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exist for the publication of theoretical and experimental investigations of all aspects of the mechanics and thermodynamics of fluid-flow with special reference to fluid-flow machinery

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HYDROFORUM

KONFERENCJA NAUKOWO-TECHNICZNA

na temat

ZAGADNIENIA HYDRAULICZNYCH MASZYN WIROWYCH

Gdańsk-Władysławowo, 24-27 września 1985 r.

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HYDROFORUM

SCIENTIFIC-TECHNICAL CONFERENCE

on

PROBLEMS OF HYDRAULIC TURBOMACHINES

Gdańsk-Władysławowo, September 24-27, 1985

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ГИДРОФОРУМ

НАУЧНО-ТЕХНИЧЕСКАЯ КОНФЕРЕНЦИЯ

на тему

ПРОБЛЕМЫ ГИДРАВЛИЧЕСКИХ ТУРБОМАШИН

Гданьск-Владыславово, 24-27 сентября 1985 г.

Report

on the First Discussion Meeting on

Problems of Pumped-Storage Water Power Plants Construction and Operation at the Example of the Żarnowiec Power Plant

Eng. Kazimierz Pietryka, M.Sc., the managing director for technical matters of the Northern Power District in Bydgoszcz, chaired the meeting.

The discussion was based on the information delivered to the Conference participants during the visit to the Żarnowiec Water-Power Plant and three introducing communications read by the engineers from the Power Generating Industry and the representative of ČKD Blansko.

During the visit to the Power Plant the managing director Eng. Bolesław Sokołowski, M.Sc., together with his co-workers spoke about construction work, equipment and basic operating parameters of the plant. The introducing communications were delivered by Eng. Stanisław Cicholski, the managing director for technical matters of the pumped-storage water power plant at Żarnowiec, Eng. Stanisław Lewandowski, M.Sc., the head of the Żarnowiec Pumped-Storage Water Power Plant Operation Department and Dr. Viktor Kanický from ČKD Blansko.

Eng. S. Cicholski and Eng. S. Lewandowski discussed properties of the Żarnowiec Power Plant operation and presented information and conclusions resulting from the experience gathered during the construction and three-year operation of the object, and concerning the organizing and technical problems as well as some defects requiring repair. The most important general information about the Żarnowiec Pumped-Storage Water Power Plant is given below.

The Żarnowiec Water Power Plant, built in the period 1973-1982, is a pumped storage plant equipped with four hydroelectric generating sets, each consisting of three units: a reversible turbine of Francis type, a motor-generator and a starting motor, designed for the rotational speed of 167.7 rpm.

Basic data on the power plant

The power in the turbine mode of operation amounts to 680 MW while in the pumping mode it is equal to 800 MW. The maximum static head is 125 m and the maximum energy storing capacity of the upper reservoir equals 3.6 GWh. The upper, artificial reservoir has the volume making possible operation of the power plant in the turbine mode for 4.8 hours at the maximum flow rate, and a 6-hour operation in the pumping mode. The Żarnowieckie Lake serves as the tail water reservoir. The L/H ratio equals 9.6, L being the penstock length and H — the difference of water levels.

The starting times amount, in average, up to 3 minutes for the turbine mode and 10 minutes for the pumping mode of operation.

In the power plant provisions have been made for the remote control of the turbine sets and power control within an automatic frequency and power control system. The power plant is connected to the electric power network on the 400 kV level.

The cost of the Żarnowiec Water Power Plant together with 400/100 kV station was equal to 7132.7 million zlotys in prices related to the year 1982. Its present value is 22 382.6 million zlotys.

Characteristic data of the basic units of the power plant

Upper reservoir

Total volume: 16×10^6 m^3

Effective volume: 13.7×10^6 m^3 in a layer 16 m thick

Water surface area: 95 ha

The bottom of the reservoir is completely covered with an asphalt-concrete compound. The inlet chamber

is made of concrete. The volume of concrete used is 36×10^3 m^3. The chamber is provided with trashracks, repair head gates and quick-acting penstock inlet closing slide valves.

Penstocks

Four welded steel penstocks, each of them 1200 m long, are composed of 8 sections joined together with compensators. Sections Nos 1 and 8 are covered with earth while the remaining ones rest above the ground on supports. Diameters of the penstocks are graded. Sections Nos 1 have diameters of 7100 m while the final ones, Nos 8 — 5400 mm.

Building

The volume of the underground part is 180×10^3 m^3 while the steel structure above the ground (together with the erection shop) has the capacity of 87×10^3 m^3.

Turbine sets

Three-unit vertical sets of 167.7 rpm rotation speed, rotating clockwise in the turbine mode of operation and anticlockwise in the pumping mode. Turbine set powers are 170 MW in the turbine mode of operation and 200 MW in the pumping mode.
Turbines: reversible, Francis type
Flow rate in the turbine operation mode: 175 m^3/s
Flow rate in the pumping operation mode: 142.5 m^3/s
Manufacturer: ČKD Blansko
Generators: synchronous, air-cooled
Rated voltage: 15.75 kV
Flywheel moment: 32×10^3 tm^2
Manufacturer: Heavy Electric Machinery Works, Kharkov
The generators operate in conjunction with 240 MWA 15.75/400 kV transformers installed above the draft tubes outside the power plant building.
Starting motors: asynchronous, slip-ring type
Rated voltage: 6 kV
Rated power: 13 MW for 15-minute operation, and 8 MW for continuous operation
Rated speed: 185 rpm
Liquid-driven starters.

Channel

Connects the power plant to the tail water reservoir. It is 835 m long, 100 m wide at the bottom and 7 m deep. The channel has been designed for discharge of 714 m^3/s at a velocity of 1 m/s. The banks are strengthened with the asphalt-concrete compound.

Tail water reservoir (natural) — the Żarnowieckie Lake

Area: 1450 ha
Water level fluctuations corresponding to the effective volume of the upper reservoir: about 1 m.
Mean annual inflow of water to the lake: about 3,0 m^3/s.

The Piaśnica River flows through the Żarnowieckie Lake. On the discharge side of the Lake a weir has been built which allows to control the water level in the lake.

The next speaker, Dr Viktor Kanický dealt with the matter of pins used to protect the guide-ring of a pump-turbine against damage. The contents of his talk are given on pages 85 to 91.

Referring to the talks of Eng. Eng. S. Cicholski and S. Lewandowski, Prof. Kazimierz Steller from the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences in Gdańsk pointed to expediency of large water power plant instrumentation with basic diagnostic equipment for control and current assessment of machinery and approach flume condition. He also pointed to the need of building a movable specialistic laboratory for carrying out tests and comparative analysis by the staff of ENERGOPOMIAR or the Repair Works of the Power Generating Industry. Referring to the remarks which concerned building new plants and entering contracts for delivery of machines from foreign manufacturers he made a proposal to carry out supplementary model tests at home. They should be useful for verification of results of tests

carried out abroad and should be the ground for correction or specification of supplementary requirements from a supplier.

Dr. Josef Bednař from ČKD Blansko pointed to specific phenomena in reversible machine dynamics and presented his opinion about some statements made during the discussion; he also informed about the design-research background of his firm. The speaker pointed out that due to flow pulsation and vibration phenomena occurring in pump-turbines only some producers have decided to manufacture this type of machines. He emphasized that operation of the machines at the Żarnowiec Power Plant as well as that of their prototypes at the Dalešice Power Plant in Czechoslovakia go on properly and that experience from assembly and initial operation of the Żarnowiec Power Plant is of great value for the design engineers as well as for the manufacturer. Next he discussed the problems of the guide-ring vibration, carbon gland lifetime and bearings accessibility. According to his opinion the easy access to bearings is a question of economy which must be taken into account by the machine designer. Limitation of space, and therefore difficulties in access to bearings, decreases costs, whereas expansion of space, making access to bearings easier, increases costs. That is why cost and operation reasons should determine the solution. Finally Dr J. Bednař informed about hydraulic and dynamic investigations carried out at ČKD Blansko. He emphasized their practical use, and especially connection of the research with successful construction of a power plant and easiness of putting it into operation.

Prof. K. Steller referred to the statement of Eng. S. Lewandowski, M.Sc., concerning post-cavitation repairs. Among others he pointed to necessity of regarding cavitation loads, that is the kind and intensity of the phenomenon when working up the repair technology, and pointed the usefulness of carrying out technology tests before a particular technology of repairs has been accepted.

Prof. David Rachman from the University of Strathclyde pointed out to water properties which affect cavitation erosion. In his statement he referred to the post-war difficulties of Neyrpic firm which delivered turbines to the tropics. Great quantity of carbon dioxide in water causing increase of cavitation intensity was the reason of these difficulties. Keeping this in mind he asked about expected changes in Żarnowiec Lake after completion of construction of the nuclear power plant, especially about expected influence of water temperature change and biological phenomena on cavitation processes.

Eng. Maciej Kwiatkowski, M.Sc., the head of Mechanical Supervision Department in the Żydowo Power Plant, informed that physical and natural changes in Żarnowiec Lake are expected after setting the nuclear power plant in motion. For the present one has not dealt with the influence of these changes on cavitation process although the problem is worth of notice.

Referring to preceding statements Dr. Josef Bednař pointed out that the manufacturer of reversible pump-turbines, expecting occurrence of cavitation in machines, used stainless materials for parts exposed to cavitation erosion. Thus, the runner vanes are made of chromium-nickel steel with 13% Cr and 6% Ni content. This material permits to repair cavitation damages avoiding machine disassembly.

Eng. Bogdan Sienkiewicz, M. Sc., a specialist from the Porąbka-Zar System of Water Power Plants, stated that all observations concerning organizational and technical problems from the time of building the Żydowo Pumped-Storage Water Power Plant are similar to observations made in the Porąbka-Żar Power Plant. He devoted the fundamental part of his talk to the upper reservoir of the Porąbka-Żar Power Plant which, like the reservoir of the Żarnowiec Power Plant has an asphaltic concrete seal. However, both reservoirs differ in construction; unlike the reservoir at Żarnowiec the reservoir at Porąbka-Żar has a multilayer seal with a drainage layer between two sealing layers. Such construction, it appears, does not require keeping a protective water layer which would protect the bottom of the reservoir against getting warm and developing gas bubbles in summer, and against getting frozen and breaking in winter. Resignation of the "dead" water in Porąbka-Żar allows to increase the duration of the Power Plant operation by about 15 minutes, and thus increase the energy production by over 100 MWh during one cycle. On this basis the speaker presented the opinion that use of more expensive solutions i.e. multilayer reservoir seals is a profitable undertaking, thus economically reasonable and worth of recommending.

Further on, Eng. B. Sienkiewicz, M.Sc., answered questions concerning the way of protecting guide-rings in the Porąbka-Żar Power Plant against damage. The speaker explained that parts of the guide-rings are protected with friction devices. These devices have stood the test in practice and have aroused trust of the user.

Eng. Tadeusz Kiedrowski, M.Sc., responsible for start-ups of the Żarnowiec Power Plant expressing himself on the subject of machinery diagnostics stated that first and foremost simple measuring and control devices are necessary for the user of water turbines. They are necessary for current and quick assessment of state of different sets. Assessment of bearing vibration after adjustment may be an example. Lack of own diagnostic instrumentation and waiting for carrying out tests by special control groups is unreasonable.

An animated discussion arose on a subject of machinery "monitoring". The necessity of obtaining quick information was emphasized in the discussion. Possibility of use of diagnostic equipment from the Repair Works of Power Generating Industry in Wrocław was pointed.

Eng. Wiesław Biliński, M.Sc., the chief engineer of the Porąbka-Żar Water Power Plants System, pointed out usefulness to equip big power plants, especially the system power plants, with microcomputers for gathering and analysing quantities characterizing operation of generating sets. He referred to the Altes-Bades Power Plant where automatic recording and analysis of the quantities mentioned is carried out.

Prof. David Rachman pointed out usefulness of use of central computers for diagnostics. Information recorded on a tape in the power plant should be directed to the centre from where, after data analysis, the power plant staff should get either control information or recommendations for operation.

Eng. Stanisław Lewandowski, M.Sc., discussed the following problems: post-cavitation repairs, dead zone in the upper reservoir, penstock control, and machine diagnostics. He informed that cavitation damages which occurred at Żarnowiec surprised the users. The first repairs were made according to Polish technology. They were made by the Repair Works of the Power Generating Industry in Gdańsk with use of chromium-nickel electrodes EN10-10.

Referring to the statement of Eng. B. Sienkiewicz, M.Sc., he pointed to different functions of dead water zones in reservoirs. The dead zone in Porąbka-Żar is to protect the bottom of the reservoir while in Żarnowiec — to protect reversible pump-turbines. Referring to the penstock control he informed that measurements of stresses in penstock casings are carried out periodically. One searches for better methods of control and protection. Referring to the statement of Prof. Rachman on a central computer application he informed about experience of data transfer from Turów to Wrocław. In view of frequent interferences and errors the central system has not stood the test. In his statement he supported the suggestion of Eng. W. Biliński, M.Sc., on providing large power plants with microcomputer devices of simple and easy service.

Dr Viktor Kanický spoke of machine diagnostics. In his talk he referred to the information delivered by himself during the HYDROFORUM'80 Conference at Kozubnik. The diagnostic system worked out by ČKD Blansko is based on the microprocessor technology. He pointed out that measuring and processing of the input signal is a very important matter. Particularly it concerns pressure pulsation in flow and vibration which are phenomena characteristic for different operation modes of machinery and in particular for transient regimes. Gathered and processed pieces of information serve as well the user as the machine designer. On the basis of them one classifies operation of a machine, determines its characteristics, comes to conclusions about different factors affecting machine condition and takes decisions about technology. The whole system works automatically. The information is recorded on floppy discs and transferred to the Central Laboratory in Blansko. There an analysis of the obtained results is carried out. ČKD Blansko Firm may deliver suitable devices at a cost of about 0.5 mln Czechoslovak krones.

The Chairman of the meeting Eng. Kazimierz Pietryka, M.Sc., recapitulating the discussion on machines diagnostics in water power plants, emphasized great interest in this point and pointed to necessity of solving this problem in the range of whole the country.

Eng. Marian Hoffmann, M.Sc., the chief specialist in the Ministry of Mining and Power Generating Industry, pointed out to the need of penstock state control in water power plants over 50 years in operation. Recommending services of the diagnostic laboratory of the Repair Works of the Power Generating Industry in Wrocław he uttered a doubt as to possibility of very low frequency vibration measurement. Finally he emphasized the need to consider the possibility of Żarnowiec-Lake oxygenating during the Power Plant operation and to examine the influence of this phenomenon on cavitation.

In connection with the information of Prof. D. Rachman about creation of a special committee in Great Britain which controls technical condition of old dams Eng. M. Hoffmann gave information that in Poland such examinations are carried out within a scheduled system.

Eng. Władysław Fugiel, M.Sc., the chief design engineer in the ENERGOPROJEKT Power Engineering Studies and Design Office in Warsaw, referred to the statement of Prof. K. Steller on approach flume control and explained that the plant project provided for differential protection of the penstocks. However, due to the lack of a supplier of appropriate devices the investor installed in his own capacity devices for measuring water level in rapid flows. These devices are equipped with a level signalling indicating occurrence of larger water quantity in consequence of expansion joints damage or penstock failure.

Closing the session the Chairman thanked everybody for the participation in the meeting which he called exceedingly useful for power engineers.

Worked out on the basis of a magnetic tape record by:
Marek Targan and Kazimierz Steller