HYBRID FISH PROTECTION SYSTEMS AT HYDRO POWER PLANTS

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Abstract: Fish protection systems are necessary to prevent downstream migrating fish from a turbine passage. The hybrid fish protection barrier called *FishProtector* is combining a mechanical barrier (screen) with the behavioral barrier of an electric field. This enables effective fish protection at intake screens with bar clearances of several centimetres, preventing operational problems and reducing hydraulic losses. This paper shows important outcomes of the development work of this innovative fish protection system at the University of Innsbruck (Austria) and technical details of the pilot projects.

1 Introduction

The implementation of the European Water Framework Directive and its translation into national legislation in many countries lead to an increased demand of fish protection measures for hydropower plants. In order to install or improve fish protection measures, an effective system has been developed. The basic principle of this system is the creation of a hybrid barrier, which consists of a mechanical barrier (e.g. existing screen) and a behavioural barrier. The behavioural barrier is created by a pulsed electric field induced into the water through an arrangement of electrodes. The electrodes are mounted as additional structures at or near the screen bars and have a deterring effect on fish, which extends a few decimetres upstream.
Extensive research and tests with fish have been carried out in the past years. The effect of the barrier could be shown in many scientific papers [1] [2] [3].
The technology is suitable for usage at any kind of inlets (run-of-river power plants, diversion power plant, pumped storage power plants and other water extraction structures).

2 Hybrid fish protection barrier

A hybrid fish protection system in the sense of the technology presented here is a combination of a mechanical barrier with a behavioural barrier. The mechanical barrier is formed by bars or steel cables arranged in a regular pattern with regular clear widths of several centimetres. The behavioural barrier is created by an electric field. This electric field can be created by applying an electric current in a suitable manner to electrodes attached to the bars or directly to the steel cables.
The concept of hybrid fish protection was developed at the University of Innsbruck, Austria. The system is now used in practice under the name FishProtector and is continuously improved technically.

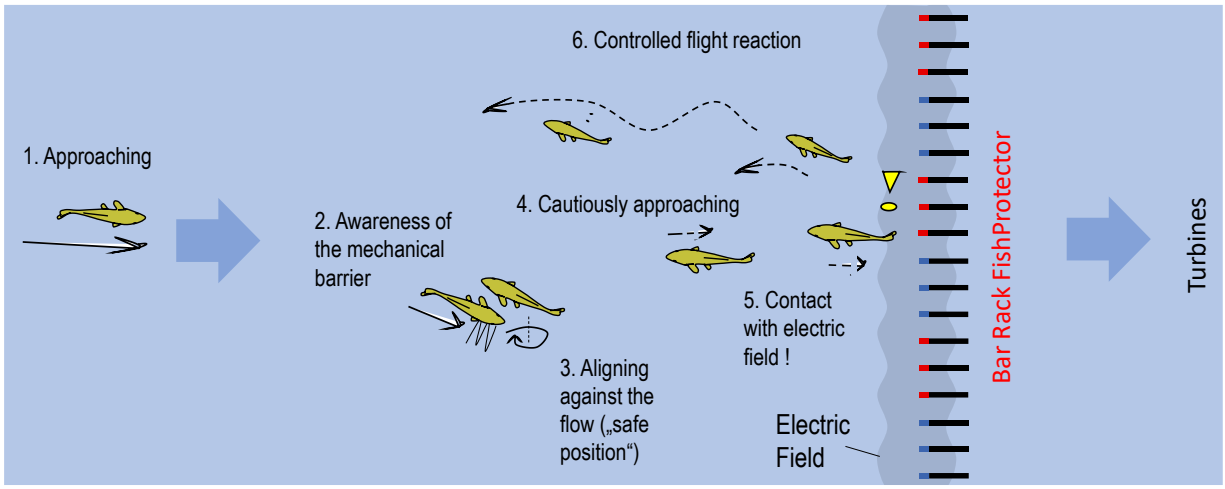

Fig. 1. Hybrid fish protection system - basic principle in plan view

The downstream migrating fish approaches the inlet with the current (Fig. 1). At a certain distance in front of the hybrid fish protection system, it perceives the barrier and recognizes a special situation. The fish becomes cautious and turns around. In this safe position, the fish slowly approaches the FishProtector with its tail fin. As soon as it comes into contact with the electric field and is affected in an unpleasant way, the fish quickly moves forward and leaves this area. This escape reaction now happens in a controlled and directed manner. The direction of escape is already predetermined by the orientation of the body against the current, which has already been reached during the approach. Among other things, this distinguishes the mode of action of a hybrid fish protection system from previously known fish deterring systems, which were not able to achieve a sufficient deterring effect.
This basic mode of operation, which is based on the described behaviour of the fish (Fig. 1), is well suited to prevent the individuals from swimming into the inlets of hydropower plants and other water extraction facilities. However, the system does not enable migration in the downstream direction, if a bypass is not available. The longer the fish remain in the near field of the barrier and the greater their desire to migrate becomes, the higher the probability that passages towards the turbines will occur.

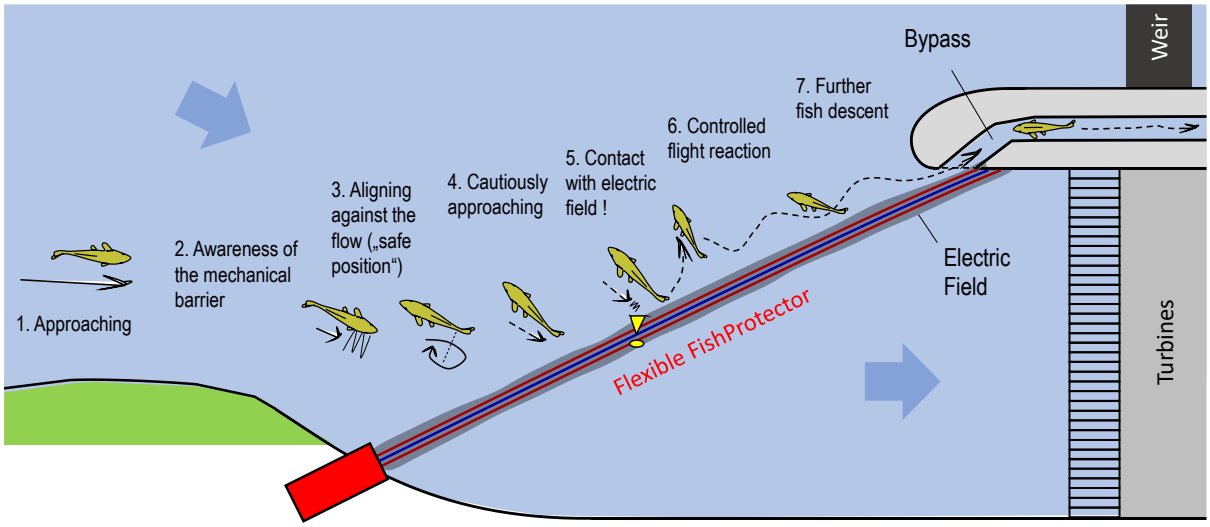

Fig. 2. Hybrid fish protection and guidance system - basic principle (for guiding fish to a bypass)

If the FishProtector is arranged diagonally to the direction of flow (Fig. 2), it is possible to guide the fish towards a safe bypass. With this arrangement, the individuals will repeatedly approach the electric field and be shooed there in a controlled manner. Due to the spatial position of the FishProtector, this usually results in a wave-like movement of the fish towards the downstream end of the barrier.

The validity of the principles of hybrid fish protection and the efficiency of the FishProtector were proven in various ethohydraulic tests at the test facility of the University of Natural Resources and Applied Life Sciences in Lunz am See (Austria) as well as in the course of further tests at pilot projects.

3 FishProtector technology

For the application of a hybrid fish protection barrier in the sense of the technology described above, a control cabinet, a connection cabinet and the respective FishProtector construction are required (Fig. 3).

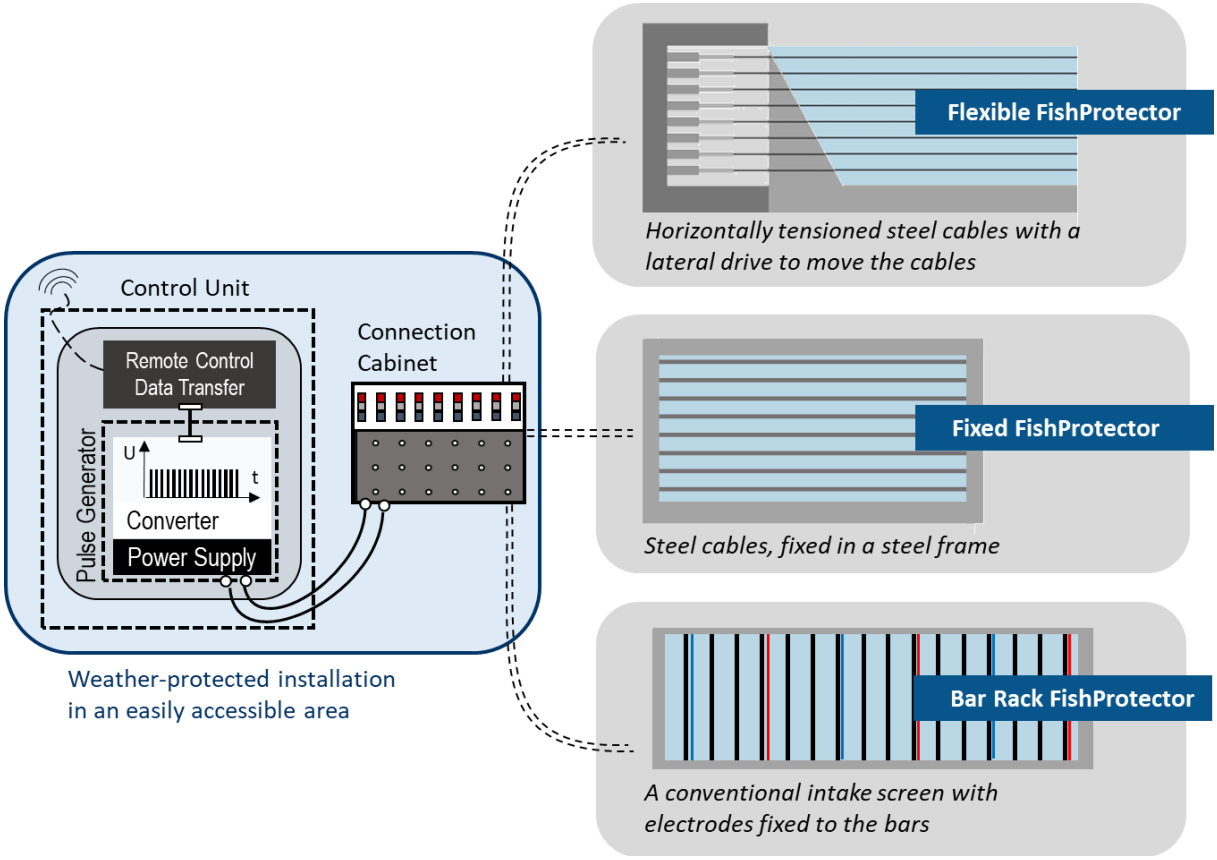

Fig. 3. Components of FishProtector systems

Of particular importance for the functionality of the system is the electrical control cabinet. This is suitable for generating very short low-voltage DC pulses with different signal strengths and time sequences. These temporal sequences are being further improved as part of ongoing research work. The goal here, in addition to providing the best possible fish protection, is to avoid damaging corrosion processes on the electrodes. The power consumption is very low due to the very short duration of the

individual pulses and is usually not a relevant decision criterion when selecting the fish protection system.

The FishProtector installation selected for the respective location is connected to the control cabinet via a connection cabinet. Both cabinets are to be installed protected from the weather and should be easily accessible during the entire operating time.

The spatial distance between the connection cabinet and the FishProtector installation can be several tens of metres or even longer. By planning the system as purposefully as possible, an attempt is made to limit the number of cables required.

4 FishProtector design and types

4.1 Background

The operating methods, sizes, arrangements and designs of intakes and intake screens are very diverse. The requirements on the part of fish ecology are highly dependent on the fish fauna and the boundary conditions in the catchment area. As a result, the concrete requirements for fish protection and fish guidance systems are also very different. During the research and development work on hybrid fish protection, it has been shown that this concept can be successfully implemented in practice in very different types of environments.

4.2 New intake screens (Bar Rack FishProtector)

When building a new hydropower plant, a new intake structure or when replacing a screen, a new hybrid fish protection screen (Bar Rack FishProtector) can be installed. When replacing screen elements, the use of a fish screen is only possible if the inflow velocities are sufficiently low (typical approach velocity $v < 0.5$ m/s).

As with conventional intake screens, the spacing of the bars is based on the requirements of turbine protection. The electrodes required to generate the electric field are already applied to the front of the bars in the factory. They are electrically separated from the screen bars by suitable insulation. The hybrid fish protection screen meets all the requirements of conventional screens, can be cleaned in the same way with screen cleaning machines and does not cause any increased hydraulic losses.

If the hybrid fish protection screens are used in a similar way as conventional screens, i.e. typically at a right angle to the approaching flow, it is not possible to guide the fish. However, the individuals can be prevented from swimming through the screen, at least for a certain period of time. This technical approach is of particular interest for withdrawal from reservoirs (Fig. 4). The hybrid fish protection system Bar Rack FishProtector is currently part of the design of the intake/outlet structure at a new pumped storage power plant in Germany.

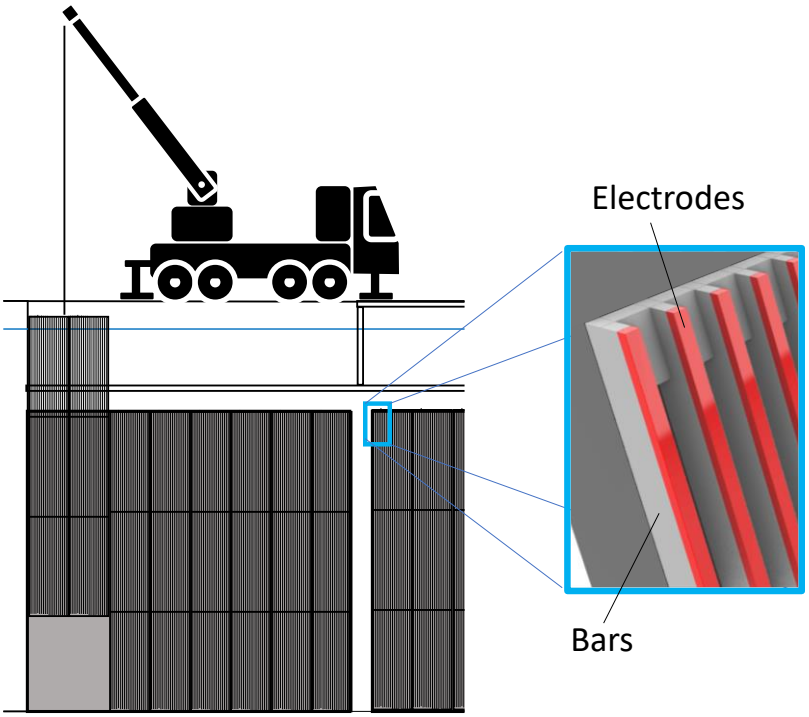

Fig. 4. Concept study for a modular hybrid fish protection with a Bar Rack FishProtector at the intake/outlet structure of a pumped storage plant

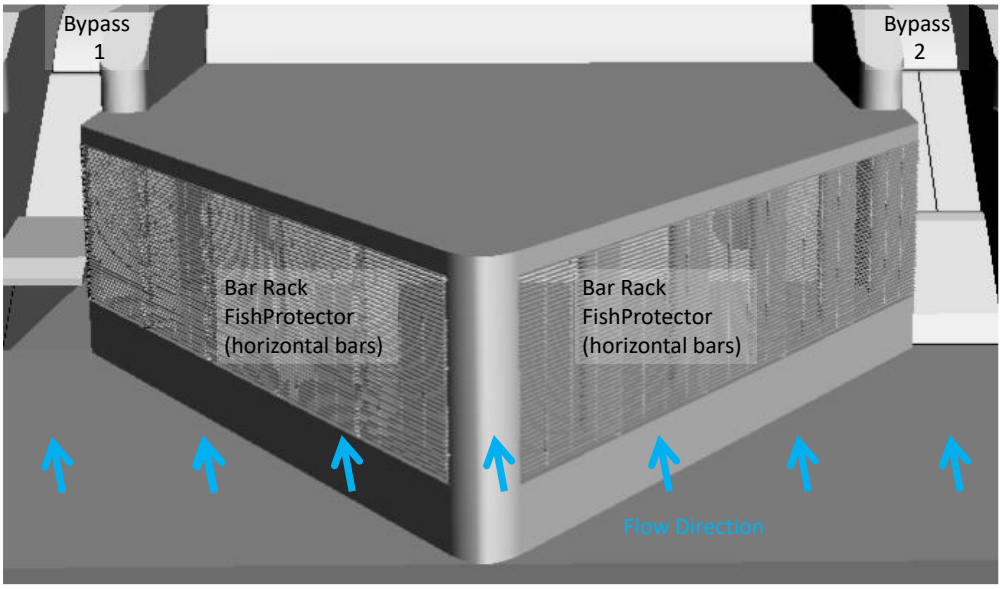

Fig. 5. Concept study for hybrid fish protection at a river power plant with low head (with completely submerged horizontal bar screens)

Especially at new run-of-river hydropower plants, however, it is possible to arrange the screens at an angle to the main flow. In this way, the conditions for efficiently guiding the fish to a safe bypass can be created (Fig. 5). The spacing between the individual bars of the horizontal screen is several centimetres. Compared to the fish guiding screens commonly (mainly in Germany) used today, which have considerably smaller clear widths, this system has operational advantages (considerably less effort for cleaning, considerably lower hydraulic losses). Fish are guided along the barrier towards the bypass, which is situated at the end of the barrier.

4.3 Retrofitting of existing intake screens (Bar Rack FishProtector)

If the flow velocity at existing intake screens is not too high and if there is no need to improve the fish guidance function, electrodes can be attached to the upstream side of the existing bars (Fig. 6). In this way, it is possible to achieve a significantly improved fish protection effect despite constant bar spacing. Usually, the screen cleaning system can be adapted in a simple way, so that there are also no restrictions in operation. There are various methods for fixing the electrodes on the bars. An insulating layer between the electrode and the bar is absolutely necessary. Great care is required during installation. An installation of a Bar Rack FishProtector has been realised successfully at the inlet of the cooling water system of a nuclear power plant. The screen cleaning system has been in operation there since mid 2021 without any operational restrictions.

Fig. 6. Retrofitting of electrodes at the upstream side of the bars of an existing screen

4.4 Fish protection elements for installation in the headwater of intake screens (Fixed FishProtector)

In the course of the research and development work carried out so far, the use of very simple fish protection elements, each consisting of a steel frame equipped with steel cables, has proved to offer very feasible fish protection solutions.

Typically, these elements are used in the headwaters of existing screens. They can only be cleaned by moving them or by removing the entire modules. Therefore, their use is typically limited to applications with a very low inflow of leaves, grass and other floating debris. In special cases, however, the modules can be arranged in such a way that they can be cleaned by suitable movements (e.g. by turning around). A first application of a spatial structure of three elements has been successfully in operation since August 2021 at an intake to a storage power plant in the Alpine region (Fig. 7).

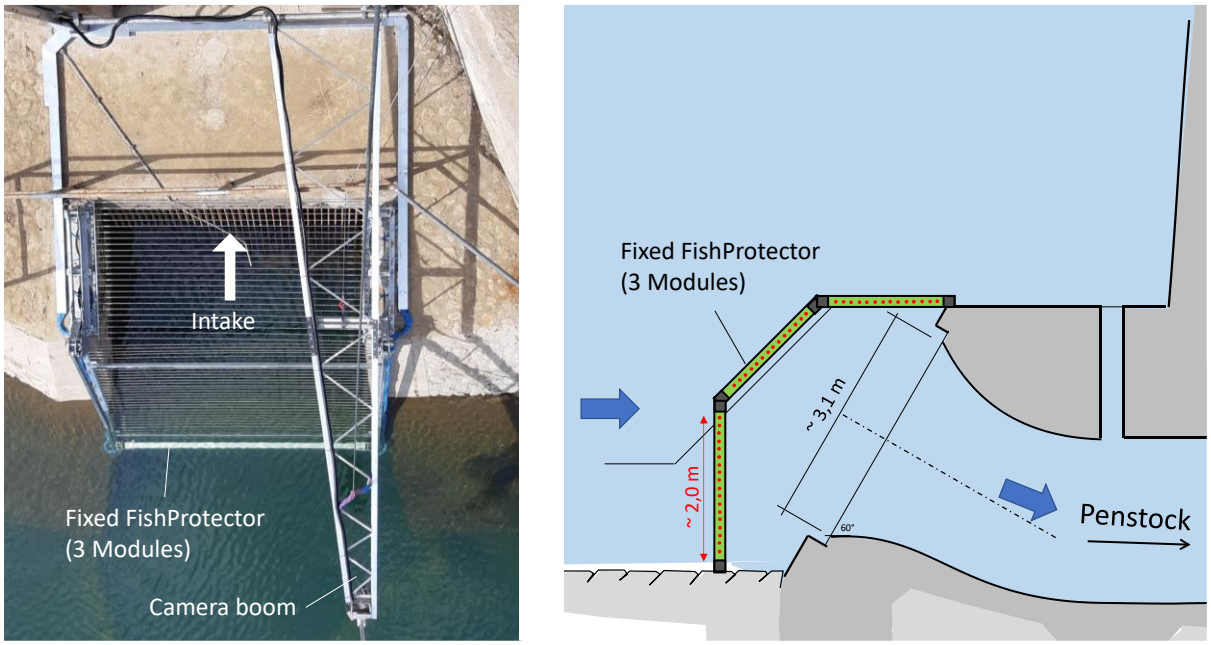

Fig. 7. Modular fish protection (Fixed FishProtector) at the inlet of an alpine reservoir (Left: top view; Right: Simplified sketch in longitudinal section)

4.5 Retrofitting of a fish guiding device in front of an existing intake screen (Flexible FishProtector)

A fundamental and long unsolved problem is the retrofitting of fish guiding devices on medium and large existing river power plants. Here, the Flexible FishProtector offers a special solution. For this purpose, steel cables are placed horizontally in front of the existing intakes. The existing turbine protection screens including the cleaning device remain unchanged. The Flexible FishProtector is situated diagonally to the main flow. This arrangement guides the fish to a bypass located at the end of the steel cables. Cleaning is done by laying the cables partially or completely on the bottom of the inlet. This is made possible by a special drive unit located on one side of the Flexible FishProtector.

During the first operation period of the pilot plant (Fig.8, right), the cleaning performance of the Flexible FishProtector was proven through comprehensive operational tests but also through continuous operating experience. Even in the event of a particularly heavy accumulation of debris, the system could be permanently cleaned by laying down and re-tensioning the steel cables. However, the operating experience has also shown the high importance of a reliable control system for the cable drive system. After an unscheduled and unexpected failure of the control system, the system was damaged due to a static overload. As a consequence of this event, the control system was improved. Furthermore, technical improvements were made to the cable drive system in a simple way. The system is now well prepared for long-term trouble-free operation.

The Flexible FishProtector is a pure fish protection and fish guidance system. It does not replace the existing intake screen. The screen and the related cleaning device are still necessary. The Flexible FishProtector enables ecological retrofitting also at the inlets of medium-sized and large hydropower plants, for which such technical

possibilities were not available until now. Technically, lengths of more than 100 m are possible. However, experience still needs to be gained here.

Fig. 8. Flexible FishProtector - installations in the ethohydraulic test (left) and in the first pilot project on a pre-Alpine river in Bavaria (right, during construction period in 2020).

4.6 Barriers in the tailwater of hydropower plants (Bar Rack FishProtector or Flexible FishProtector)

At diversion power plants, there is often a certain risk that upstream migrating fish will reach a dead end in the tailwater of the hydro power plant. Here, too, hybrid fish barriers offer various possible solutions. If a fish ladder already exists at the diversion weir, then a FishProtector at the downstream end of the tailwater can lead to a significant improvement (Fig. 9). Depending on the amount of floating debris, a Flexible FishProtector or a Fixed FishProtector, for which a cleaning concept has to be defined, can be installed here.

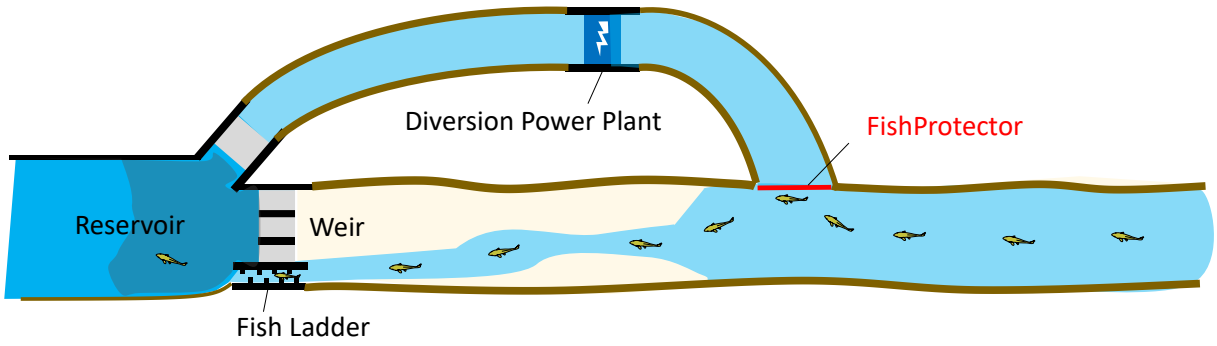

Fig. 9. Typical arrangement of a FishProtector at the end of the downstream channel of a diversion power plant (Note: The migration of fish in the downstream direction is not shown here).

5 Conclusion and Outlook

The FishProtector represents a promising technology to efficiently improve the fish protection and guidance at hydropower plants. It combines a mechanical barrier (screen) with a behavioral barrier (electric field in the water) in order to create a hybrid barrier. In 2020, the first application of the Flexible FishProtector at a real-life hydropower plant was realized. In 2021, another project with a Fixed FishProtector was installed. At both sites, the monitoring shows that the barrier works well and fish protection rates could be significantly improved.

References

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Markus AUFLEGER studied Civil Engineering at the Technical University of Munich. Subsequently he worked there as research assistant at the Institute of Hydraulic and Water Resources Engineering, obtained a doctor's degree in 1996 and his postdoctoral lecture qualification in 2000. Furthermore, he worked as Manager of the Laboratory of Hydraulic and Water Resources Engineering in Obernach. Since 2007 he is full professor for Hydraulic Engineering at the University of Innsbruck. He conducted many

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