prototype hill chart according to [4] and [5];
- testing of hydro units for checking of the performances;
- special software for the project [6], [7];
- connecting the system with the hydro unit equipments (Figure 1).

The system measure the main mechanical and electrical parameters and compute the performances of the turbine and the hydro unit. The C.C.H.A.P.T. software assures the operation of hydro units with the maximum efficiency.

## 2. THE FUNCTIONS OF THE OPTIMAL SYSTEM OPERATION OF THE HYDRO UNITS FROM HPP RUENI

The system uses the following measured parameters:

- the spiral casing pressure – measured with pressure transducer, Figure 2;
- the Winter-Kennedy pressure difference – measured with transducer Siemens SITRANS 7MF4433-1DA02-1AA1-Z, Figure 3;
- wicket gates servomotor stroke – measured with displacement transducer; the transducer is fixed on one of the control drive servomotor of the adjusting ring, Figure 4;
- the active power – measured from the hydro unit automation;
- head water level – measured before spiral casing with level transducer type Presley code 192L2940.
- tail water level – measured after draft tube with level transducer type Presley code 192L2940.

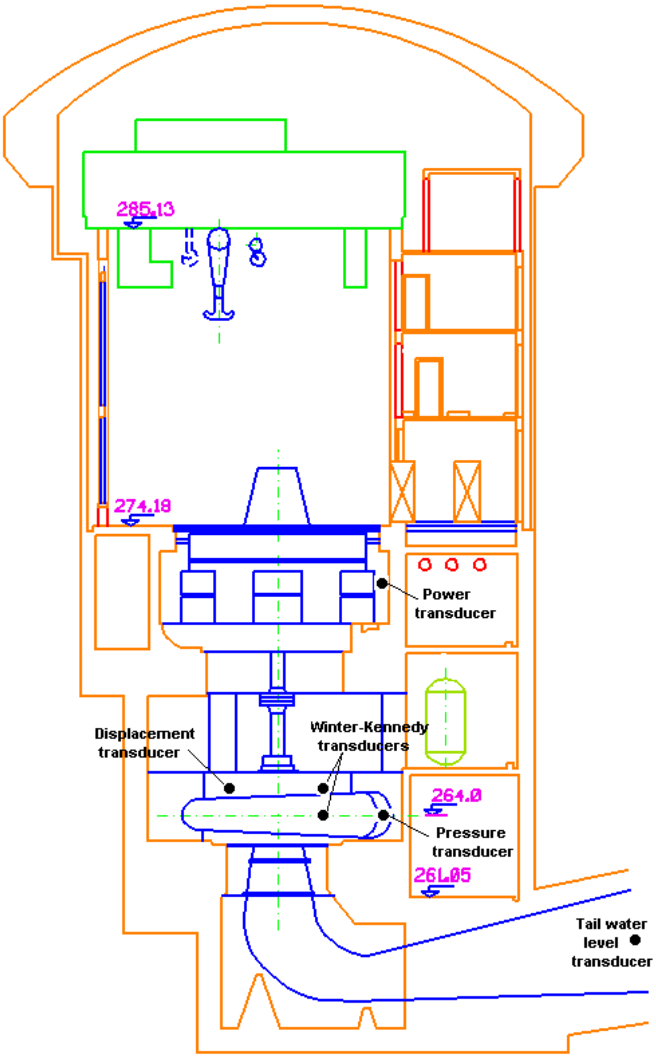


Figure 1 *Rueni HPP section*


Figure 2 *The spiral casing pressure transducer*

Figure 3 *The Winter-Kennedy pressure difference transducer*

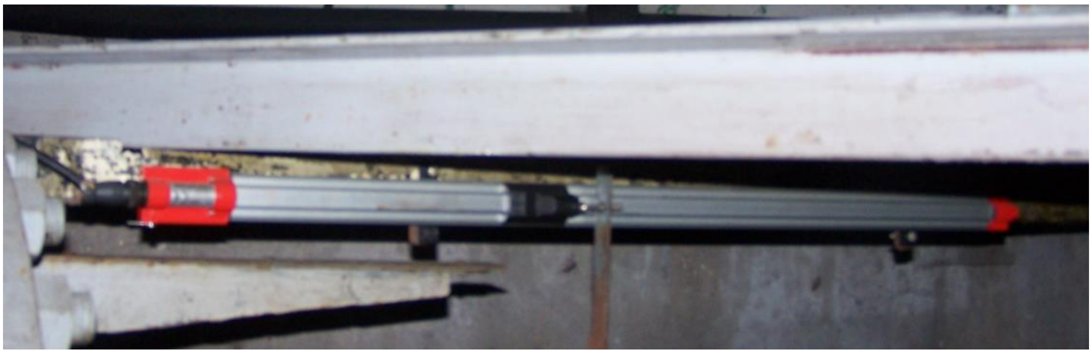

Figure 4 *The wicket gates  displacement transducer*

The system uses the following constant parameters, reference levels and control surfaces:

- water density **ρ** – the constant value is calculated based of water temperature;
- gravitational acceleration **g -** the constant correspond to the geographical position of the Rueni HPP;
- upstream turbine level $\mathbf{z_i}$ – correspond to the entering level of the spiral casing where is placed the pressure transducer; the local value is $z_i$ = 265 over the see level;
- downstream turbine level $\mathbf{z_e}$ – at the exit of the draft tube where is placed the level transducer; $z_e$ = 265,35 + $z_{av}$ where $z_{av}$ is the transducer value;
- the input turbine section (spiral casing input section) $\mathbf{S_i}$ ;
- the output draft tube $\mathbf{S_e}$ .

The system uses the following relations for calculated parameters:

- the net head turbine:

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

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

- the loss head due to the trash rack:

$$\Delta h_R = z_{am} - \frac{v_{dg}^2}{2g} - z_{dg} = \sum hp_{am-dg} \tag{3}$$

where: $\mathbf{z_{am}}$ is the upstream level 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 loss head due to the clogging trash rack:

$$\Delta h_z = \Delta h_R - \Delta h_{RC} \tag{4}$$

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

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

$$P_T = \rho \cdot g \cdot H_n \cdot Q \cdot \eta_T = \frac{P_a}{\eta_G} \tag{5}$$

- the turbine efficiency:

$$\eta_T = \eta_h = \frac{P_T}{\rho \cdot g \cdot H_n Q} \tag{6}$$

- the hydro units efficiency:

$$\eta_A = \eta_T \cdot \eta_G \tag{7}$$

- the wicket gates opening $\mathbf{a_0}$ is correlated with the wicket gates servomotor stroke $\mathbf{S_{AD}}$, by a numerical polynom calculated from measured of the two parameters for an imposed number of points, Figure 5;

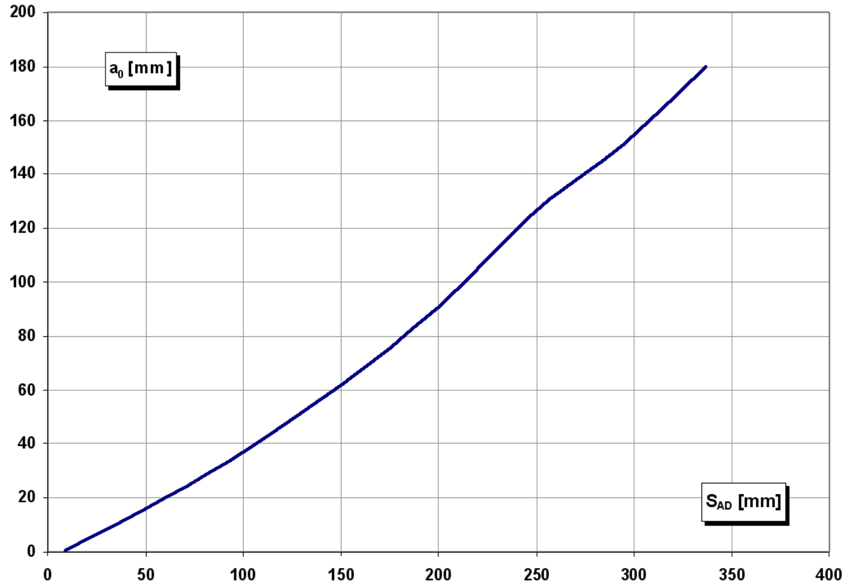


Figure 5 *The variation of wicket gates opening $\boldsymbol{a_0}$ as a function of the wicket gates servomotor stroke $\boldsymbol{S_{AD}}$*

The programmable logic controller will make data acquisition for the following parameters:

- active power - $\mathbf{P_a}$
- the input spiral casing pressure - $\mathbf{p_i}$
- pressure difference Winter – Kennedy - $\mathbf{\Delta p_{WK}}$
- the wicket gates servomotor stroke - $\mathbf{S_{AD}}$
- the upstream level - $\mathbf{z_e}$.

The instant data acquisition parameters are mediated and transferred to the computer as input parameters for C.C.H.A.P.T. software. Figure 6 present the optimal system operation diagram of the hydro units.

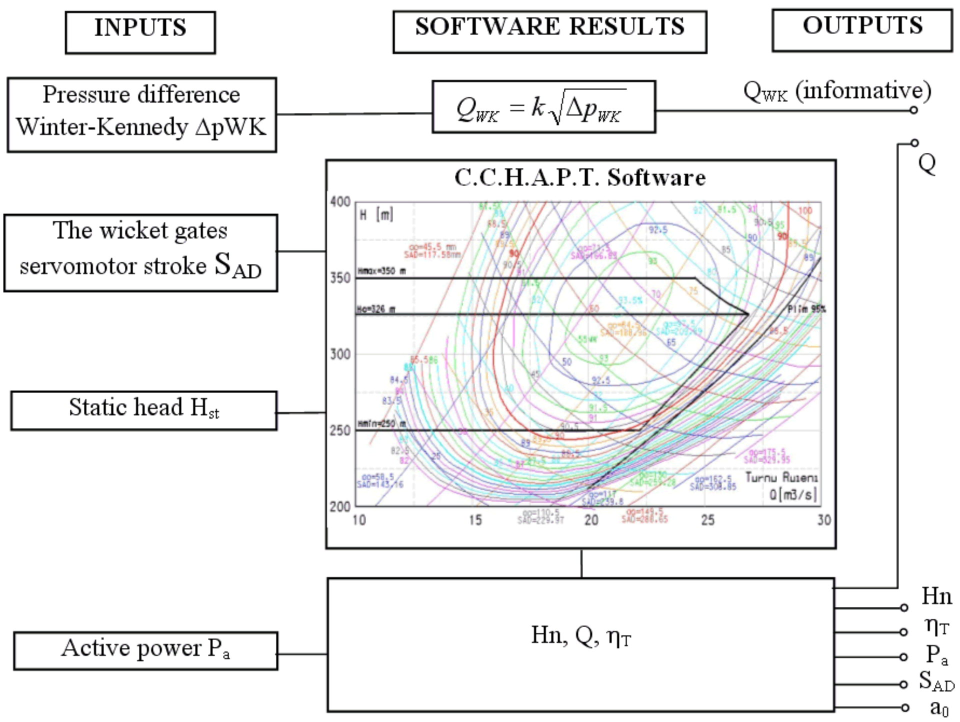


Figure 6 *The optimal system operation diagram of the hydro units*

## 3. THE C.C.H.A.P.T. SOFTWARE

The C.C.H.A.P.T. software was designed to compute the turbines characteristics, based on spline curves generated by cubic polynomial function. The software was detailed described in [6], [7]. Briefly, will summarize the main functions of the software:

- the primary data is grouped in curves with power $P_G$ as parameter, which include the following points: PG, η PL, QP, H, α, β. For primary data the software can draw the following curves: $\eta_{PL} = f(Q_P)$, $H = f(Q_P)$, $\alpha = f(Q_P)$, $\beta = f(Q_P)$, $q = f(Q_P)$, $\eta_{PL} = f(H)$, $Q_P = f(H)$, $\alpha = f(H)$, $\beta = f(H)$, $q = f(H)$, $\eta_{PL} = f(\alpha)$, $\eta_{PL} = f(\beta)$, $\alpha = f(\beta)$, with $P_G$ as parameter; the primary data points can be exported to Excel or HTML file.
- for the option menu „**Intersectii**" the software will calculate the intersection curves between the hill chart diagram and the intersection parameter, which can be: head „**Cadere**", discharge „**Debit**", power „**Putere**", wicket gates opening „**Alfa**", runner opening „**Beta**"; the numerical results can be exported to Excel, HTML or text file.
- for the option menu „**Grila P-H**" the software will calculate the intersection points between parameters head and power, in the interval defined by $H_{min}…H_{max}$ values with step **Pas H** for head parameter and the interval defined by $P_{min}…P_{max}$ values with step **Pas P** for power parameter.
- the option menu "**Diagrama de exploatare**" is destinated to the calculated point in the hill chart area and associated numerical values, that can be obtained with the following methods:
    - click mouse in the hill chart area – which will get the mouse coordinate (H, Qp) from the hill chart area and will transmit calculated numerical values to text controls;
    - by input value in one of the text control head „H [m]", discharge „$Q_P$ [m3/s]", power „$P_G$ [MW]", efficiency „$\eta_{PL}$ [%]", wicket gates opening „α [-]", runner opening „β [-]" – will generate the intersection curve between the parameter with the hill chart area and will transmit calculated values to text controls;
    - by input value in two of the pairs text control head „H [m]" and discharge „Q [m3/s]", head „H [m]" and power „$P_G$ [MW]", discharge „$Q_P$ [m3/s]" and power „$P_G$ [MW]" or wicket gates opening „α [-]" and runner opening „β [-]" – will generate the intersection point between two intersection parameters and will transmit calculated numerical values to text controls.

Calculated points will be marked with circle in the hill chart area.

- for every graphic generated by the software, at the bottom of the window area is placed a toolbar with command buttons marked with specific icons. The software offer a popup menu, by right mouse click in the graphic area, with the same options like the command buttons. The function of command buttons are:
    - close the graphic window;
    - view the table of primary data coordinates;
    - tools for modifying graphic parameters: width and colours of curves, the visibility and colours of the markers, the identification numbers of the points, the width, colours of axes, the name and colours of labels, the limits of grid, the decimals number, etc.;
    - zoom in, zoom out, auto zoom (fit), zoom area;
    - print the graphic;
    - copy graphic to clipboard;
    - info graphic points, info curves points (intermediary points between graphic points);
    - intersection of curves;
    - modify the curves label position file.
- the option menu „**Achizitie**" is designated to data acquisition from the system. The system will made instant acquisition for an imposed number of points and will calculate median points which will be saved in software database. The interface is designed to data acquisition from two units and is presented in Figure 7, which include the following sections:
    - the hill chart area $H = f(Q_p)$;
    - text controls for instant data acquisition points: ID point, upstream level, active power, downstream level, pressure difference for Winter-Kennedy, the wicket gates servomotor stroke, for unit no. 1 and unit no. 2;
    - two buttons for start and stop acquisition process and one button to quit the acquisition window;
    - text controls for mediated parameters: date and hour of the acquisition, ID of the mediated points, the calculated head, the calculated discharge, the wicket gate opening, the turbine power, the calculated turbine efficiency, the calculated hydro units efficiency, the calculated hydro units power and Winter-Kennedy discharge. The value of Winter-Kennedy discharge is used as a secondary method to verify the calculated discharge.

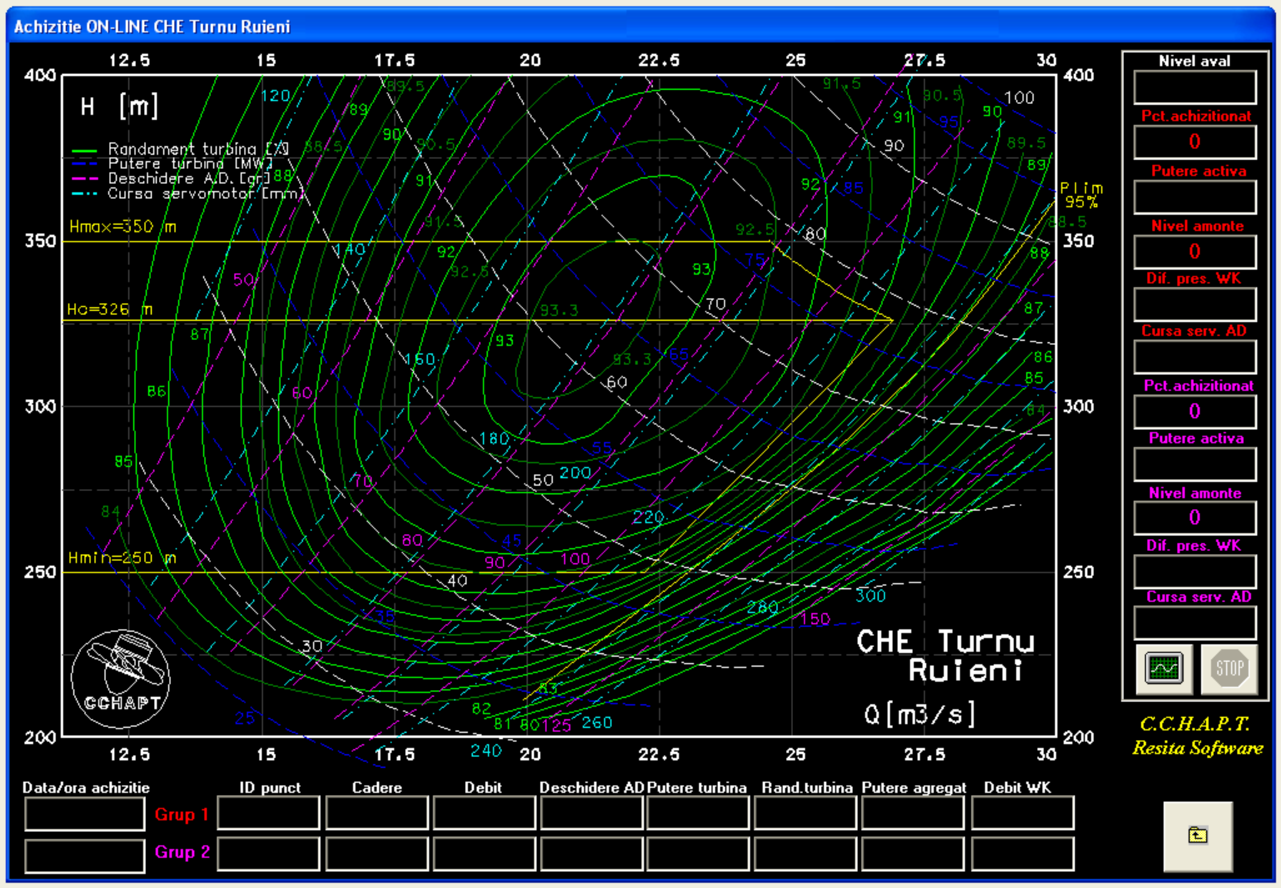


Figure 7 *The interface of the acquisition software option menu*

## 5. CONCLUSIONS

The system is designated to monitoring on-line the hydro units operation. The database obtained after a long period of operation will be used to obtain optimize functional criteria for operation with maximum efficiency. In the same time, the system is a diagnose system.

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