

## EVACUATION SYSTEMS OF SCREW-TYPE WATER TURBINES IN SMALL HYDROPOWER PLANT

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### ABSTRACT

This paper presents evacuation solutions of hydroelectric power set applied in a screw-type turbine in Small Hydropower Plant (SHP). The article compares the solutions applied in Poland and other European countries in the yield of green energy from the water sector. Innovative solutions of the turbine safety problem in hydro building development in case of flood waters of rivers in Poland.

**Keywords:** construction machinery, water turbine, Small Hydropower Plant.

### INTRODUCTION

A major problem for hydraulic structures is a periodic occurrence of floods leading to material and social losses. Quite a common and very dangerous phenomenon in dry areas is the so called flash flood. Flooding is a transient hydrological phenomenon involving a stage of increased water level in rivers or seas in watercourses which cause flooding of large areas of land, coastal areas or depressions when the water is beyond the shoreline. The fight against flooding is an ever present problem known worldwide. A major impact on the occurrence of floods is the existing system of rivers and occurring in different periods of the year hydrological and meteorological situation. The main causes of flooding include: heavy rain, spring thaw, river damming by ice jams or landslides, damage to hydraulic structures (e.g. interruption of the dam), and others.

This paper presents an evacuation solution of the hydroelectric set used for the functioning of a screw-type turbine in a Small Hydropower Plant (SHP). New-approach solutions to the problem of turbine safety, in case of flood in the hydro building development at national rivers, are presented. Attention is paid to the solutions used in other European countries where green energy yield of the water sector is much higher than in Poland.

### PROBLEMS OF SMALL HYDROPOWER PLANT

One of the most important ways to protect the environment is the gradual introduction of energy efficient technologies in industry and in power production replacing conventional energy sources – renewable energy [8]. The renewable energy sources (RES) include: water, wind, solar, geothermal energy and bioenergy. According to Directives 2001/77/EC and 2003/30/EC (OJ. EU L 140, 05.06.2009, p.16), the Member States of the European Union are required to increase the level of energy production from renewable sources up to 20% of the total energy balance by 2020. In Poland, this share is expected to be 15%. In the interwar period in Poland there were about 6500 small hydro plants. Unfortunately, by 1982, only about 100 were left, and now there are approximately 700. In 2011 the share of electricity produced from renewable energy sources in the national gross electricity consumption in Poland was 7.9% [2] and increased from 2.58% in 2005.

Hydropower, the energy from moving water, is one of the oldest renewable energy sources and the total global electric power capacity of hydropower, including large hydropower, small hydropower, and ocean power, was approximately 820 GW in 2005, which accounted for almost 20% of

the renewable energies [10]. In the field of hydropower, the SHP are important, characterized by an installed capacity of up to 5 MW. The theoretical hydropower resources in Poland – depending on the evaluation method – are estimated to be: 23,000 – 25,000 GWh/a. [6]. In Poland, in 2009, hydropower plants produced 2683 GWh, which represents 1.8% of the total electricity generation of 151,697 GWh [1]. Each hydropower plant is individually designed with close fit to local conditions [4]. The decisive criteria for choosing a solution include minimal construction costs, short delivery time and broad possible use of river flow [9]. In the domestic setting, details of the objects which have been implemented and the new ones are prototypical [6].

In Figure 1, a comparison of the efficiency of turbines are presented: Archimedes screw – 1, Kaplan – 2 and Francis – 3. At low heads the most ideal solutions are: Kaplan turbine, Archimedes screw, Banki-Michell's turbines and the so-called siphon turbine [3]. Banki-Michell's turbine does not apply to low heads because of the loss induced by the lack of a suction tube.

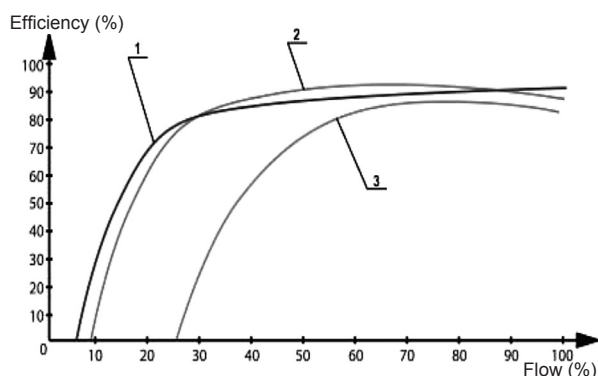


Fig. 1. Performance chart of individual turbines, (description in the text) [11]

To simplify and reduce the cost of SHP solid turbine blades are used. It is important when working with constant load or constant transfer to the turbine. In a SHP more often, also in Poland, power plants based on Archimedes screw turbine [3] are built. Archimedes screw uses the kinetic energy of flowing water, usually provided by the river, and even a small stream [11]. Its simple design manifests high reliability of the device; the main elements are arranged in a rotor mounted gutter. The turbine wheel is connected mostly to the asynchronous generator by means of a gear, with a low speed of 500–700 rpm. According to some manufacturers [13, 14, 17–19], the efficiency of these turbines is up to 90% and the obtain-

able capacity is up to 500 kW. Small hydraulic structures have a great potential for drawing energy from natural flowing water [17].

## DEVELOPMENT OF EXISTING HYDRO BUILDINGS

Exploitation of hydraulic structures is considered in two ways. The first one is the operative exploitation, which aims to make the best use of flow and head to obtain the highest possible energy production and distribution of the most favourable time [7]. The second one is a technical operation designed to provide a normal and trouble-free use of power as long as possible, maintaining safety regulations.

Threats of SHP may occur as a result of flow operation exceeding reliable flows. The operation of hydrological or geological conditions with exceptional features, such as a very thick ice, improper passing of excessive water or ice flows, moving parts' freezing, etc. The passage of excess water by water structures of small power plants, especially passing the great flood water should be carried out in a manner to ensure safety and to minimize the damaging effects of water [7]. Huge congestion and water thrust affect the hydro building as well.

## WAYS TO EVACUATE TURBINE

Very often a mobile crane is used with the first turbine unit installation. So far turbine installation and removal were made with the use of lifting equipment, gantry cranes or, for smaller turbines hoists embedded in the frames were used. These solutions of disassembly or partial disassembly by crane has its drawbacks, of which the principal one is the time in which the operation is carried out and which may last a few hours. In case of flood, time is a critical parameter and in specific weather conditions driving up a specialized equipment may not be possible. Evacuation system is created in order to pass the flood waters including  $Q = 1$  [16] (so called „century water” – that is one that theoretically occurs once every 100 years).

The main way to prevent damage caused by flood is locating an object on the side channel of the river bank and not on the main channel (mill builders have used such a strategy for a long time). By-pass channels are also used. A diagram of such a solution is shown in Figure 2.

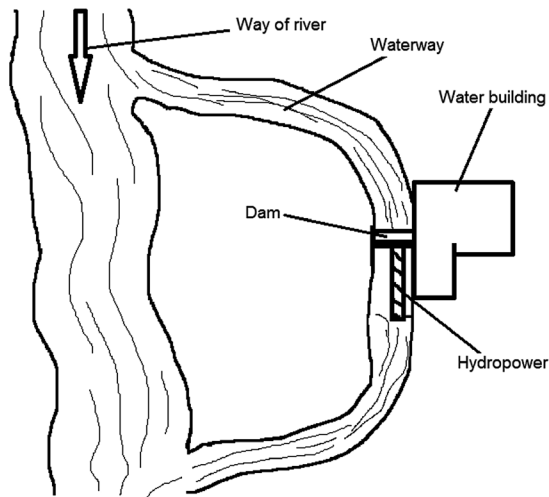


Fig. 2. Diagram of hydraulic engineering structures built on the bypass channel

Evacuation systems are good in situations where a dam or other hydro-technical structure, equipped with only a single path for water are electrified. Then, in the event of water excess, it can be let through easily, quickly and without resistance, protecting the device from damage. One of the evacuation systems of the entire turbo system with an Archimedes screw above the surface of the water

is the solution proposed by a company called EM-NET. It involves installing a rail construction aside, with a crane, at the edge of the dam or other hydro structure. This device is also equipped with a flap that lets the flood water through after being opened in the place of turbinemachinery, which is then put aside (Fig. 3). The principle of operation of the turbine set for working with maximum and minimum water flows is shown in Figure 4. Unfortunately, this type of solution has not been implemented so far on the river, it is still only in a draft form.

These risks can be eliminated by appropriate preventive measures, such as responding in an appropriately short time. Another solution allows for very rapid changes in the Archimedes screw turbine operation and evacuation of the whole turbo machinery above the water surface using a specially designed evacuation equipment construction. Czech unit GESS [14] uses a hydraulic cylinder system that can extend over the surface of the water, the turbinemachinery embedded in the gutter of the turbine (Figures 5–7). This design is aimed at rapid evacuation and protection of the turbine from damage in danger of flooding. The entire assembly mechanisms are normally submerged in water and can eas-

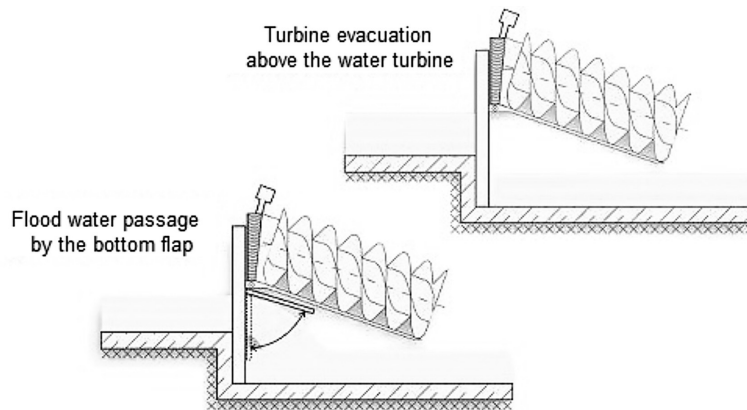


Fig. 3. The way of turbine evacuation over the surface of water and passing through of the flood water [12]

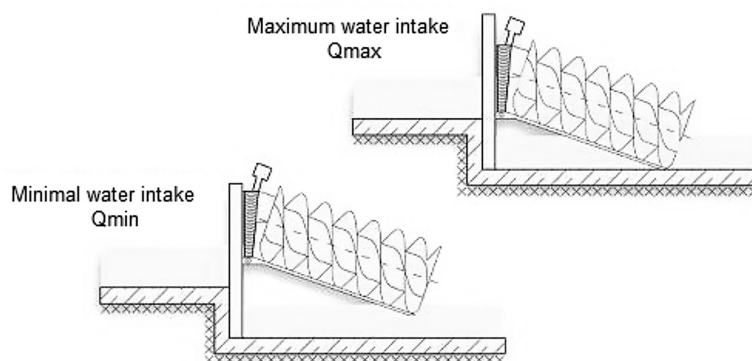


Fig. 4. The method of turbine operation at different levels of water [12]

ily be raised above the upper level of water as it is rotatably mounted on a special hinge system. Body design also allows greater deflection of the bearing during installation and operation of the

turbine [14]. Such solutions already exist in our country. Figure 7 shows the solution of GESS turbine during normal operation, i.e, the actuator is in the stowed position.

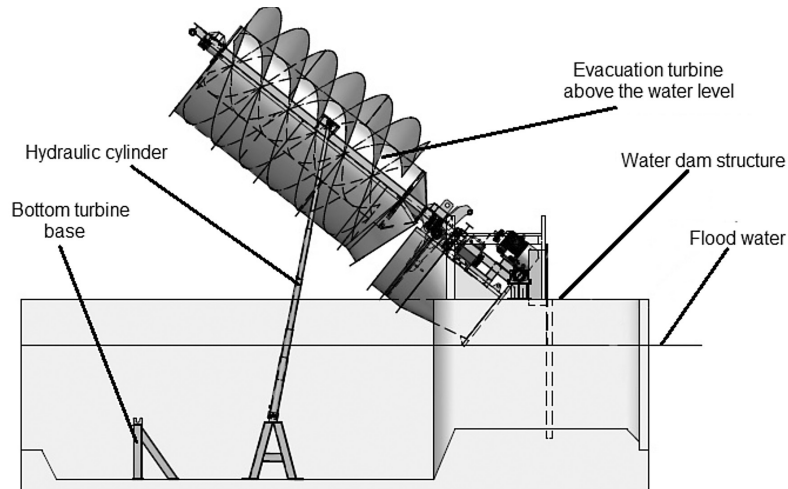


Fig. 5. GESS Turbinemachinery in the evacuation position after stopping over the top water [14]

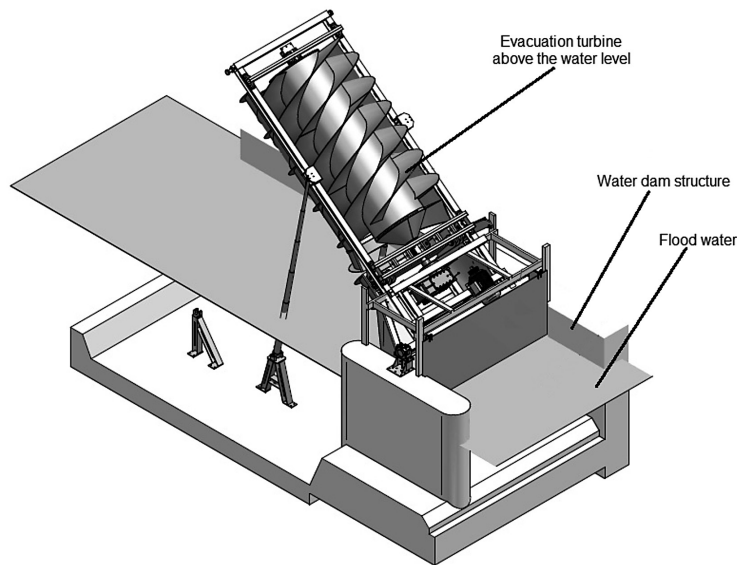


Fig. 6. GESS turbine machinery in the evacuation position in the view from the top water [14]

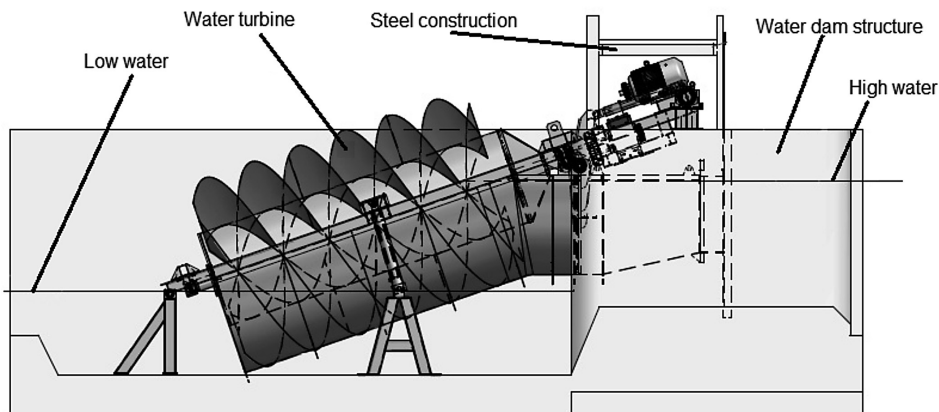


Fig. 7. GESS turbine machinery in the normal work position [14]

In the second half of September 2011 construction and assembly SHP works in Bieleckie Młyny in Świętokrzyskie Voivodship were completed [20]. This is the third hydro power plant in Poland which uses this type of solution. And it is also one of the first hydromachinery of this kind in the world. Two other small hydro turbines were installed on the Radomka river (Fig. 8) [11, 13, 15, 20] by the end of June 2011 and on the river in Luboszyce on the Mała Panew river [11, 20].

Mass production allows the use of special solutions, using high-quality materials, in advanced - and also cost competitive technology in comparison to individual solutions [6]. The presented machine concept design will eliminate the problem of flood and water resource management in the area of the lowest damming. This approach significantly improves the technical parameters associated with the evacuation of the Archimedes screw turbine over the surface of the water. The advantage is the increase of device functionality in hydroclimate of Poland. The solution offered by Czech company GESS is new to the market and significantly different from other products for SHP. An example of the evacuation system is a very creative combination of the known technologies used in transport systems (e.g. tipper trucks) adopted to the evacuation of Archimedes screw turbine self-supporting structure. It should be mentioned that it is not identical solution, it works in entirely different specific environmental conditions, but operates on the basis of a similar technical concept.

Among European (Austria, the Netherlands, Germany) manufactures of Archimedes screw turbines [17–19] there are no reports on the production of evacuation systems for turbine unit. As it is clear from the conducted analysis, the evacuation system was developed exclusively by GESS company also with a view to the market and the Polish customers.

As it has been pointed out, the hydropower plants, driven by an Archimedes screw turbine have now permanently attached turbine unit. In practice, this means that each amount of water greater than the nominal swallowing capacity of turbine is not energetically used. The solution allows moving the turbine inlet up and down generating the energetical use of large water flows, thus significantly improving the SHP technical parameters along with the Archimedes screw turbine. It is estimated that the energy yield from the water additionally introduced onto the turbine can increase the efficiency of the turbine by about 20%, compared to the energy from the water in the nominal swallow capacity of turbine. The problem could be only the rotor flooding. To avoid it, effective decrease is reduced by a half of the diameter of the rotor plus the distance for the low water at large flows.

Separation the turbine from the turbine unit allows the use of larger amounts of water indicated on the rotor. The technical solution also allows rapid evacuation of Archimedes screw turbine on the water surface. As mentioned ear-



**Fig. 8.** First in Poland Archimedes screw turbine on the Radomka river [11]

lier, none of European manufacturers which are global providers does not have such a range of products (for the Archimedes screw turbines). The example of evacuation system based on the technical concept known from transport systems (e.g. lifts, winches) was used to evacuate self-supporting structure of Archimedes screw turbines. Figure 9 shows the turbine during normal operation. While working, the turbine unit is based on the lower bearer and manoeuvring rolls placed on the abutment and the pillar of the dam and this is so called operational phase of the operation of the plant.

Evacuation is carried out by using two mechanical- and hand-driven chain hoists mounted on a crane beam of a steel structure. A scheme of the evacuation way of the turbine above the surface of the water by means of a chain hoist is shown in Figure 10.

## CONCLUSIONS

It has been pointed out that depending on the type of management section of the river and the present SHP technical solution, there are various ways of quick turbine evacuation in danger, and hence, prevention of damage to the turbine. The solutions presented in this paper concerning prevention from damage to the turbine in the event of flood waters are an innovative approach for SHP investors.

The concept of separation turbine unit and control system of water flow onto the turbine rotor, while maintaining a constant level of the top water, allows for greater energetic use of the flowing water.

The presented solutions can be an inspiration to renovate the existing hydro buildings or building or the reconstruction of existing hydro-engi-

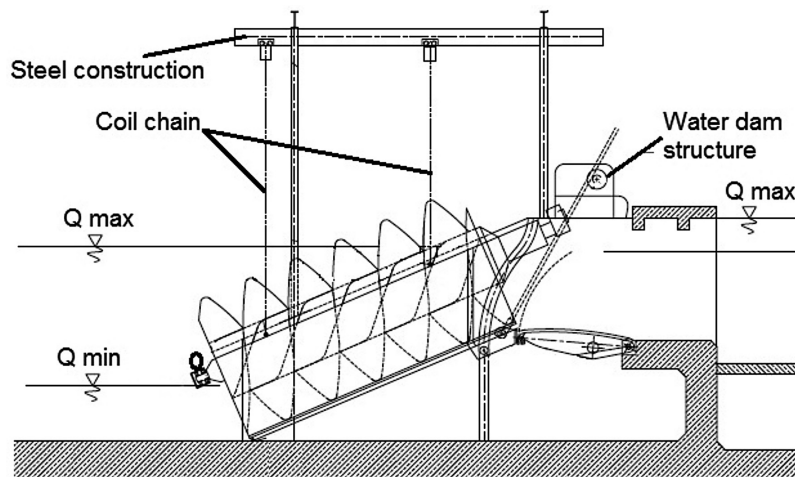


Fig. 9. Archimedes screw turbine scheme of evacuation system at work

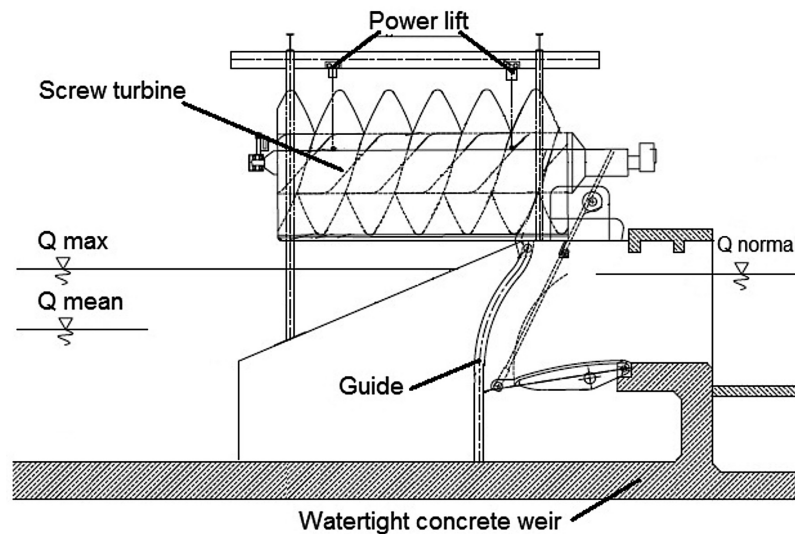


Fig. 10. A scheme of the evacuation way of the turbine above the surface of the water by means of a chain hoist

neering facilities. In a view of the possibility to obtain funding from various structural and ministerial sources and funds, the investment in SHP becomes more favourable. Hydroelectric power plants operate at a predictable time and power and are the most reliable source of electrical energy from renewable sources. The advantage of hydroelectric power is the ability to stabilize river flow and prevent flooding (e.g. Czorsztyn-Niedzica dam on the Dunajec river). Small hydro-power systems have been increasingly used as an alternative energy source so that a small system is installed in small rivers or streams with little environmental effect [5]. In addition, investment in turbines with fish-friendly technology “fish friendliness” allows the use of energy in protected areas, such as “Nature 2000”.

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