Siphon turbines – a cost-effective solution for ultra-low heads

Until now, locations with low heads have been considered unattractive and for this reason have often not been developed in terms of energy. In order to exploit this undeveloped potential, IOZE hydro has developed a compact technology that is designed for deployment in locations where the use of traditional turbines proves uneconomic. Dedicated ultra-low-head technology, high electricity selling prices and a fixed feed-in tariff system mean that now is a very good time to implement such projects, thus allowing them to be marketised and provide satisfactory profitability.

Despite the significant technical potential of ultra-low-head locations (i.e. locations with a difference in level between high-level reservoir and low-level reservoir of less than 2 m), few of these sites have been developed for hydropower so far, due to the negative results that financial analyses indicate for them. This state of affairs is caused by the fact that commercially available solutions for low heads and high water flow rates, such as the Archimedes screw, VLH turbine, horizontal-axis Kaplan turbine or vertical-axis Kaplan turbine, among others, are not able to provide acceptable profitability. The inadequate profitability is due to the relatively high cost of purchasing the technology and carrying out the construction work relative to the profits generated. The use of traditional technologies in this type of project usually results in a payback period of more than 10 or even 15 years, making them unattractive.

With a view to significant development opportunities in ultra-low head and high water flow locations, IOZE hydro has developed the siphon turbine technology, thanks to which SHP investments projects that were previously considered uneconomic have a chance of being realised. The simplicity and reliability of the design, the relatively low investment cost and the minimal construction work with the high efficiency of the siphon turbine's power generation make it the most cost-effective solution on the market, capable of providing a payback period of up to several years.

Operation of the siphon turbine

The operation of the siphon turbine is based on the phenomenon of the water siphon, which is based on the transport of liquid by gravity from the high-level reservoir to the low-level reservoir, overcoming an obstacle whose peak is above the liquid surface in the high-level reservoir. It is nothing more than a pipeline with submerged ends in the high-level and low-level reservoirs, working as a water siphon with an impeller inserted inside, driving a power generator through a transmission system. Such a system must be properly primed and is unable to excite itself until the high-level reservoir is higher than the highest point of the siphon. To make this happen, the easiest way is to reduce the pressure inside the turbine by pumping air out of it. An important element in the proper functioning of the turbine is the tightness of the system. Any leaks, whether on the casings, suction pipe, turbine structure, connections, etc., will cause air to enter, which will result in at least a reduction in output and, in extreme cases, make the unit inoperable.

Design and foundation

The main advantage of siphon turbines is their foundation. Due to their design, they do not require deep excavations and significantly reduce the need for reinforced concrete work. The two basic foundation elements are the mounting blocks for the inflow chamber and the suction pipe. The siphon turbine can be "flipped" over the fixed dam without interfering with its construction. In addition, all turbine components can be made weatherproof, allowing the power station building not to be constructed and further generating investment savings.

Mechanically, the turbine design is also uncomplicated. The whole machine is housed in a steel casing, in which the main shaft is supported in two roller bearings and terminated by a rotor. A significant advantage is that the entire rotating system is mounted in a structural component that is assembled in the workshop, and assembly on site is limited to inserting it into the pre-mounted inflow chamber and suction pipe. This allows the entire system to be set up precisely in the workshop, tests to be performed and assembly

Photo. Assembly of siphon turbines

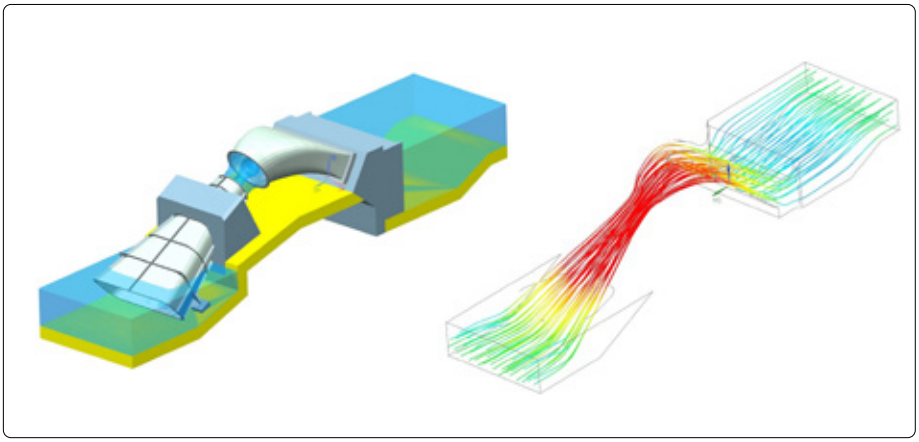

Fig. CFD simulation of a siphon turbine flow system

Operating parameters of Sulejów SHP

- installed capacity of the SHP: **200 kW**
- power generation over 3 months: **366 MWh**
- capacity factor: **83%**
- actual power generation efficiency of the SHP: **75%–85%**

Parameters recommended for the siphon turbine

- Head: 1–3 m
- Flow: 10–40 m³/s

errors to be avoided. The shaft transmits torque to the generator connected to it via a belt transmission. These components are also mounted directly on the turbine structure in the workshop.

The flow system of a siphon turbine consists of an inflow chamber, a fixed or movable steering system, a rotor chamber and impeller, and a suction pipe. Although the overall technology is simple and functional, it is proving to be a major challenge to design the flow system in such a way that the water flow is as orderly and laminar as possible, which has a key role in achieving adequate efficiency. The flow systems of the IOZE hydro siphon turbines have been modelled and simulated in a CFD programme to guarantee the highest possible efficiency of the hydrosets.

Methods of regulating water flow

A siphon turbine can be designed as a propeller turbine. This means that neither the rotor vanes nor the guide vanes are movable. The operator can control the flow in the SHP by switching individual turbines on and off. This solution results in much lower manufacturing costs for the machines, so that the affordability of the turbines increases significantly and the waiting time for an order is much shorter than for individually designed and manufactured turbines. In justified situations, siphon turbines can also be equipped with double control or the option to control the guide or rotor vanes. The correct and automatic operation of the deployed plants is supervised by an IT system, which ensures optimal utilisation of the available hydropower potential. Before deciding on the target configuration of the plants (number of turbines and method of control), in order to select the machines in a technically and economically justifiable manner, a curve of the sum of flow durations must be developed.

SHP Sulejów II – implementation in practice

IOZE hydro has successfully implemented a pilot project using siphon turbines installed on a water barrage on the Pilica River. The resulting small hydropower plant, Sulejów II, is located adjacent to the artificially created Sulejowski Reservoir. The reservoir was created between 1969 and 1974 by damming the Pilica River with a 1,200-metre-long and 16-metre-high concrete and earth dam. Just 500 metres below the dam is a water barrage that stabilises the riverbed below the Sulejowski Reservoir. The difference between the high-level reservoir and low-level reservoir in this case is 1.1–1.8 m, depending on hydrological conditions.

IOZE hydro carried out the investment project as general contractor. The works included the complete construction of a small hydropower plant with the installation of hydrounit and the necessary infrastructure to ensure efficient power generation. The works included the installation of 4 siphon turbines with a diameter of 1170 mm, with a total installed capacity of 200 kW. Significantly, the simplicity of this technology, its modularity and the existing water dams meant that the cost of the civil works for this project only accounted for about 10% in the total cost structure. The stage of operation demonstrated the high efficiency and effectiveness of the equipment – the power generation efficiency calculated at the generator terminals, depending on the head and flow, is in the range of 75%-85%. The installed turbines successfully generate power even with a head of 1 m. In this case, the high production and relatively low implementation costs of the project allowed the project to achieve high profitability. The return on investment is estimated at 2–3 years, which is a very good result in the hydropower industry.

Conclusions

IOZE hydro's proprietary solution allows for the efficient, both energy and cost-effective development of the lowest damming, whose investment viability has so far been questioned. Advantages of the siphon turbine include uncomplicated and low-failure design, short on-site installation time, small scope of construction work required, high efficiency of power generation, and short technology delivery time. In addition, the simplicity of the equipment also affects the ease of operation and servicing.

IOZE hydro is a technology company which manufactures highly efficient water turbines on the basis of proven proprietary technology. With a comprehensive product portfolio we deliver complete solutions for mini and small hydropower plants.

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