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APPLYING DIGITAL CONTROL OF THE DISCHARGE IN HYDRAULIC MODELS

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Abstract - Investigations of the dynamic processes in hydraulic models of hydro plants showed that the control over the water supply is essential. Transient events, that is, the start or stop of the turbines or pumps must be simulated. Especially, in pumped storage plants we have to investigate transient operations which are evolving from the rapid changes between the pumping and the generating mode. In hydraulic models there are also cases of repeated operation (danger of resonance) that have to be simulated. For the simulation of the pump or turbine an experimental unit was built. With this unit a high flexibility of the parameter in the time diagram was achieved.

Keywords: pumped storage plants, hydraulic model, valve control, discharge control

1. INTRODUCTION

Following the liberalization of the European electricity market, power has become a commodity traded on the stock exchange, and this has fundamentally changed the setting for the generation of electrical energy. Many different power station types cooperate to provide the clients with electricity of the desired quality and availability. Thermal power stations – the dominant power station type in Europe – supply their energy “blindly” to the system. Their purpose is primarily to generate energy in abundance, so as to make optimal use of the fuel, producing a maximum amount of energy with a minimum of pollutant emission. Any change in output from large-scale thermal power plant is slow. As forecasts of power demand can never be a hundred percent precise, there may often be too many or too few power stations working, without the “blind” power stations being aware. Moreover, the rapidly increasing development of wind energy has added to the flexibility problem, because unforeseen variations may now occur on the production side as well. Thus, energy suppliers need rapid and flexible means to balance variations in power demand at short notice. Pumped-storage stations help to make efficient use – in terms of both energy and ecology – of extra capacities in the system by pumping water to a high-level reservoir and using it when the demand arises. The total capacity of such plant is available at very short notice, that is, nowadays within not more than a half of minute. The same applies to shut-down or change-over to the pumping mode. In the light of the general energy shortage and the problems faced in meeting peak loads there is a constant need for the construction of new pumped-storage schemes. Pumped storage has come to be the environmentally most compatible method of balancing sudden drops in demand or unexpected production increase from wind power stations. Present-day electricity generating plant is characterized by optimal utilization of hydrostatic head and turbine efficiency. As the available numerical simulations of the complex hydraulic processes involved tend to be limited to one-dimensional analyses whose results are not sufficiently reliable, unsteady processes are studied in physical models.

The particular case discussed in this article is a pumped-storage station equipped with three pressure surge tanks, for which the dynamic processes in the tailwater portion were studied. The design of pressure surge tanks provides for a low-level underground chamber to ensure sufficient inlet pressure for the main pump. This, however, places the rotor of the Pelton turbine below the drawdown level of the tailwater basin, which implies the need to apply air pressure to keep the wheel clear of the water surface. A pressure above atmospheric of 2 or 3 bar lowers the water level in order to ensure sufficient clearance for the Pelton turbine. Another problem is the surge waves caused by the increasing rapidity of the mode changes between the pumping and generation modes. That means, however, that the hydraulic equipment – water conveyance structures and mechanical equipment – of present-day power stations must satisfy extremely high demands. This new situation is being met by improvements in surge-tank strategy and especially in the tailwater portion of power plants. The sophisticated design of the hydraulic scale model (equipped with process control) presented in this article has provided valuable general information on the complex behavior of surge waves.

2. MODEL SET-UP AND INSTRUMENTATION

For these purposes a hydraulic model of the tail-water part of a pumped-storage plant was constructed. The model was built, mainly of Plexiglas at a scale of 1:22.5 at the laboratory. The overall model included the entire tailwater system over a length of about 350m (nature) and the simulation of the turbine and pump operation.

Figure 1 is a photograph providing an overview of the model set-up at the Institute's laboratory. The water supply to the model was provided (regulated) by a pipeline system which is part of the Institute's own water supply. Each of the three turbine units was supplied separately, and measured by an inductive flow meter 100mm in diameter.

In addition to an inductive flow meter of dia. 100mm for the pump unit another one of dia. 250mm was installed in the tailrace tunnel of the system to measure the total discharge. All pressure surge tanks (DWS) and the chamber surge tank (KWS) were provided with the instruments to measure water level variations. In fig. 2 the applied sensors in the hydraulic model are shown.

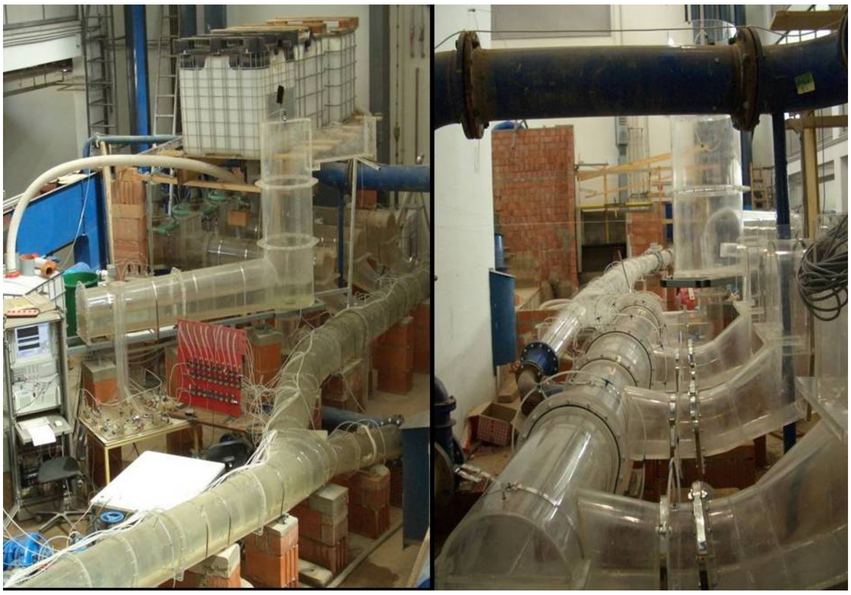

Fig.1. Details of the model set-up at the Institute's laboratory.

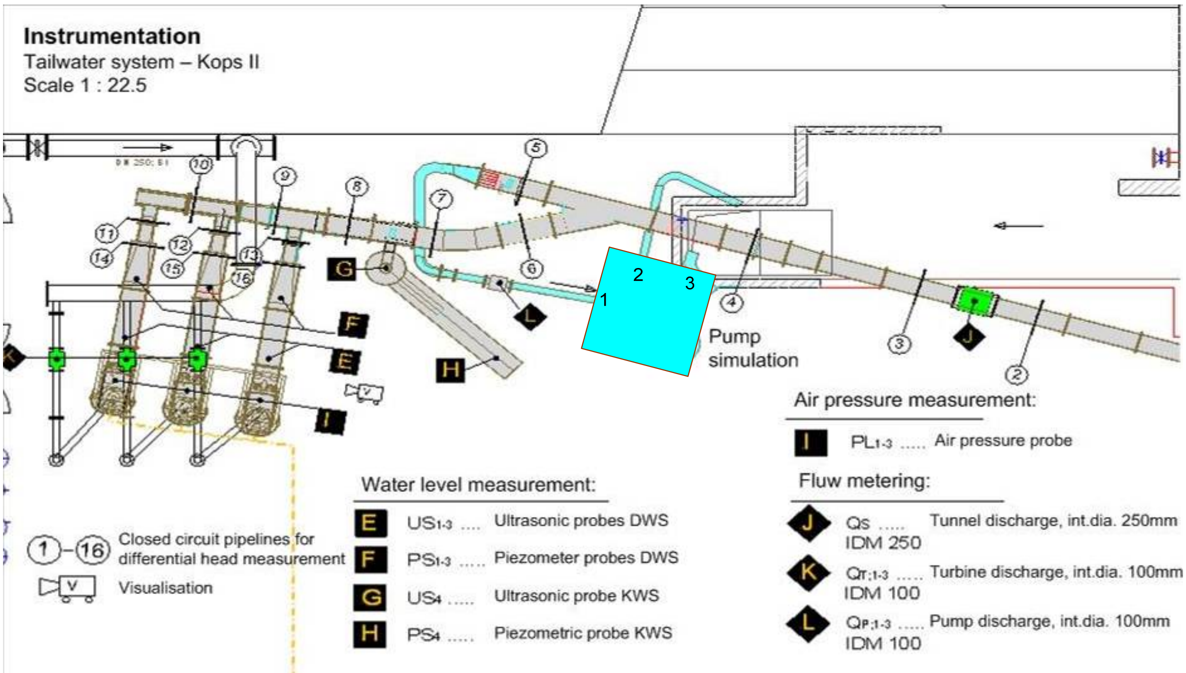

Fig. 2. Schematic drawing of the model set-up and instrumentation.

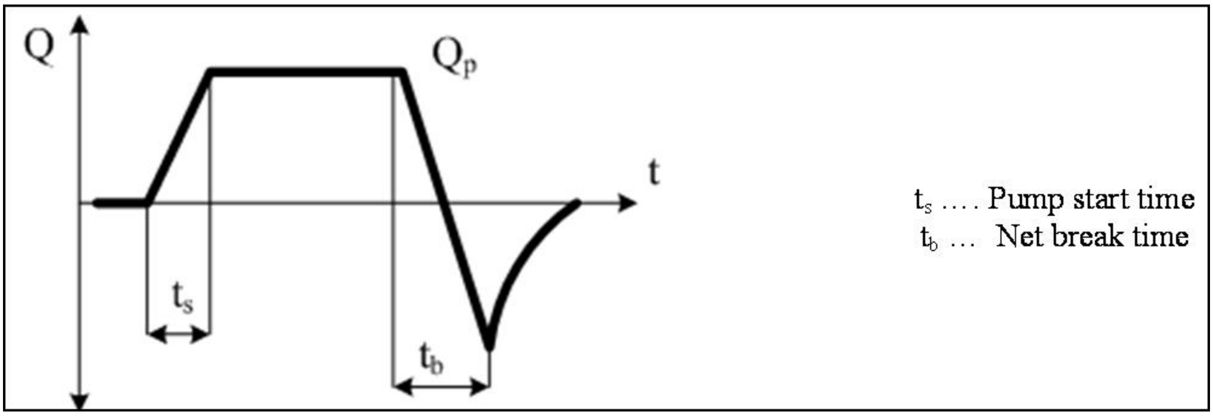

Fig. 3. Time diagram of the pump discharge.

For the simulation of the pump or turbine operation – steps (fig. 3). For example the start up followed by a sudden net break is depicted. The appropriate experimental unit was developed. With this unit (fig. 4) a high flexibility of the parameter in the time diagram was achieved.

Figure 4 illustrates an electro-pneumatic controlled valve and its application in the valve group. Each valve group contains 5 or 6 valves controlled with air actuators and electro-pneumatic valves. The pipe 1 has a connection to hydro plant model for simulation of the pump. The pipe 2 presents the high pressure supply part and the pipe 3 presents the low pressure supply part.

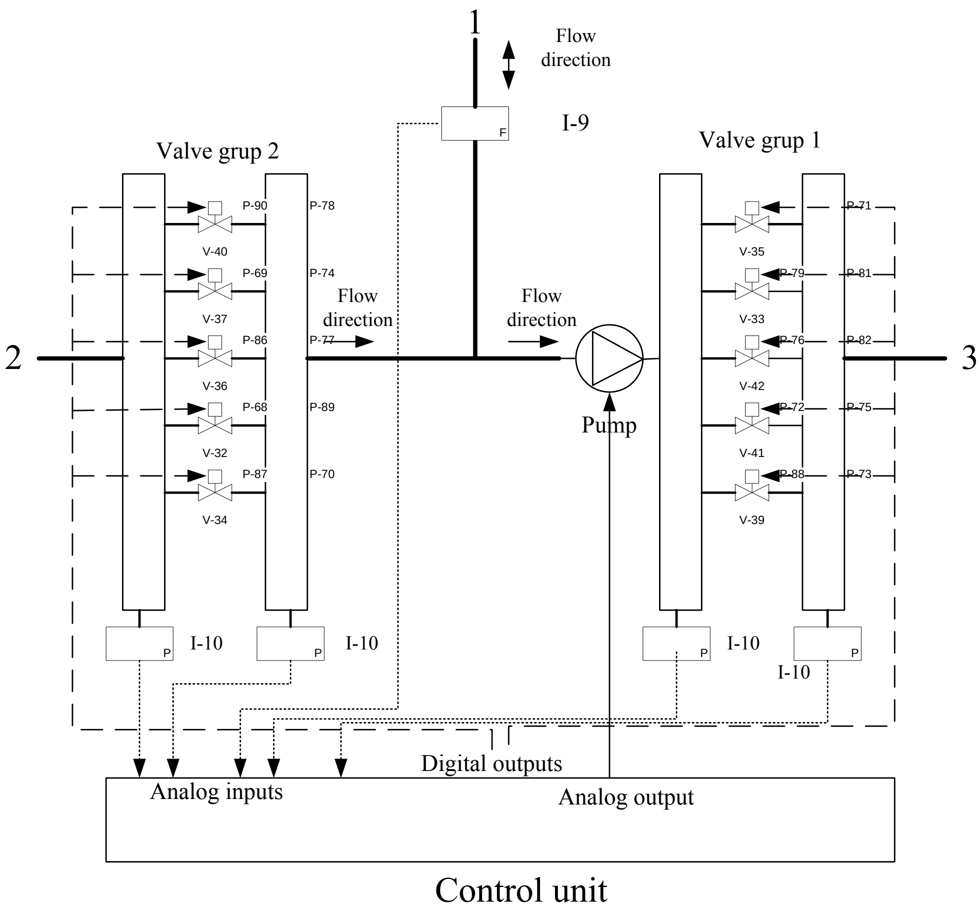

Fig.4. Experimental unit for the simulation of the pump operation – steps.

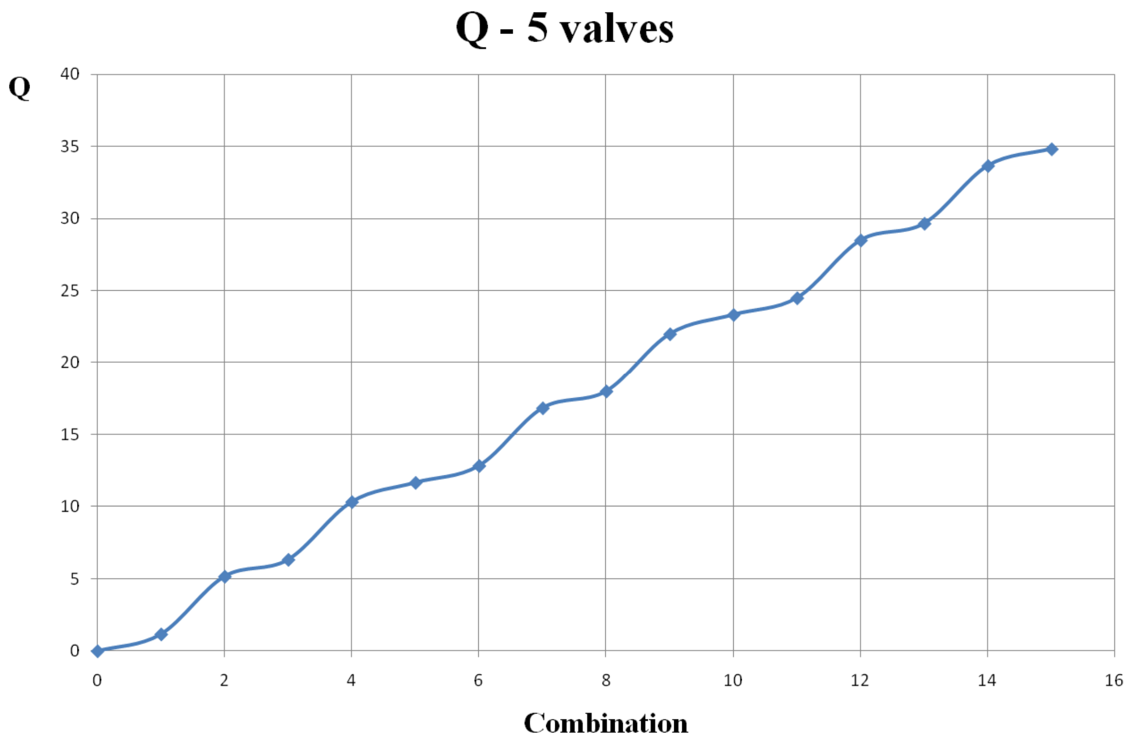

Fig.5. Discharge Q[l/s] diagram for valve group (combinations).

Each valve group was tested on a test rig to establish the characteristic flow curves at different pressure levels. Discharge diagram for 5 valves – in this case 16 combination of valves are used - is shown in figure 5. The figure 6 shows the practical construction of valve group.

Fig.6. Electro-pneumatic controlled valve (left) and valve group with 5 valves.

3. CONCLUSION

The main task of a valve group is to provide a time dependent flow. To establish the flow in both directions, two valve groups are operated, as shown, in sequence (Figure 4). In the experimental work the changes must occur very quickly, therefore, digital switch on-off valves were used. The time response of such a valve is limited for achieving a smooth change of flow. Usually used valves are too slow to achieve fast flow changes or have problems with control stability. A solution was achieved with the combined use of conventional electro-pneumatics valves and digital control. In this way we achieved the discharge control with a fast response.

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