TIDAL POWER PLANT EQUIPMENT

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Keywords: Straight-Flow Unit, Bulb Unit, “Straflo” Unit, Orthogonal Unit, Axial-Flow Turbines, Reversible Units, Step-Up Gear, Cycle Generator

Contents

Summary

This chapter deals with some aspects of tidal power plant equipment (TPP). Low heads and changes in the direction of water flow, which are periodic with the lunar day, are characteristic for TPP. Considering these characteristic features, research on the development of optimal horizontal low-head sets with axial-flow turbines, which was unprecedented in terms of scope, was brought into play in the design of the Rance TPP (see *Historical Sketch, Perspective and Classification of TPP Schemes*). Reversible capsule sets have been developed and are currently operating successfully at the Rance TPP as a result of this research. After construction of the Rance TPP, capsule sets came into widespread use at large-scale low-head hydroelectric plants, where they are used only in a one-way turbine mode. The direct-flow “Straflo” set with an axial-flow horizontal turbine for which the generator rotor is placed directly on the rim of the impeller, and the stator is placed around the perimeter of the turbine chamber, was developed at this same time. A modified horizontal set based on a high efficiency Kaplan turbine proposed by the Sultzer Escher Wyss (SEW) Company for the Mersey tidal electric plant and intended for operation only when water is discharged from the basin into the sea has recently appeared. In this set, a metallic shaft with a reduction

generator is immersed in the flow owing to use of a high-speed generator with variable number of revolutions connected to the turbine via a step-up gear.

Search for cost-effective and technologically simple turbine for TPP led to elaboration of the orthogonal unit at the start of the 21st century.

1. History of Turbine Optimization for TPP

The use of tidal energy dictates operation of TPP turbines at fairly low heads, varying both in magnitude and direction (in case of double-effect operation). At a minimum tidal range possible for use, equal from 1 to 4 m, the heads applied to the turbines vary from 0.5 to 12 m at maximum tidal ranges.

The first projects of TPPs in which the installation of vertical-shaft turbines was proposed, featured large head losses and, in the case of double-effect operation, assumed a complicated structure of the underwater part of the power house. According to the designers of the Fundy TPP, the use of vertical-shaft generating units increases the powerhouse length by 50% and the depth of foundation by 8 m. It is clear that the turbine with a horizontal shaft was an efficient solution of the problem for TPPs (see Figure 1). The use of a horizontal-shaft generating unit was proposed for the first time by Professor Graftio for the low-head Hydro Power Plant of Neva river in 1912. Subsequently, they were installed at a series of small HPPs in France, Finland and Germany. The generator was placed outside the flow by mounting the turbine shaft in a slant-axis position.

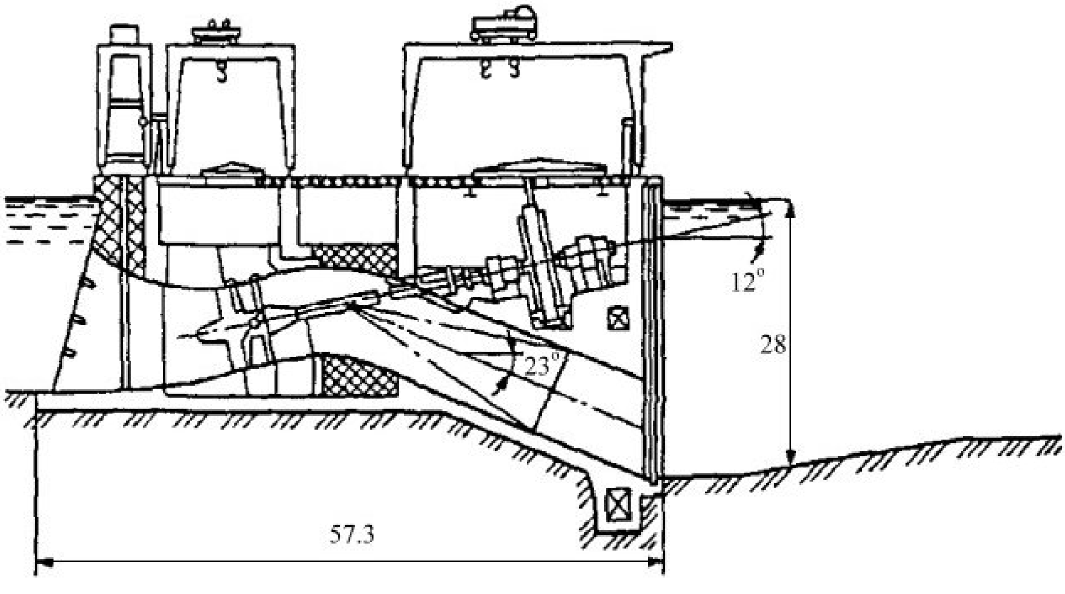

Figure 1: Slant-axis unit with remote generator

Such a scheme, called “tube-type”, has found wide application and is used now in the USA and Canada for small HPPs.

Two approaches were proposed for installation of the generator:

- To mount the generator on the perimeter of the turbine blades resulting in creation of the “straight-flow” turbine-generator’
- To install the generator in a streamlined casing immersed in the flow, which led to the submerged “bulb” turbine-generator.

2. Straight-Flow Turbine

Ideal for a TPP from the hydraulic point of view is the idea of R.D. Harza, to mount the generator rotor on the turbine runner rim. However, it is difficult to make a seal between the generator rotor and stator; this was the reason why Escher Wyss Ltd. has built four small units at the Iller HPP in 1938, and then 73 straight-flow machines with less than 2 MW capacity, with D_1 = 2 m, and ceased their manufacturing in 1951. Three such machines of larger capacity (6.3 MW each) and 3.3 m in diameter, installed in 1953 at the Ortachaisk HPP, USSR, were replaced by vertical-shaft units as well. Probably, because of this, the Neyrpic Company thought it impossible to use straight-flow units more than 2 m in diameter.

But, as a result of about 30-year efforts of English and Swiss specialists, in 1980-1982 Escher Wyss built 10 machines with D_1 = 3.7 m and N up to 8 MW each for four HPPs in Austria. Belgium, and Switzerland. The machines performed well at heads 3.5 to 11 m. This machine later named “Straflo” solved the cardinal problems of the straight-flow units of large sizes: protection against leaks and design of support system the idea of which was borrowed from the heavy-duty press equipment wherein use is made of hydrostatic bearing and pneumatic seals.

In this alternative, use is made of non-contact seals operating on hydrostatic pressure with continuous automatic back flushing. The sealing of the Straflo unit to prevent leaks into the space between the rim of the runner and the generator stator is shown in Figure 2. The repair seal is made in the form of a shaped rubber hose filled with compressed air. The major seal consists of separate segments and pneumatically controlled hold-down hoses. The sealing segments made of creep-resistant synthetic material are impregnated with filtered water in order to use the hydrostatic action for preventing sliding directly between the sealing segment and the runner envelope and protecting the sealing surfaces against detritus.

In case of sea water penetration into the generator rotor space normal operation of the power set will be resumed only after the seals restoration and rotor washing and drying. To prevent sand deposits the sealing segment butt joints were specially designed. Besides, specific systems were used to provide supports and equalize tangential loads.

The use of Straflo units in place of vertical-shaft units by Manitoba-Hydro Quebec HPP reconstruction has saved 10 to 15% of the capital investments. It saves 10% in case of newly constructed HPPs. The generator, alone is 25% cheaper than a vertical one. Compared to vertical-shaft units, the advantages of the Straflo unit, demonstrated at the HPP of Gissen, allowed the Sulzer-Dominion Bridge Company to build the Straflo unit to Escher Wyss designs for the Annapolis TPP that was commissioned in 1984. This machine represents an important stage in the evolution of horizontal-shaft units. It is considered to be a prototype for application not only at river HPPs of medium scale, but at TPPs too, in particular, at two powerful TPPs in the Bay of Fundy, where in one of the project alternatives it was proposed to install 140 Straflo units.

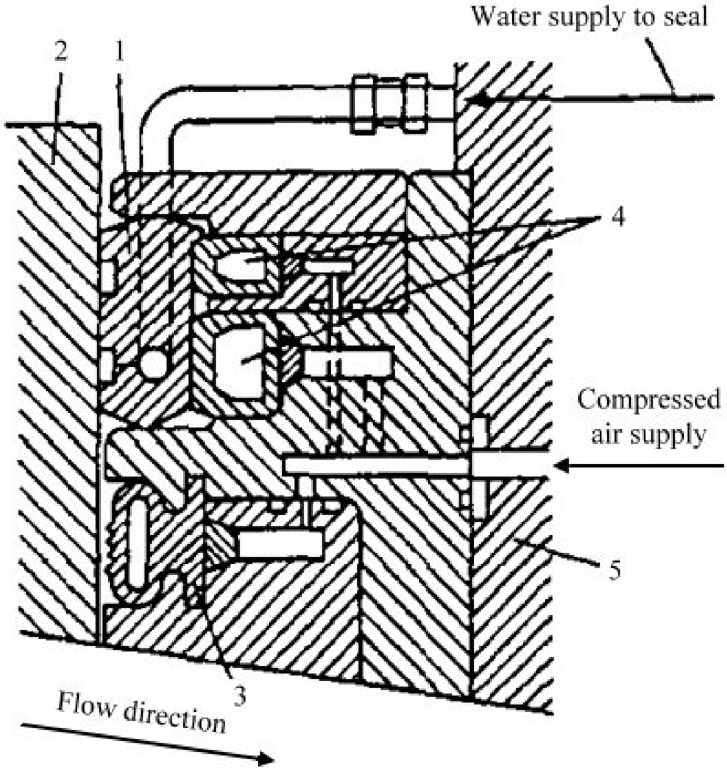

Figure. 2**:** Radial section of Straflo unit seal:
1 - sealing segment; 2 - runner rim; 3 - seal operating with unit stopped; 4 - hose-type seal (pressurized when turbine operates); 5 - runner envelope (from DPR)

3. Straight-Flow "Straflo" Pilot Unit for the Annapolis TPP

The Annapolis TPP generating unit (see Figure 3), 19.9 MW in capacity, has a mass of 864 tons. The turbine operates at heads from 1.4 to 7.1 m (at H_0 = 5.5 m; N = 19.6 MW) and rotational speed of 50 rpm (the runaway speed of 98 rpm). The runner is mounted in a chamber, has a diameter 7.6 m and four fixed blades of stainless steel; 18 variable blades of the distributor are actuated by two servo-motors rotating a control ring. External and internal insertion rings of the distributor serve as supports of the upper part of the turbine casing. The external ring is anchored in concrete by prestressed bolts, and the internal ring, in central reinforced-concrete pier located on the axis of water intake, also by prestressed bolts. Runner blades are welded to outer rim press-fitted on them. Generator rotor poles are screwed on the rim. The wetted surfaces of bush and rotor rim are plated with stainless steel. The turbine shaft is supported by two bearings upstream of which is a combination of a thrust and guide bearing self-aligning and self-controlled with regard to support.

The downstream bearing is located in the case of the lower cone of the fairing having three ribs through which the loads from bearings are conveyed to lower ring embedded in the concrete of the TPP power house. The bush is furnished with upper and lower hollow short taper shafts on which seals are installed between bush and housings of bearings.

Access to the upper bearing is through a pit provided in the concrete pier. The short distance between the bearings together with the stiff structure of the hollow shafts ensures maximum stability and safety when operating within the rotational speed range from rated to maximum runaway speed, and the concentric rotation of the runner rim in the generator stator.

The rated power of the three-phase generator is 18.1 MW, the maximum capacity 19.25 MW, cos $\varphi = 0.9$, frequency 60 Hz, the outer diameter of the stator (by the housing) 10 m.

To provide repair access to the rotor, stator, and runner, the stator can be removed axially on rails. The generator is air-cooled. To prevent damp air from getting into the spaces protected with seals, these spaces are at positive pressure.

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Biographical Sketches

Prof. Igor N. Usachev was born in July 4, 1932, Moscow, USSR

1957 – Graduated from the Moscow Power Engineering Institute.

1973 – Candidate of Technical Sciences (Thesis Investigations of very high frost concrete and fine-wall reinforced concrete hydraulic structures at the North.

1957 – up to now – engineer, chief engineer of the projects, Director of Laboratory and Head of Department, Design, Survey and Scientific Research Institute «Hydroproject».

1963-1984 – Chief of Group on Working Designing and studies of Hydroproject, Kislaya Guba tidal power plant.

Author of more than 400 scientific papers and 7 monographs

Main activities: mastering tidal energy; introduction of floating techniques in erecting of hydropower projects; development of long-living marine construction materials; electro-chemical and biological corrosion protection.

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Prof. Lev B. Bernshtein was born in December 21, 1911, Nizhni Novgorod, Russia/

1939 – graduated from Moscow Engineering Construction Institute.

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Main activities: Creator of a Russian school of tidal energy usage; author of the first Kislaya Guba tidal power plant; developer of lightened structure for low-head hydropower plants; leader in using of bulb units at hydropower projects.

Honorary Member of the Academy of Water Economical Sciences, Member of International Power Academy.

1999 – died (his executor and co-author in some Articles of Tidal Energy Topic EOLSS is Prof. Igor N. Usachev)

Prof. Boris L. Istorik was born in July 4, 1932, Moscow, USSR

1957 – graduated from the Moscow Power Engineering Institute.

1973 – Candidate of Technical Sciences (Thesis Investigations of very high frost concrete and fine-wall reinforced concrete hydraulic structures at the North.

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