Voith's StreamDiver® solution for decentralized low head hydropower plant operations

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Background

In many regions around the world, low head hydro is gaining importance due to its chance to exploit untapped potentials for a reliable and sustainable electricity generation. Globally, around 85 percent of the existing dams have not been utilized for power generation so far. As the majority of the sites are at lower heads, there is tremendous potential for decentralized power generation and developing a sustainable renewable energy mix with less CO_2.

However, in many ways low head hydro differs from its larger cousin: The commercial viability of low-head hydropower projects is mainly driven by simple, modular solutions that reduce complexity and cost of equipment as well as required civil work to integrate the power house. Beside the need of minimizing investment costs, the decentralized operation at smaller scales raises new requirements to reliability and maintenance.

Voith has developed the StreamDiver® turbine technology to address these challenges. The innovative solution combines new design with long operational history and long-standing experience in hydro turbine engineering. It also sets new standards for a safe and environmental-friendly hydropower generation.

The StreamDiver® had been introduced in the last Asia Conference in 2014. This presentation will continue the storyline around the StreamDiver® with the focus on operation experience and innovative plant layout solution. On the example of a real showcase it will be shown how the StreamDiver® technology copes with the requirements of a reliable operation with minimal maintenance. Remote condition-monitoring of all relevant operational parameter and system states reduces manual inspection to a minimum. In addition, the minimization of moving parts and support systems lowers the complexity of inspection works and maximizes the availability of the unit. Due to its compact and modular design the StreamDiver® can be flexible integrated in existing weirs, dams and revitalization projects. This approach ensures a fast project implementation as well as an economical and reliable operation.

Introduction to StreamDiver®

The core element of a low-head plant concept is the turbine itself. The StreamDiver® is a turbine where simplicity is the key principle. It runs completely submerged, the housing is flooded and the bearings lubricated with water. There is no risk for oil spills and no complex seals are needed. The direct-driven permanent magnet generator makes a gearbox redundant. The absence of adjustment mechanism, seals and peripheral systems increases availability and minimizes maintenance. Finally, a highly standardized, non-complex product means low investment cost.

Rather than a complex guide vane adjustment system the power control is achieved by switching on and off individual units if the flow is not constant.

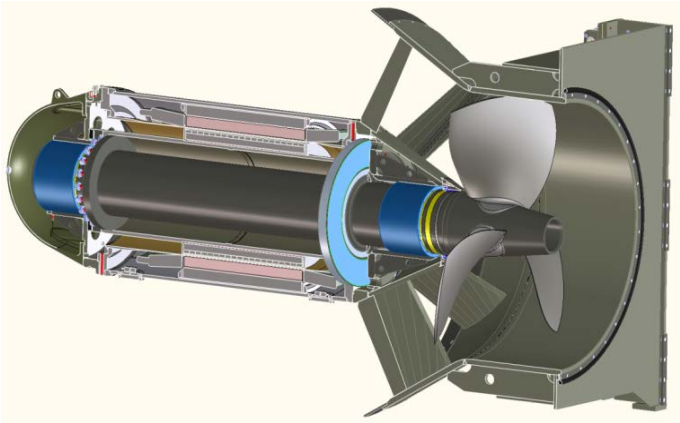

Fig. 1: StreamDiver® turbine

Innovative Plant Concepts

The StreamDiver® is very flexible and can be integrated in different plant concepts like diversion type power plants, overflowed power plants, irrigation or cooling water canals, closed pipe systems or even ship locks.

In the following, the most common two concepts are introduced in some detail:

The **diversion type application** is similar to conventional power plants and can be implemented like those in river systems, but has some decisive cost benefits compared to power plants e.g. with horizontal or vertical Kaplan machines. First of all the layout is much simpler. No complex shapes for inlet or outlet channels need to be cast in concrete. The inlet chamber consists of an open pit and the outlet is a horizontal draft tube cone. Engineering can be processed much faster due to the modular, standardized layout.

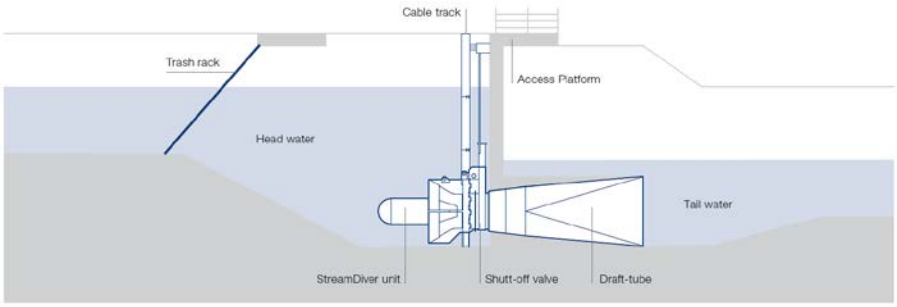

Fig. 2: General run-of-river diversion type hydro power plant with a StreamDiver®

The following schematic drawings demonstrate the lower complexity of a StreamDiver® power plant compared to conventional plants using vertical Kaplan or S-downstream units.

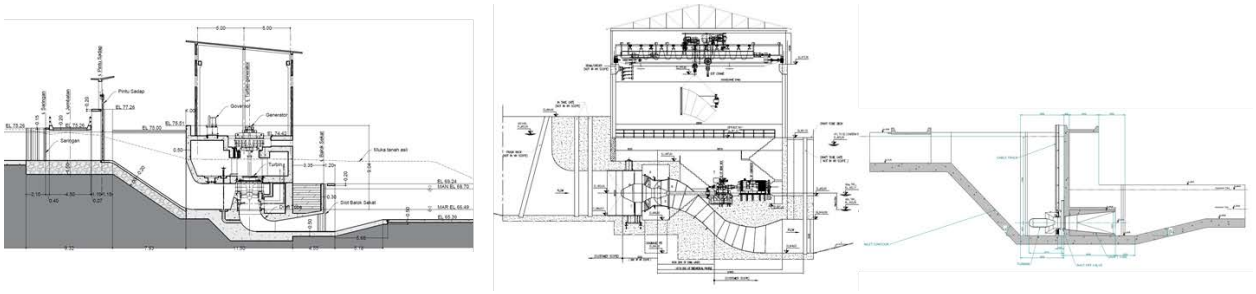

Fig. 3: Examplary layouts of power plants with (from left) Kaplan, S-turbine and StreamDiver®

Exemplary case studies using the same boundary conditions (head, flow and output) and system limits have shown that projects with a StreamDiver® would reduce necessary concrete volumes substantially compared with conventional power plants. This is not only thanks to the simplified structures, but also because a massive powerhouse with overhead crane is not required.

And simplified structures are faster to build, in combination with the short delivery times of the highly standardized StreamDiver® units this might enable operators to feed power to the grid some months earlier compared to conventional power plant concepts.

Layout	Units	Vertical Kaplan	S-downstream	StreamDiver®
Numbers of units	-	3	2	6
Width	m	23.1	16.4	22.2
Length	m	24.2	19.1	20.0
Depth+Height [1)]	m	12.4	13.2	14.5
Volume	m³	6,932	4,135	6,438
Concrete volume	m³	3,600	2,300	1,200
Concrete volume		100 %	64 %	33 %

[1)] civil structures without powerhouse

Table 1: Plant concept comparison

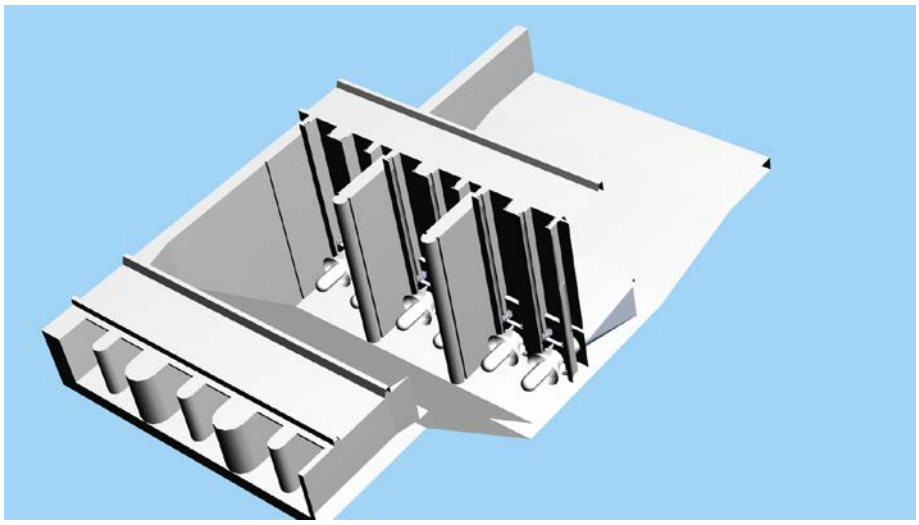

Fig. 4: 3D-model of a 2 MW 6-unit power plant

The StreamDiver® is also perfectly suitable for integration in a completely **overflowed power plant**. Not only the turbine, but all its components are completely submerged including trash rack and the rack cleaning system. Submerged plants are nothing new and have been built already in the past. However, dry powerhouses required water-tight covers, accessibility was poor and maintenance was not easy. With the water-filled StreamDiver® the integration into a submerged power plant does no longer require complex and watertight turbine chambers.

As result, the installation and maintenance can be performed easily from the top using guide rails for installation and retrieval. No powerhouse crane is needed, a normal mobile crane or a simple chain hoist system is sufficient to retrieve the turbine and lift or fold the trash rack.

Fig. 5: Overflowed plant with fish migrating downstream over gate

Fig. 6: Cross section of overflowed plant with 3 StreamDivers® underneath flat trash rack

The overflowed power plant concept has been developed at the Chair of Hydraulic and Water Resources Engineering of the Technical University of Munich and is protected by various patents. It has two key characteristics:

- a flat oriented trash rack system
- a vertical gate for level control, debris flushing, fish descent and flood relief

With the flat oriented rack the power plant concept is very fish friendly. Unlike with vertical racks fish will not be pushed against the rack bars. Due to the low velocity they can swim over and away from the rack and use the gate to descend over the tip to tail water.

Bed loads can easily pass the plant directly to the tail water when the gate is opened to flush the rack. A separate bypass canal is not required and saves civil, operation and maintenance cost. Other, organic debris like leaves and branches can pass the power plant as well. This eliminates the need for a collection system and storage area and saves cost for disposal.

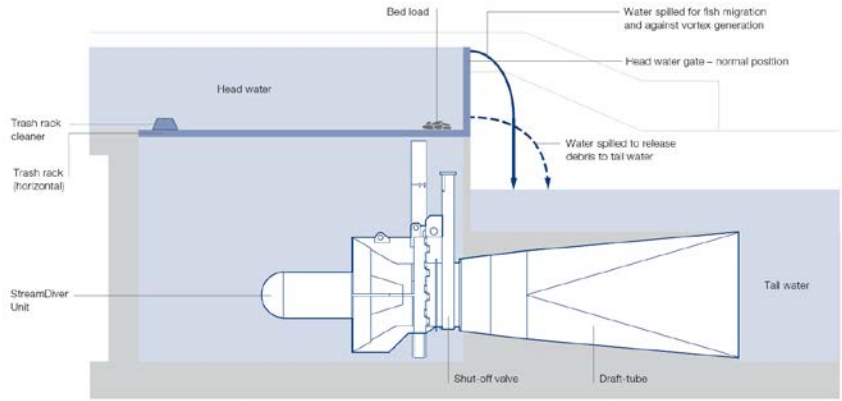

Fig. 7: General layout of the overflowed hydro power plant concept

The gate is not only important for fish descend and debris transport but for the flood discharge as well. In case of floods the gate will be totally retracted and discharge will not be affected at all.

This is why the Shaft Hydropower Plant can be integrated in existing weirs where flood discharge capabilities must be maintained due to restrictions in the river banks.

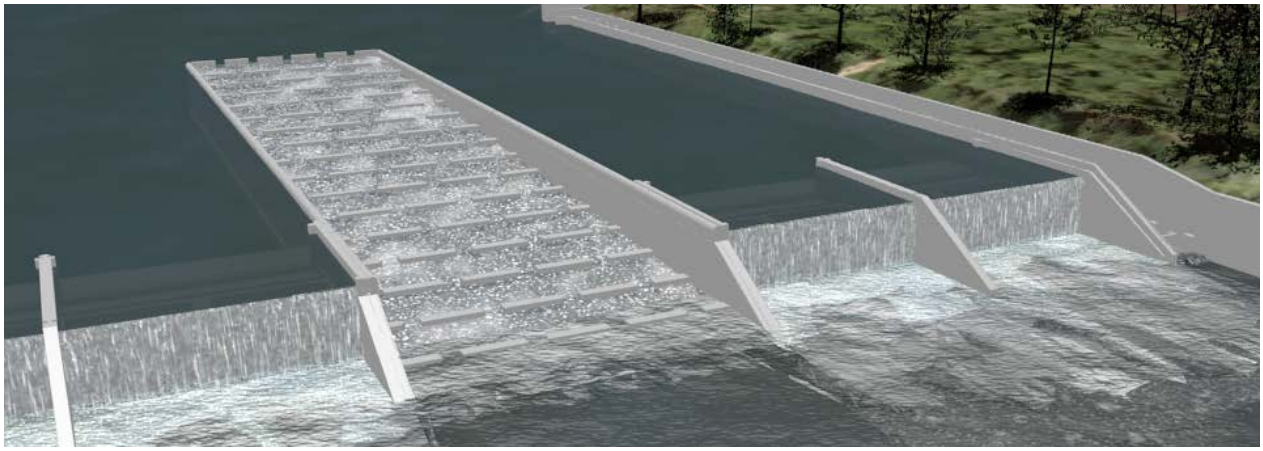

Fig. 8: Schematic illustration of overflooded hydro power plant, consisting of several bays, all of them equipped with 2-3 StreamDivers®. In between those bays a fish ladder for upstream migration may be integrated.

Service and Maintenance

Frequent service interventions are not viable for low-head, decentralized hydro power plants. An excellent availability and low cost for service and maintenance are most important for the profitability. Due to its simplicity the StreamDiver® fulfils these requirements perfectly.

What does not exist cannot fail. The absence of gearboxes, belts, seals, adjustment mechanisms, cooling and lubrication systems results in an excellent availability.

In case of a service no oils, transmissions or seals need to be replaced. The only wear parts are the water-lubricated bearing pads which are designed for a lifetime of 5 years minimum, depending on water quality. Planned service intervals are required only every 5 years with an inspection on site in between.

Due to the modular concept a power plant is normally equipped with several units and each unit can be serviced independent from the others whilst they are running. If we compare for example an 8-unit StreamDiver® plant with a 2-unit Kaplan plant the generation loss is in worst case only 1/8 instead of 1/2. If serviced during the dry season power production might not be affected at all.

Operational Experience

The described advantages have been demonstrated under real conditions in Nussdorf, Austria where a StreamDiver® has been integrated in an existing power plant near Vienna.

The StreamDiver® is completely overflowed and invisible from the outside. That has been a pre-requisite from the operator as the plant is part of an urban heritage conservation area.

The StreamDiver® has been in continuous 24/7 operation since August 2012. No maintenance or repair works have been necessary so far. Only a visual inspection was done. No troubles or malfunctions have been detected and in more than 28.000 operating hours over 7,4 GWh of renewable electricity has been fed to the Austrian grid.

Fig. 9: Plant view at the historic weir site in Nussdorf near Vienna.

Operator	Verbund, EVN and Wien Energy
Start-up	August 2012
Unit type	StreamDiver® SD 13.10
Generation type	Permanent magnet generator, 333 rpm
Rated/max. head	3.58 m / 4.68 m
Rated discharge	9.96 m³/s
Rated/max output	314 kW / 450 kW
Operation	Fixed speed (variable speed as option)

Table 2: Nussdorf data

Fig. 10: StreamDiver® installation

Summary

Low head hydro power generation is renewable, sustainable and helps to develop remote regions with a stable and reliable power supply. Due to the relatively low energy yield there is a strong focus on the total cost of ownership. The overall concept needs to consider not only investment cost, but also eco-friendliness for a smooth licensing process and low operation and maintenance cost.

The StreamDiver® turbine fits perfectly into this. Standardization and modularization are resulting in low investment costs. Simplicity and long service intervals keep operation and maintenance costs low, a smart retrieval concept assures highest availability. It is environmental friendly due to the absence of any lubrication oil. Fully submerged, it runs invisible and quiet.

Innovative plant concepts can reduce the civil costs as a conventional powerhouse is redundant and thus much less concrete is needed. The power plant is almost invisible and does not need much space at the river banks. All environmental impacts are minimized. There are no emissions like noise or vibrations. New submerged concepts combine ideally economic and ecological requirements. The system is fish friendly and a fish downstream migration possibility is given.

The Authors

Joerg Lochschmidt graduated in 2007 from the University of Applied Science in Ulm, Germany with a degree in industrial engineering and management. Since 2007 he works as a Product Manager at the headquarters of Voith Hydro in Heidenheim, Germany. Between 2007 and 2010 he executed various projects within the development of the small hydro division at Voith. In the position of a Project Manager he was responsible for the development of the StreamDiver® Technology till 2014. At present he is holding the position of a team leader for the StreamDiver® core team located in Heidenheim, Germany.

Stefan Reich graduated in Mechanical Engineering from the University of Applied Science in Schweinfurt, Germany and holds a certificate in Project Management of the University in Siegen, Germany. He joined the Voith group in 1990 working in various roles including application engineering and project management. Since 2012, he works in Voith's hydro division as Project Manager for tidal energy and presently as Business Development Manager for the low-head hydropower technology StreamDiver®

Mandar Pachegaokar is graduated in Mechanical Engineering from the Maharaja Sayajirao University of Baroda and has total 9 years of professional Experience in hydro industry. At Voith Hydro Pvt. Ltd., India, he has been involved in Small hydro Product development and its standardization activities for global Voith applications. He has worked in Voith Canada as offer proposal engineer for small hydro. At present he is holding the position of Offer Project Manager for South East Asian countries and product co-ordinator of StreamDiver® for the regional sales support.