AUTOMATIC CONTROL OF A HIDROPOWER DAM SPILLWAY

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Abstract **– A very important element to a safety functioning of a hidropower dam consist in the possibility to manipulate quick and safe the lappet and the gate of dam. In this paper is presented a application concerning automation driving and monitoring a mechanical, electrical and hydraulic plants who realize the actioning of the penstock who rig a hidropower dam. The steps to be taken are : electric power plant design, control, automation and protection design, integration of the overall functioning of the whole dam spillway in SCADA system, purchase, manufacture cabinets and panels, mounting equipment, the completion of power circuits, secondary circuits, communication and finally testing and commissioning. The role of the automatic control consists in increase of the safety of the entaire dam. The difference impose between the left and right driving chain of a gate is less 1 cm. Beside, is realised a complex control system on four level who make a balanced open and close of the gates for a controlled discharge. In this paper is present the general arhitecture of the control system, the algoritm, the comunication and the general performance. The authors of this paper have realised the hardware design and software implementation in almost one year.**

Keywords: *automatic control, SCADA, PLC, protocol*

1. INTRODUCTION

The general arhitecture of the automation system is shown in Fig.1. From the point of view of comunication is implemented a Master-Slave structure where the master is graphic station Siemens and the slaves are 4 PLC Siemens S-300 series. Physical environment of communication is RS485 and protocol used is PROFIBUS. In the section 2 is presented the structure of a control system for driving of a gate of dam. In section 3 is presented the control system used for a controlled discharge of the dam spillway.

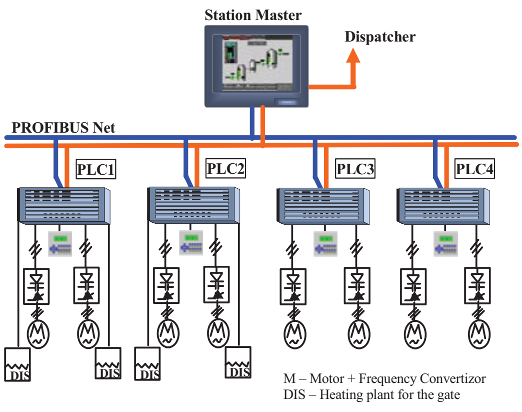

Figure 1: General arhitecture of the control system

2. AUTOMATIC CONTROL OF DRIVING GATE

The Programmable controllers collect process and transmit information to the master computer which provides oversight of the dam operation. Information circulated between programmable controllers and computer refers to states, commands, signals and protection, and will be listed in part below:

- Operating regime of hydromechanical equipment is on "Manual / Pause / Automatic;
- The state of the choice key of hydromechanical equipment functioning "local control / remote control";
- The choice of power supply is "the source base / source backup";
- The position of the automatically switch power from main source (power reserve) is "switched on / switched off";
- There is command "opening / closing gate";
- The position of the power automatic switch engine on the left (right) for the opening drive, is "switched on / switched off";
- The position of the power automatic switch engine on the left (right) for the closing drive, is "switched on / switched off";";
- The voltage source base (reserve) on the phase R, S or T;
- The absorbed current by the engine on the left (right) phase R, S or T;
- The position of the gate is "on the threshold";
- The gate is in "fully open position";
- The Electricbrake drive for the left\right mechanism is "powered / nonpowered";
- Temperature of the heating plant of the gate;
- The automatic protection switch of the power supply cabinet base (reserve) was triggered;
- The automatic protection switch of the engine on the left (right) was triggered on the opening(closing);
- Overload operation left arm (right arm);

- PLC - fault;
- The difference between drive chains position is higher than 1cm;
- The pressure and level in hydraulic installations
- The currents for the heating plants of the gates

The information conveyed from the master computer located in the control room and programmable controllers located in dam cells are used for the control of the dam from control room, and in the future from the regional Hydro dispatcher.

The characteristics of a dam gate that was controlled for opening/closing with a difference between drive chains position less than 1cm are the following:

- Nominal load mechanism: 200tf
- Light opening: 16m
- Clear height: 10m
- The total report of the reduction mechanism: 10500

The electric plant for control, automation and protection is composed from :

- the control cabinet;
- the automation and protection equipments;
- static frequency converters;
- power circuits;
- secondary circuits,
- electric motors actuators;
- position transducers;
- limiters race and / or load;

The PLC performing the command operation of the hydromechanical equipment for surveillance and togheter with the computer station realise the integration in local SCADA system .

Electrical power circuits containing:

- breakers with overload and short circuit protection for the power supply cabinet base (General Services power loop);
- breakers with overload and short circuit protection for backup power source cabinet (Diesel group power loop);
- automatic switches and breakers with overload and short circuit protection for power supply to drive motors;
- network analyzers Circutor, who give us informations of the operating parameters of electric motors (current, voltage, active power, reactive power factor power), and use a serial port communication can send the measured parameters to the Master PLC through Profibus protocol;
- special modules for the cancelling of the electrical perturbation generated by the choppers

Secondary circuits are equipped with: PLC, signal converters, sensors and communications networks.

The opening/closing of the gate could be realised like a combination of the following keys manual/automat and local/remote.

Beside is implemented and a emergency actioning who is done pure mechanical (electrical power is off).

For opening and closing of the gate are used two chain mechanisms placed on the left and on the right of gate. Each mechanism is driven by a motor controlled by one static frequency convertor.

The Telemecanique frequency converters have the following functions:

- mantain togheter with the PLC the engine speed so that the engines will always have the same speed (i.e. the actuators have the same speed) thus making the synchronization;
- online monitor load on the mechanisms for determining the overload or failure.

Achieving of the synchronization with frequency converters is made through an automated system which analyse the engine speeds. These speeds are measured on-line through the speed sensors each consist of one inductive proximity sensor and a current-frequency converter. Automatic control loop is shown schematically in Fig 2 and Fig 3.

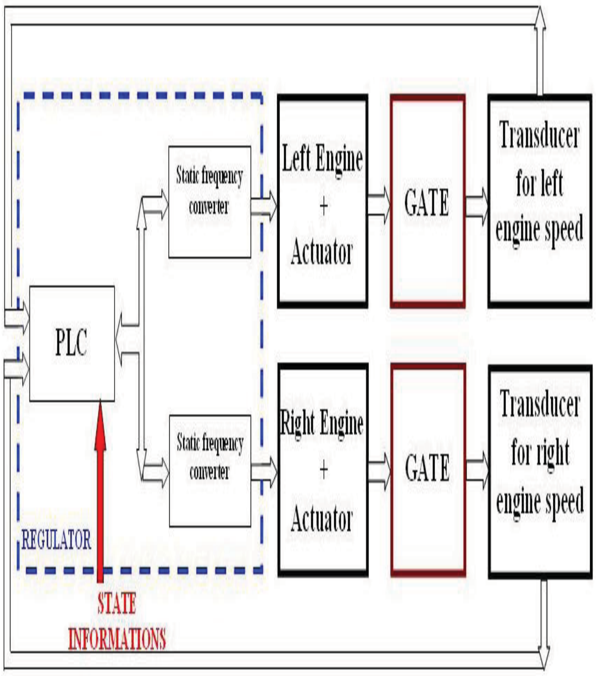

Figure 2: Automatic control loop

The position of the gate is provided by a Rivert angular transducer, which is programmable through a communication interface with Hart Protocol.

Logically, the drive control system is organized on three levels.

The upper level is implemented in PLC as a nonlinear multivariable compensator [1].

The ARM - multivariable control algorithm - is implemented soft and has a discrete integrator with saturation and variable amplification factor [2].

We use a control with saturation for alleviating of the high amplitude oscillations that could occur in the system.

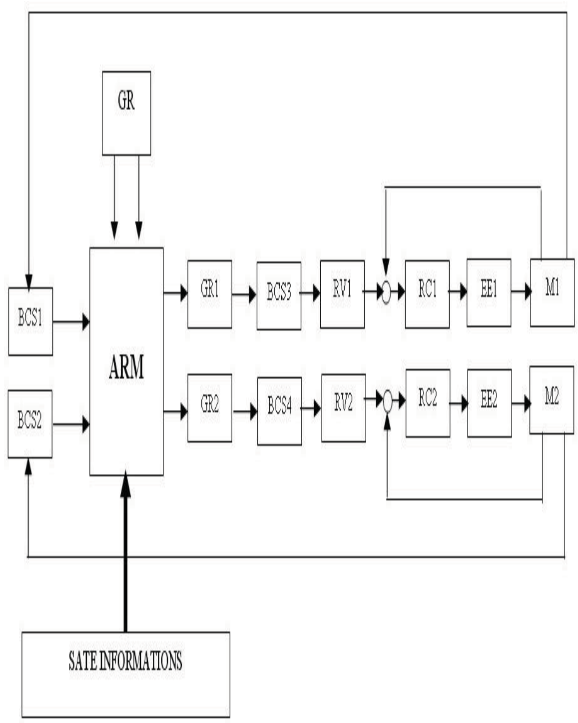

Figure 3: Automatic control loop - detailes

Where:
ARM - Multivariable Control Algorithm
GR, GR1, GR2 - Reference Generator
BCS1, BCS2, BCS3, BCS4 - Signal Conditioning Blocks
RV1, Rv2 - Speed Controllers
RC1, RC2 - Current Regulators
EE1, EE2 - Actuators
M1, M2 – Engines

The inputs into the algorithm are passed through filters with pulse cutting 1/3 rad/s, and discrete transfer functions on the form:

$$H_f(z) = \frac{T(z^{-1}+1)}{(T-2T_1)z^{-1}+(2T_1+T)} \tag{1}$$

where:
- z^{-1} is delay discrete operator;
- T is sampling period;
- T_1 is filter constant

The other two levels of control are implemented in each frequency converter in principle as cascade control algorithms, PID type. Inner Loop is a quick adjustment and is designed using the current operating characteristics of engine and outer loop is designed for speed control (speed) controlled engine.

Actuators are made with thyristors and their mathematical model can use a simplified transfer function:

$$H_{ee} = Ke^{-\tau s} \cong K\frac{1}{1+\tau s} \tag{2}$$

Where:
- s is the complex operator;
- K is the amplification factor;
- τ is the switching delay time;

The speed control loop, is basically on type PID filter in the form :

$$H_v(s) = \frac{KT_iT_ds^2 + KT_is + K}{T_iT_\gamma s^2 + T_is} \tag{3}$$

Where:
- s is the complex operator;
- K is the proportionality factor;
- T_i is the integration constant;
- T_d is the derivation constant;
- T_γ is the filter constant;

GR1 and GR2 reference generators are realised with adjustable parameters, which provides a good balance for this subsystems.

The results are excellent; a very good behavior of the system is obtaining even in presence of the disturbances. When the system was deliberating unbalanced with 10 cm, the control system is able to quickly rebalance the positions of the chains. An important role to achieving a fast response it has the variable amplification factor from ARM.

3. AUTOMATIC CONTROL FOR DISCHARGE OF THE DAM SPILLWAY

Hidroelectrica give the specifications for the opening/closing of the gate in the case of discharge of the dam spillway with a desired flow, such that the exerted pressure by the water on the dam to remain admissible. This complex control system (see Fig 4) is organized on four levels. The last three levels are implemented in the equipments what serve each opening of the dam.

Upper level management is implemented in a graphics station, with a complex algorithm, which receives information about the entry flow in real time, reference discharge flow, position of the gate, protections and general status of the dam. The output of the general algorithm provides the starting and stopping commands to the driving gates to achieve the objectives of the settings imposed by the operator, with the specifications and restrictions.

The operator can see on the display the general state of the dam, events, message; alarms (see Fig. 5 and Fig. 6).

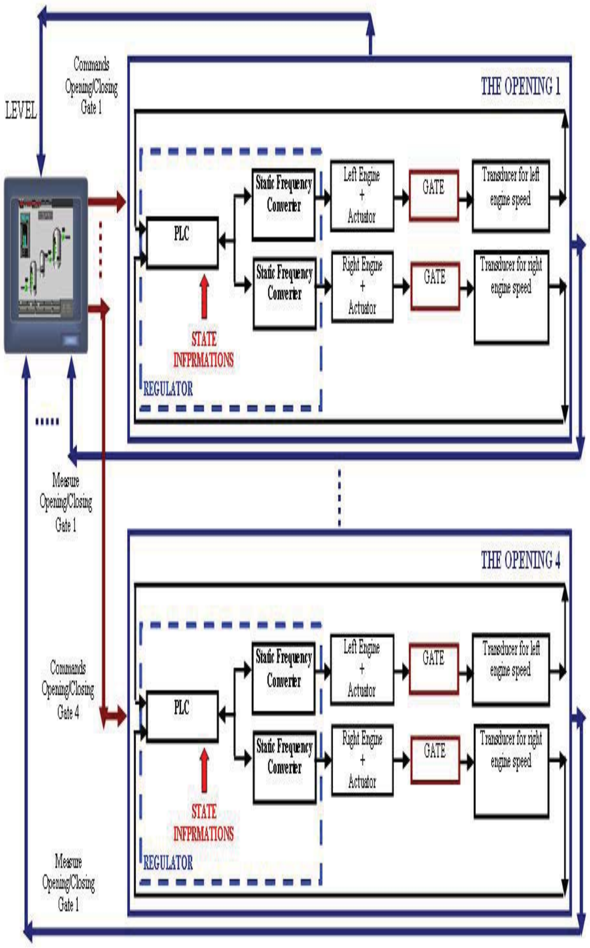

Figure 4: General control loop

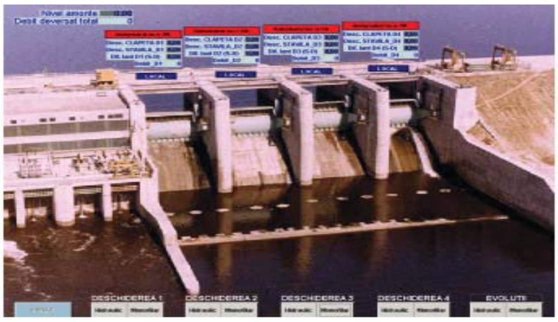

Figure 5: General view of application

A few date of application(for two dams) could give a better image about of the complexity of her : 2 Workstations, 13 PLC, 13 Operator panel, 24 Communication networks, 23 Automation loops, 16 Static frequency converters, 23 Network analyzers(see Fig. 7), 100 programmable interfaces and transducers, about 5000 variables in 28 software programs.

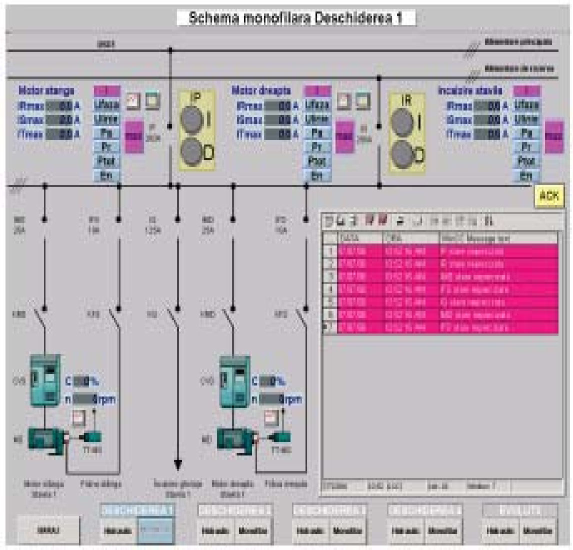

Figure 6: Monofilar schema

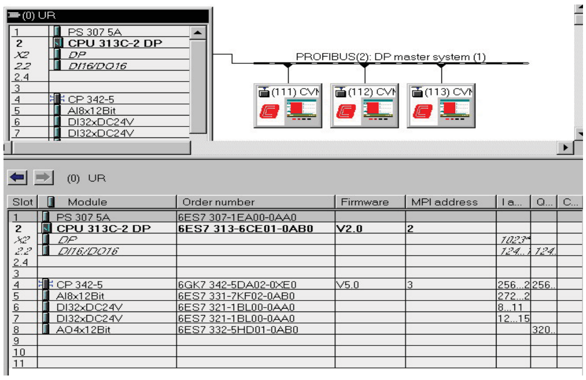

Figure 7: Profibus Net for Circutor analyzers

4. CONCLUSIONS

This application permit to local supervisory staff and the local dispatcher (Hydro) to know the status and operating parameters of the plant, increasing the safety, reliability and ergonomics in the operation of the dams. The general performance obtained is very good and better in comparison with the old classical driving system.

References

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