

ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ – СОФИЯ

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## A NEW FISH PROTECTION CONCEPT - FLEXIBLE FISH FENCES

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*Research area: low head hydro power*

### ABSTRACT

The flexible fish fence is a new fish protection concept, which is being developed at the Unit of Hydraulic Engineering, University of Innsbruck. Horizontally arranged steel cables are installed upstream of the turbine intakes and pose a mechanical barrier to fish. The flexible fish fence is especially practicable for the application on overflowed power plants and within an ecological upgrading of existing hydro power plants. The first experiments were performed in the hydraulic laboratory of the University of Innsbruck to demonstrate the general functionality of the new fish protection concept. This paper concentrates on the technical concept of the flexible fish fence. Further investigations of the fish behaviour in front of the barrier and optimizations of the technology are planned on a prototype, eco-hydraulic experiments and a pilot project.

### 1. Introduction

Hydropower as a renewable source of energy has a long tradition and therefore a high priority in alpine regions. Since an expansion of renewable energy production is planned within the context of European policy on climate change, a further exploitation of hydropower is focussed by the Austrian as well by other European governments. Here a

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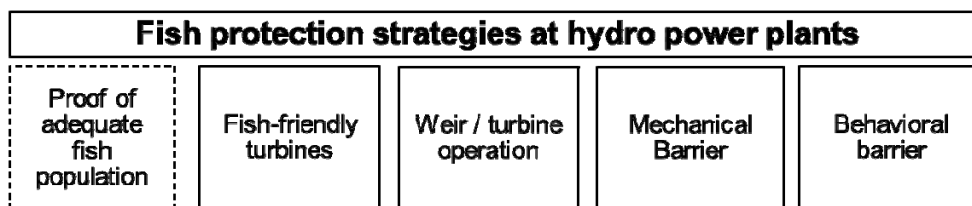
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comprehensive conflict may arise with the achievement of the key aims of the EU Water Framework. Hence, hydropower generation and the design of new hydro power plants need to be optimized in a way that environmental impacts are minimized; not least because this also urged within approval processes of hydropower projects.

So far the development of downstream passage of fish at hydropower plants is not much advanced. At least to a certain extent fishes are harmed or killed when they pass the turbines of a hydropower plant. Despite the risk of injury depends on many aspects, such as fish species, fish age or the turbines and operational design of the hydropower plant, appropriate measures are inevitable for fish protection and downstream passage.

Actually different fish protection strategies are pursued during the design phase and the approval procedures for new hydro power plants but also during the license renewal procedure of existing hydro power plants (Fig. 1.)



**Figure 1. Fish Protection Strategies**

- Within the scope of the ongoing discussion some hydro power companies intend to demonstrate the efficiency of already existing 'old' barrier screens respectively racks for turbine protection (typically with relatively large clear widths) by proofing the existence of adequate fish population despite a longstanding hydro power operation. These approaches can be supported and strengthened significantly by realising river engineering measures to improve the morphological structure of the water body with a view to expand the natural fish habitats and to offer improved conditions for the spawning and nursery feeding grounds. Anyhow, it is a challenging task to reach sustainable solutions for these ecologically motivated additional river engineering measures in river systems, which are affected by a serious lack of river dynamics e.g. due to significant backwater effects. Better data and more research are needed to assess the relevance of this approach.
- The development of fish friendly turbines continues to reach technically and economically feasible solutions. Reducing the risk of injury by passing the turbines would help to render additional fish protection measures unnecessary. Hereby it is important to keep the efficiency, the investment costs and the possibility of replacing existing turbines in view.
- Opening weir gates and reducing or even stopping turbine operation to allow safe downstream fish migration will reduce or eliminate the damage to fish population. The efficiency of this method and the possibility of a reliable forecast of fish migration time periods depend very much on the specific fish species [5] [6] [7]. Due to the energy production losses caused by the weir flow this method might be very cost intensive in a long-term view.
- Mechanical barriers, like fine screens or thrash racks, are widely used to prevent fish from entering intakes of hydro power plants. They provide a physical barrier. Fish have to be guided along the screen toward a bypass that safely returns the fish to the water body downstream. By the current state of the art mechanical barriers respectively

‘physical barriers’, which are impermeable for fish to pass (e.g. fine screens with horizontal or vertical bars), seem to be the most promising device for small hydro power plants [4] [7]. However, in terms of operational issues, these barriers are highly vulnerable for clogging and complex cleaning systems are required, which leads to the consequence that they are technically and economically not feasible on medium and large run-off-river plants (design flow  $\geq 100 \text{ m}^3/\text{s}$ ).

- Behavioral barriers are emitting a certain stimuli to fish, which affects the fish behaviour in a way that fish are repelled from the turbine intakes or attracted to the bypass [1][8]. Similarly to mechanical barriers fish have to be guided to a bypass. There are numerous concepts for behavioral barriers (e.g. louvers, bar racks, light, sound, air bubble curtains, hanging chains, water jet curtains, and electric fields). These devices are in many cases experimentally developed. Often their performance capabilities may not be well documented. Typically the use of behavioral screens enables lower investment costs. Behavioral barriers might also offer a fish exclusion option at sites that would otherwise be difficult to screen, such as at penstock intakes positioned at great depth in a reservoir [1]. Hereby it has to be considered that the efficiency of behavioral barriers depends very much on the approach flow velocities. Typically velocities below 0.5 have to be presumed. Another technical solution are permeable mechanical barriers, like angled bar racks and louvers, which affect fish behaviour by a change of hydraulic-tactile and visual stimuli in a way, that fish are repelled from the water intake and guided to a bypass, which is located at the downstream end [9]. The transfer to European run-of-river plants is currently studied by researchers of the VAW, Zürich [10][11][12].

Due to its actuality and importance fish protection turns out to become an important research topic in different universities and research orientated companies [4]. Hereby typically a close cooperation between hydraulic respectively environmental engineers and biologists is required. There are ongoing research activities for all fish protection strategies mentioned above. At Innsbruck University there is a current research project on a mechanical barrier, which can be easily be combined with concepts from behavioral barriers.

## 2. The Flexible Fish Fence Concept

A new fish protection concept for hydropower plants is in progress at the Unit of Hydraulic Engineering, University of Innsbruck. The **flexible fish fence** is an innovative fish protection system preventing fish from turbine entrainment at hydroelectric power plants and guiding them to a bypass, which connects the head water with the tail water. It consists of horizontally arranged steel cables (Fig. 2), which are tensioned upstream of the inlet area of the turbines. The structure is positioned in a slight angle to the flow direction to guide fish to a bypass at the downstream end of the barrier (Fig. 3). First investigations were carried out on the mechanical behaviour of the steel cables, the basic functionality and technical feasibility [2] [3].



Figure 2. Flexible Fish Fence – Basic Principle

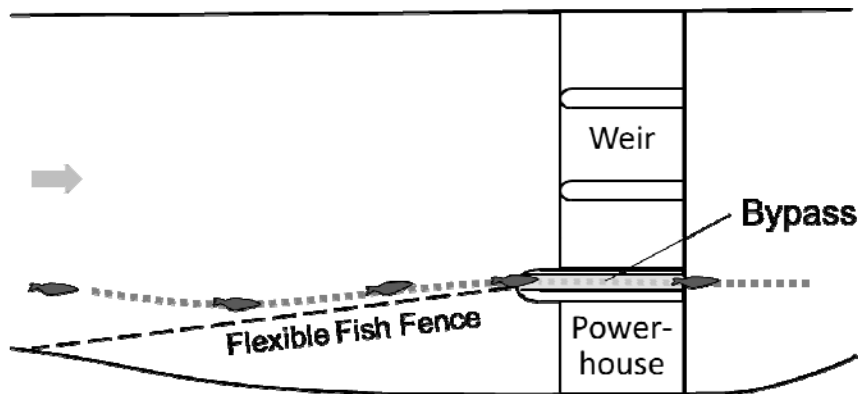
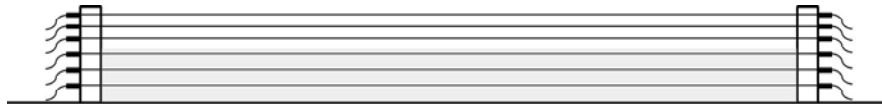


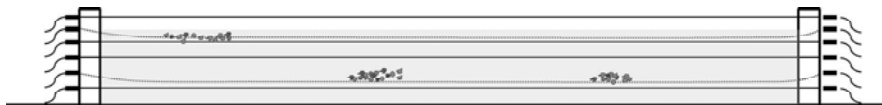
Figure 3. Flexible Fish Fence – Layout sketch

The clear vertical space between the stretched cables depends on the target fish species of the river system respectively of the size of the fishes. The system operates in a similar way as a horizontally oriented barrier screen. During normal operation, all cables are in place with a predefined clear space. This requires constant tension along all cables. Thereto, a concept for the technical realization was developed in cooperation with a mechanical engineering company [2] [3]. The design enables to operate the cables with a hydraulic system, in order to control every cable and guarantee a constant (predefined) prestress on every cable. Local cloggings at the front upstream side of the flexible fish fences (which might be caused by small branches, leaves or grass cuttings) can be cleaned by releasing individual cables or cable clusters (Fig. 4). At higher discharges carrying the major part of floating matter the cables are released and hence lie on the river bed. During this phase the cables are cleaned and floating matter is transported further downstream.

#### Normal mode of operation



#### Relaxation of individual cables to mobilize local cloggings



#### Operation at higher discharges



Figure 4. Modes of operation: flexible fish fence in operation (above), released mode (relaxation of individual cables (center)) and relaxation of all individual cables (below)

Principally it is necessary to distinguish between two different arrangements of the powerhouse in terms of handling all floating matter 'becoming free' at the flexible fish fence by the releasing it.

- In the case of an overflowed powerhouse floating matter entering the inlet structure can be discharged over the plant and thus remains in the river.
- In the case of a 'regular' powerhouse, which typically is positioned outside the flood channel and which is not overflowed, a coarser screen respectively rack for turbine protection has to be provided. Floating matter arriving from the released flexible fish fence has to be removed from the water by applying traditional rack cleaning methods.

### 3. Applications

The main focus for the development of this innovative fish protection system is providing a well-functioning and cost effective device for new hydropower plants, which has to be designed for challenging site conditions in terms of river ecology and fish habitats.

Anyhow, as flexible fish fences can be adapted easily in length, in angle and in position they own a much greater potential. Adaptable to many different site-specific boundary conditions, the flexible fence is a simple and flexible structure, which can be an opportunity for retrofitting existing hydro power plants with the objective to improve downstream migration of fish. There, the existing rack cleaning system is utilized to remove the floating matter, which is mobilized by the flexible fish fence. Many options for the layout of the fish fence at hydro power plants exist. Some of them are shown below (Fig. 4).

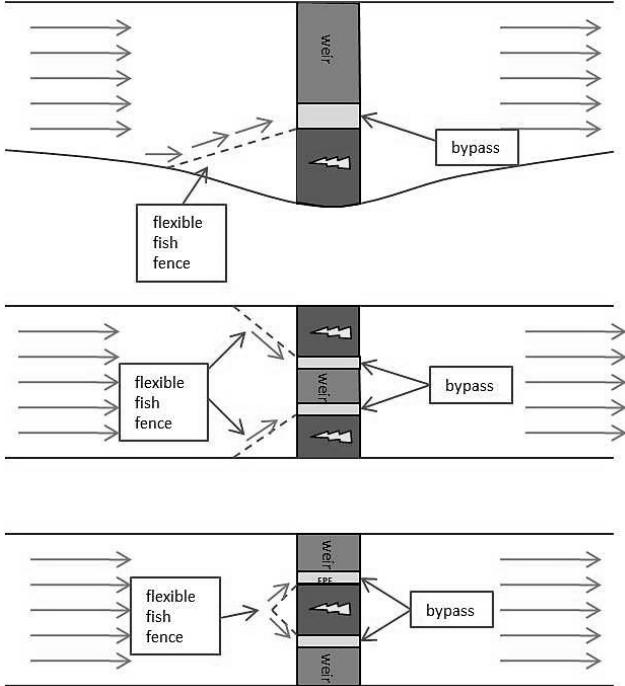


Figure 5. Layout of flexible fish fences for retrofitting different hydro power plants (from [3])

Depending on the layout of the power plant, the fish fence can be situated between the two river banks or between one bank and the middle pier [3]. With a horizontally inclined exposition to the flow, a guiding effect is generated, thus the bypass should be directly located at the downstream end of the flexible fish fence [8]. The position of the flexible fish fence can be easily modified in terms of several requirements regarding geometry or fish protection purposes. This offers a high potential for the ecological upgrading of large scale hydro power plants due to a high degree of adaption on the existing structures [3].

#### 4. Further Development of Flexible Fish Fences

According to the state of research, the technology is assessed to Technology Readiness Levels (TRL) of 2 to 3. The key aims of the next step of the ongoing research project are the investigation of subject-specific problems and the further development related to fish protection efficiency, technology, operational and economic issues. Hereby a basis for achieving the next Technology Readiness Levels, where a pilot project at a new or existing hydropower site can be realized, should be reached. The methods will be based on engineering science and theoretical considerations and, as a major part, on experimental investigations in the field of eco hydraulics and hydraulic engineering. It is planned to carry out a number of experiments with fish which will be exposed to different types of flexible fish fences in close cooperation with well experienced fish biologists. Hereby behavioral concepts (mainly cable vibrations and electrical current) will be considered, too. The outcome of the research project will help to solve important questions concerning technical, operational and biological aspects of the proposed fish protection system.

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## **НОВА КОНЦЕПЦИЯ ЗА ОПАЗВАНЕ НА РИБАТА – ГЪВКАВИ РИБНИ ОГРАДИ**

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*Ключови думи: хидроенергия, опазване на рибата, речна екология*

*Научна област: нисконапорна хидроенергия*

### **РЕЗЮМЕ**

Гъвката рибна ограда е нова концепция за опазване на рибата, разработена в Хидротехническият факултет на Университета Инсбрук. Монтирани са хоризонтално разположени стоманени възети нагоре по течението преди турбината, които създават механична бариера за рибата. Гъвката рибна ограда е особено практична за прилагане при преливащи електроцентрали и при екологичната модернизация на съществуващи водноелектрически централи. Първите експерименти са проведени в хидравличната лаборатория на Университета Инсбрук, за да демонстрират широката функционалност на новата концепция за опазване на рибата. Този доклад се фокусира върху техническата страна на концепцията за гъвкави рибни огради. По-нататъшни изследвания на поведението на рибата пред бариерата и оптимизация на технологията са предвидени на прототип, еко-хидравлични експерименти и пилотен проект.

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