HYDRAULIC MODELLING FOR THE DEVELOPMENT OF PUMPED-STORAGE SCHEMES

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Following the liberalisation 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. Changing conditions in the European energy market have brought about a rising demand for peak 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 minute. The same applies to shut-down or change-over to the pumping mode.

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.

Where ground conditions make access difficult or exhibit insufficient imperviousness to resist the planned pressures, pressure surge tanks may offer substantial advantages over the conventional designs. They are also much in use in drinking-water supply systems for damping water hammer effects.

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. As Pelton turbines can work under pressure above atmospheric, the additional head so created can be used for power generation.

The cost of constructing and operating pumped-storage schemes should be optimised by considering the following: The distance (vertical axis) between the turbine and the pump in the cavern should be as small as possible. Great economy under partial-load conditions is achieved only by Pelton turbines. On the downstream side, immersion of the turbine blades in the water leads to the malfunction of the turbine and must by all means be avoided. Therefore, an air cushion should be used to build up a pressure above atmospheric so as to keep the water surface low. Rapid changes between the turbine and pumping modes cause surge waves. These processes must be simulated by numerical means and hydraulic model tests. As most of the available numerical simulations are confined to one-dimensional analyses and produce results that are not sufficiently reliable, they must be supplemented by physical models. In the case discussed in this paper, the downstream portion of a pumped-storage scheme was modelled to study the dynamic processes. The sophisticated design of the hydraulic model (process control) provided valuable additional information on the complex behaviour of surge waves.

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