University of Craiova
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SUMMARY OF PHD THESIS

DRIVING SYSTEM OF A HYDRO ENERGETIC DAM EQUIPPED WITH RADIAL GATE AND FLAP

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Modern process control systems are computer systems that use the process to achieve automatic control of production processes. Management methodologies have occurred due to the characteristics and economic indicators characterizing the various different processes.

This paper aims at achieving an optimal management structure of a hydro energetic dam facility equipped with barrier type discharge valve segment with a view to its practical implementation.

It also aims to identify parameters related analysis of its interconnections and interlocks required determination, the determination of computational algorithms and algorithms governing the identification logic operation in different variants and their optimization in order to achieve its intended purpose.

The management structure will comprise the entire system of measuring and acquisition, conditioning and processing, operation and control and remote or local hydroelectric dam on the algorithms and implement operating system-specific structural data relating to the discharge water .

Chapter 1 provides definitions of supervisory and management systems and their components, evolution and current state of hardware and software programmable controllers, process control, the role and place of PLCs, process computers, sensors and transducers development of automatic systems and computers in process control.

In **Chapter 2** summarizes the considerations of a hydroelectric dam. It presents the general and construction related to the main components of overflows equipped with various mechanisms of control, elements of the mobile and fixed part of mobile dams, spillways for flow meter approach.

Discharge phenomenon is presented in case studies for a hydroelectric dam spillways equipped with equipped with drag and slide, highlighting its main stages.
Electromechanical drive system is presented with details of the mechanical system and electrical system, the operating conditions of the order of handling data.

Part furniture, represented by the dam, is the most important part of a movable dam, sometimes representing over 75% of the total opening of the dam (front overflow). The radial gates are mobile elements that allow the closure or opening, partial, or total overflow fields, in order to adjust the tail water levels and flows in the upstream and downstream. Adjust water level as water discharge large openings are made by different degrees of radial gates. To better meet using gates composed of two parts, which can move independently. Thus there are double gates, flat or segment, in which water can flow over the barrier, under the barrier, or simultaneously over and under it. At radial gates lift flaps were applied to allow fine tuning of the float level and discharge.

Chapter 3 presents the approach to developing a surveillance system and case management to a hydroelectric dam, which aims to determine the characteristics and process parameters to determine the solutions achieved.

This system functions are analyzed taking into account the levels of management hierarchy, system architecture solutions related to process requirements imposed on equipment and software that is developed for them.

The system analyzes the extent and possibilities for the measure level, flow discharged measure, measure spillway opening - opening in the light, as speed, measure the horizontal. Regarding the operating system are dealt with deployment options in the classical variant

electromechanical and electric shaft version with synchronization loop control of speed through frequency conversion control engine.

In this context we describe how control mechanism for follow horizontality spillway speed. Synchronizing the operating mechanism is a major aspect of monitoring and management system, which involves the study of methods of achieving synchronization at spillway system.

Based on technology currently offered on the market, both in terms of measuring equipment, acquisition and data processing equipment, data transmission networks, with respective features of them presenting a concept for achieving the supervision and control to a hydroelectric dam and barrier equipped with radial gates and flaps.

Design of the system include the specific operating conditions, levels of command sets and sequences of operation, management methods. It presents a modern version of implementing electromechanical drive system and control structure of horizontality

In this chapter are presented personal achievements in the field of hydroelectric dams on the type studied surveillance, and monitoring systems without replacing the classical synchronization system, control systems with and without replacing the classic shaft drive system power

To achieve the supervision and management of the dam is necessary to measure parameters that characterize the process. These parameters are: the level of the lake, discharged water level, overflow facility position - barrier segment and valve assembly, flow discharged, a horizontal barrier and valve mechanism.

In addition to these basic parameters are also required and other auxiliary parameters that define the process as: Electric motor drive speeds, electric torque electric motors to shafts, travel limit positions, various electrical parameters

For realizing the synchronization of the overflow mechanism it must be adjust the horizontality. Horizontality adjustment spillway barrier and latch assembly is identified by keeping the position of equal right and left arm position equipment, in a system (x, y, z) with initial conditions or the maintenance of equal angles of rotation in the joint discharge mechanism arms.

For achieving synchronization are required:

- On-line calculation of left-right imbalance (deviationν from horizontality), existence of an order of closure or opening of theν overflow mechanism,
- Implementing an algorithm for controlled variation of travel speeds of the two arms of the overflow mechanism.

Spillway system synchronization methods are given by adjusting the position of horizontality equipment spillway

A. Radial gate position obtained by measuring the angle of opening rotation of the overflow mechanism horizontality adjustment depending on the positions ofν arms radial gate, assumes that if the positions of the two arms of the mechanism are identical, then the horizontality is assured.

Radial gate arms position angle is given by the measure of openness, which is equivalent to measure the angles of rotation of the arm about the point of articulation.

The principle involves minimizing the difference between control positions / angles of rotation of he crank gear.

B. Position radial gate obtained by measuring the mechanical displacement overflow mechanism

spillway arm position can be given by the mechanicalν movement since the opening mechanism.

Synchronization mechanism is achieved by controlled variation of travel speeds of the two arms of the radial gate mechanism, three-phase motors controlled by frequency converters.

Change the speed of an induction motor, is generally difficult. Because speed is a function of sliding electric motors, this parameter is different in identical engines, so that there is an imbalance

between engine speeds, choose to use one inverter for each electric motor.

Frequency inverter speed control three-phase motorsν carried by the vector control method. In principle, the synchronization is done as follows: when the gap between the two arms exceeds a

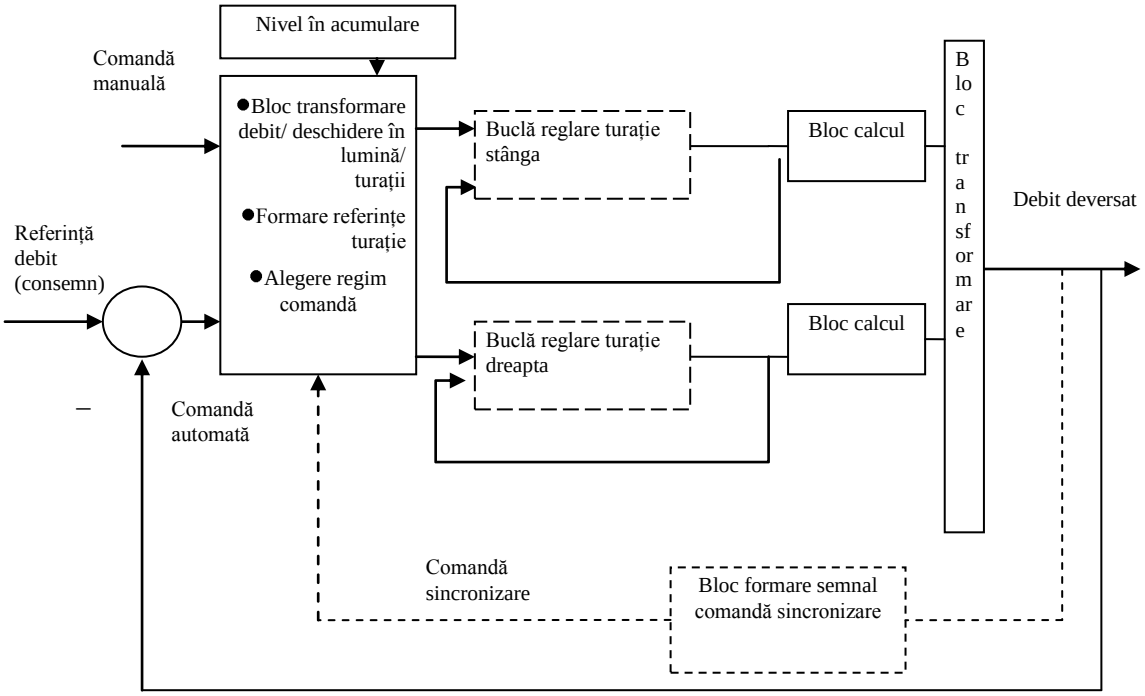


Figure 1 Structura de reglare pentru un deversor

permissible change references imbalance converters until canceled.

Achieving synchronization using the drives is doneν through an automated system of tracking who has such input speeds the two motors. These speeds are measured on-line by means of speed sensors. The synchronization algorithm is implemented in a number of specialized equipment acquisition and processing PLC (programmable logic controller).

Chapter 4 presents the theoretical research on the characterization process. It presents a detailed description of how to determine the parameters spillway barrier mechanism and damper characteristics resulting from existing methodologies in the literature for calculating the overflows. Mathematical modeling parameters are presented spillway barrier mechanism and damper characteristics resulting from their kinematics.

The study to determine the parameters related to a spillway equipped with clamshell barrier and analytical calculus, they deal with possible operational phases, namely the discharge over flap, discharge over the flap and under the barrier, barrier discharge, and discharge under free.

For each phase are presented methods for calculating discharge rates according to specific parameters. From this, relationships are determined for indirect indices of the process: opening the light load water overflow opening angle of the machine, place the mechanism chain length, and number of rotations made by each actuator.

The present method of determining the flow discharged through a spillway through spreadsheets and piecewise linear interpolation method for indeterminate values.

A significant step towards a surveillance system is to compile and run their own management

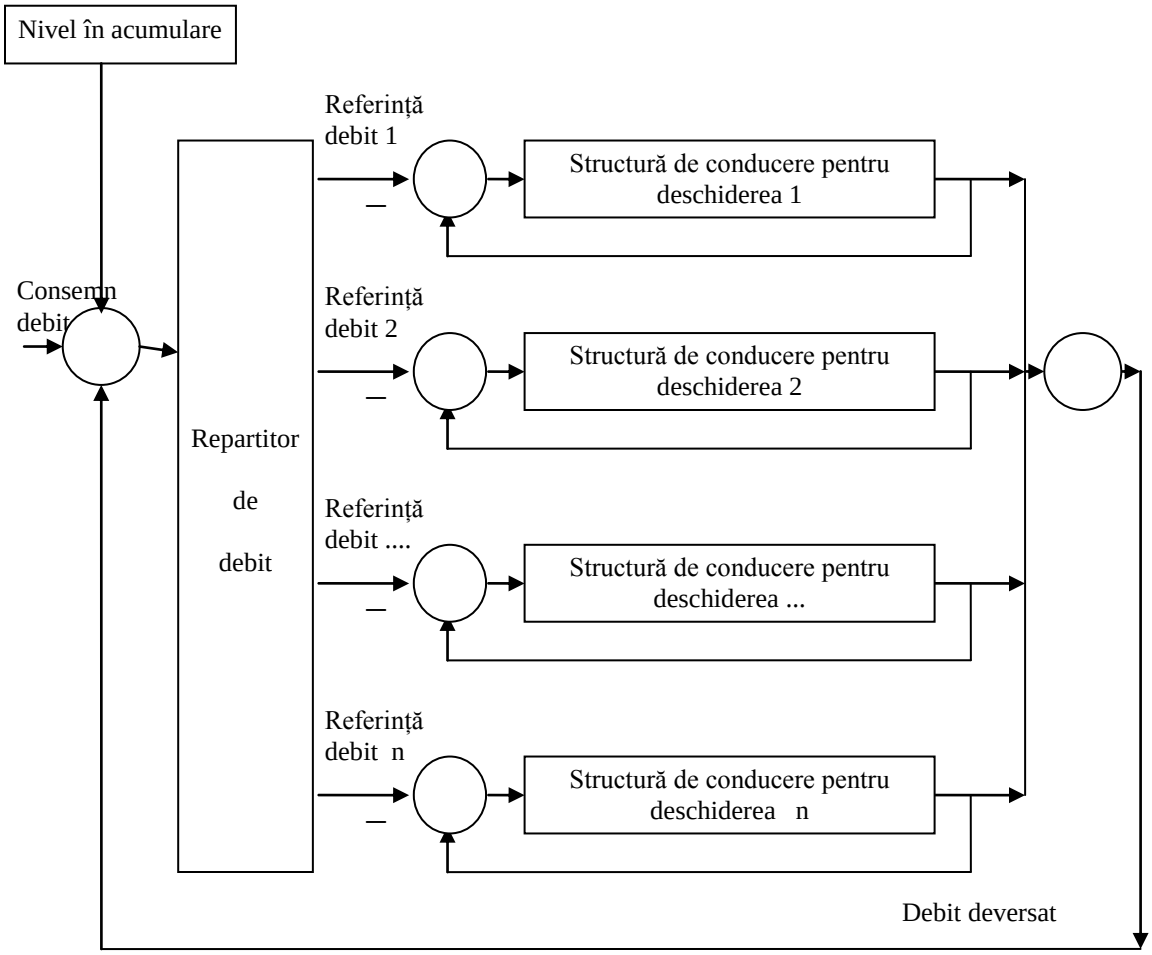


Figure 2. The structure of the leadership after confinement

algorithms. Thus, the present algorithms to determine the process algorithm for achieving synchronization algorithm for the confinement of the flow direction, flow distribution frame algorithm, algorithm for determining the stages of discharge formation algorithm that controls the opening closing mechanism for local control algorithm automatic.

Leadership as debit instruction Adjusting the flow discharge

Operation instruction after the referenced dam is:

• Set the flow to be discharged

• Ordering dam facilities (valves and gates) so as to insure the desired flow and discharged while being observed sequence of opening and closing the flaps and fielded radial gates spillways.

The flow is meant to be discharged to a reference point is called the debit or confinement.

working principle is as follows:

• After you set the computer recorded compared with the total flow discharged at that time and determine the necessary control sequence.

• After running the command sequence will equal the total flow discharged with recorded.

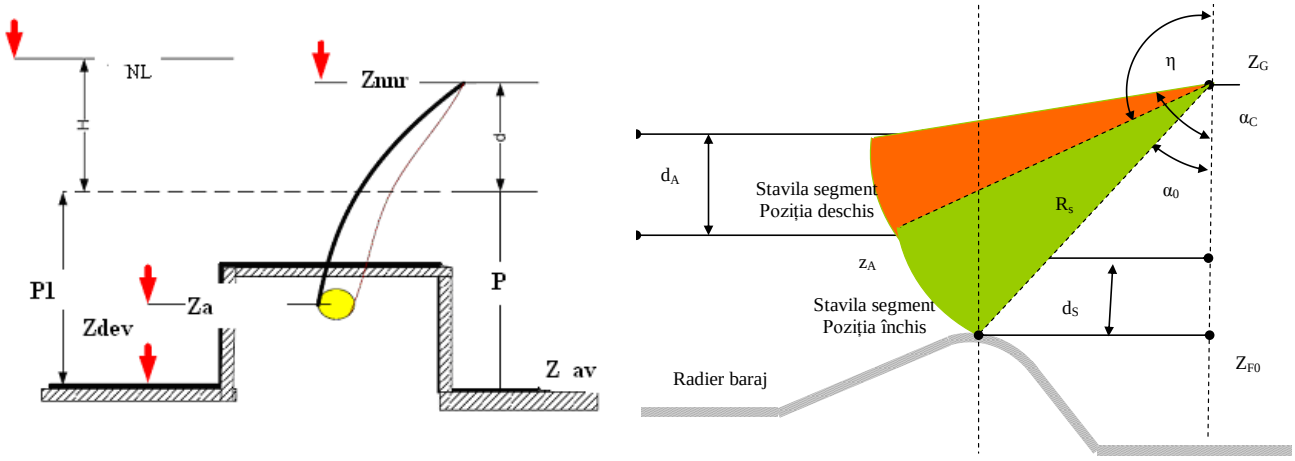
Phase I spill - spill over valve

Flow discharged by pumping water slide is $Q = f(NL, \varpi H)$ where: $H = NL-(z\ NNR - d_c)$ (1)

Flow over a radial gate with the flow over a thin wall model, sharp edge, has the characteristic equation given by [36]:

$$Q = \frac{2}{3}\mu \cdot b_1\sqrt{2g}H^{3/2} \qquad (2)$$

where H is the task and the damper coefficient μ is a flow, contraction is not lateral,



a) notation for flap flow calculation

b) notation for radial gate flow calculation

Figure 3 notation used in calculating flow

Determination feature opening flaps - rotation angle of the overflow mechanism is given by:

$$d_C = R_C \sin\beta_0 - R_C \sin(\beta_0 - \beta) \qquad (3)$$

*Phase II - spill o*ver valve fully open and under the barrier

According to [10], [11], [36]

$$Q_{II} = Q_1(H_1) + Q_2(H_2) \qquad (4)$$

where: H_1 = load of water over flap, $H_1 = N_L - z_A$;

H_2 = water load barrier $H_2 = N_L - d_S$

Flow valve and spilled over the barrier is expressed as follows:

$$Q_{II} = m_1 \cdot b_1 \cdot \sqrt{2g} \cdot H_1^{\frac{3}{2}} + m_2 \cdot b_2 \cdot \sqrt{2g} \cdot H_2^{\frac{3}{2}} \qquad (5)$$

Flow over the flap takes place as long as the upper edge of the threshold is below the accumulation upstream of the lake. When this limit is exceeded, the flow takes place only under the barrier and thus move to a new stage of computing.

Phase III - under the barrier discharge

Water flow at the opening radial gates study is modeled by flow through large rectangular openings.

Discharge under the barrier [11], [12], [13], [16] found a large hole, rectangular practiced in a vertical wall, the characteristic equation of flow can be calculated using the formula:

$$Q = \frac{\mu\tau_e T^{3/2}\sqrt{2g\,(1-\varepsilon\tau_e}}{\sqrt{1-\alpha\mu^2\beta^2\tau_e^2}} \quad (6)$$

For those considered overflows $\alpha = \beta = 1$ and $T = N_L - Z_{F0}$.

$$Q_{III} = m \cdot b_2 \cdot \sqrt{2g} \cdot H^{\frac{3}{2}} \quad (7)$$

Formulas used were those specified by choosing the mathematical model because the specific energy based on the average current in the upstream section of the tail water access, T0, energy factor which takes into account kinetic energy is finally working in specific T

Faze IV The free discharge, even the hydraulic load in the lake, namely: $H = N_L$ (8)

$$Q_{IV} = m \cdot b_2 \cdot \sqrt{2g} \cdot H^{\frac{3}{2}}, \quad (9)$$

Determination of flow discharged through a spillway by spreadsheet determinations based on structural models are determined for each spatial correlations between the level of the lake, and opening a flow discharged overflow mechanism, clamshell barrier.

For each hydropower plant, is required by operational regulations, the correlations between flow spilled into the lake and the spillway opening. Determinations are made for fixed values, with increments of 0.5m. The calculations are performed on a single spillway, while others are multiplied by the similarity baseline.

Develop management algorithms

To achieve the monitoring and management system to achieve the dam functions automatically, driving equipment, PLC and / or computer process must execute work procedures for operating conditions and algorithms for the determination of specific parameters.

For automatic operation of the supervisory and managerial procedures must be known:

Flow Management by confinement
Training mode and complete automatic operation
Training mode and complete local control actuator
Training mode and complete control opening and closing
Sequences debit confinement calculation overflow
Distribution of flow on spillways
Determination of parameters calculation system according to the phases of discharge
Lockstorage horizontality
Setting the operating system

In **Chapter 5** presents the modeling of a synchronization system for two-phase asynchronous machines and real-time simulation of electric drive system, a system for determining the parameters of dynamic models and analysis results.

The Simulink simulation software to analyze system synchronization event of an imbalance in one arm, both arms, without running the emergence of an imbalance and the occurrence of an imbalance canceled after stabilization of the engine operating mode.

Mathematical modeling of flow valve and barrier discharges for a comparative analysis of data from a structural model representing the mathematical model is presented in the concluding chapter.

To implement the Simulink system model operating of synchronization of two asynchronous machines in parallel is proposed tracking behavior, the dynamic regime, a system of two induction motors, operating in synchronization control loop in the following cases:

• normal operation without disturbance
• operation at the occurrence of an imbalance of increased static torque on one of the engines
• operation at the occurrence of an imbalance of increased static torque on both engines simultaneously
• Operating the appearance of imbalance before stabilizing engine parameters

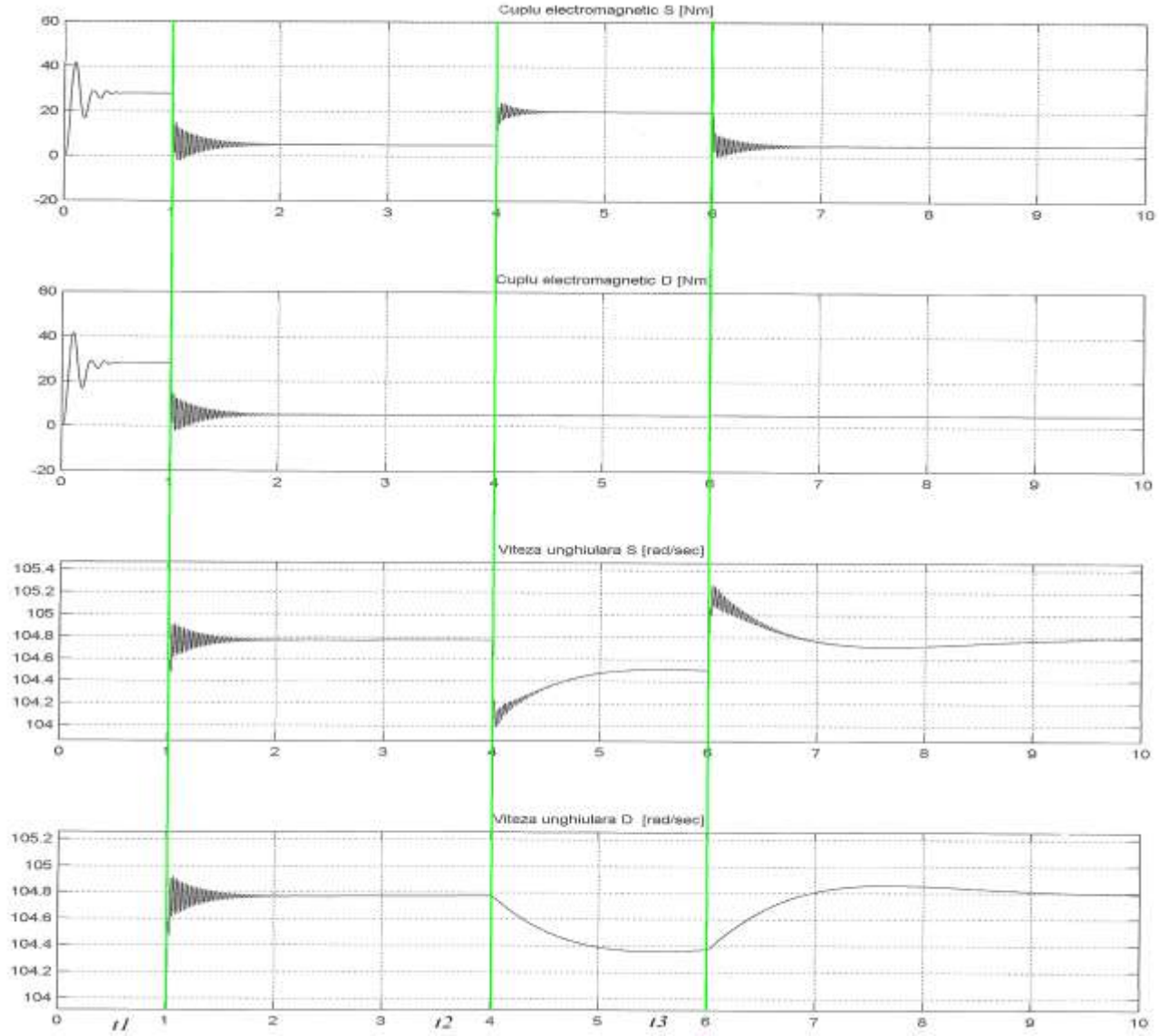


Figure 4. Evolution of electromagnetic torques and angular velocities to arm imbalance

On the occurrence of an imbalance given the difference between the number of rotations per unit time between two engines, it highlights the evolution in moments of time.

Relations are obtained for flow depends of two unknown functions (weight of water and opening mechanism) of the form $bH^{\frac{5}{2}} + aH^{\frac{3}{2}} - QH^2 - 2HPQ - PQ = 0$, where P depends on the characteristics of dam construction and opening mechanism, $P = f(dc)$, and a and b are coefficients

that depend on the structural characteristics dam.

For Mathematical modeling of flow discharged, we have considered the operating conditions studied, namely:

For the case with hedge hedge flap segment andν segment on the raft.

For the case of flap lowered and hedge lifting segment

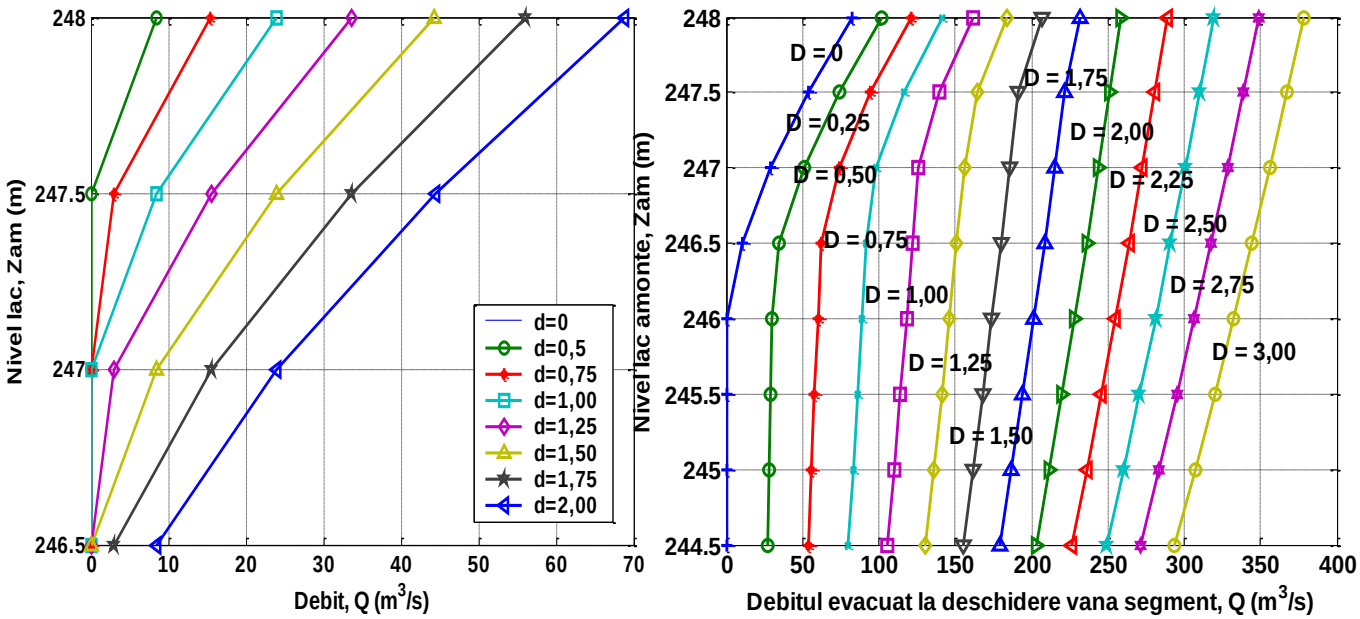
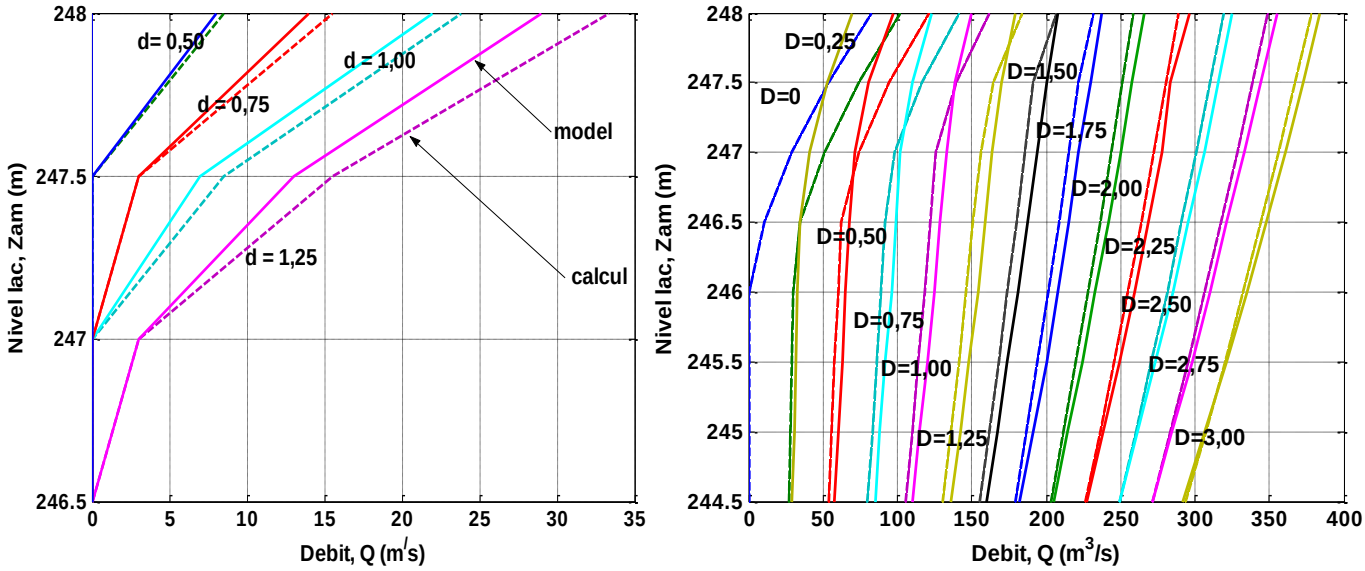


Figure 5 The exhaust radial gate/ flap flow (calculated values)

For the case with the flap segment hedge position isν high-level and flow freely.

If the operation is considered for the position ofν operating not drowned radial gate and weir type spillway is considered virtually profile WES (Waterways Experiment Station, Vicksburg).

exhaust flow through the obstacle segment



Comparative analysis of data from a structural model representing the mathematical model

Figure 8 Representation comparative Structural model - Mathematical model

Structural model obtained flows are represented by full line and the dotted line in the mathematical model. It is noted that the discharged flow hedge segment isν better approximated by the formulas of calculation than the

Structural model obtained flows are represented by full line and the dotted line the model mathematically.

Note that the radial gate discharged flow is better approximated by formulas, unless the flap.

Using mathematical models presented flow characteristics can be represented in very small steps, being able to obtain a more accurate representation of the flow on the contour and for other dams mentioned structure, the construction and operational compliance.

Chapter 6 presents implementation of system management solutions to central planning dam the river Olt, Valcea CHE, objective presentation of the measuring system used, the hardware and software structure and operation of the automation system, monitoring and control radial gate. It presents graphical user interface, network communications, and interconnection with other processes

Based on the requirements of performance issues involving electrical upgrading of the dam at CHE Valcea, I have contributed to the choose of management solutions which resulted in:

The design of automation system, identify the process quantities, the working environment, establish management structure, determining methods of measurement and calculation methods for system sizes.

Spatial analysis and determination of methods for transmitting physical and logical hierarchy of information.

Determination of physical and logical requirements for equipment procurement, processing and manufacturing such as:

- equipment selection system, the basic software for processing and operational implementation
- Determining the operating logic
- Coordination of system functionality
- Analysis, review and implement the algorithms track performance testing under real conditions
- Updating the system as required

Conclusions on the development and implementation of a monitoring and management system are presented in **Chapter 7**.

The classic motors sync phase squirrel cage induction by electrical shaft is replaced with a modern addition to providing synchronization operation itself, performed by a control loop, start the engine and taking slow shock load. In addition this method provides the ability to connect to a serial digital processing system together with all the features of this.

Starting from the thesis objectives which included:

May be mentioned that the main conclusions of the paper, the following:

Analytical methods of calculation error does not translate to acceptable forms of structural models.

Models obtained from structural models have the advantage of the possibility of building the flow curves for various openings in fine steps in order to determine the intermediate values obtained by linear interpolation to be performed with greater accuracy.

The management system involves implementing an algorithm for determining the discharged flow values for flow-controlled light-level opening in the lake, as evidenced by the spatial characteristics, structural models obtained.