Electricity from a movable power source

The first prototypes of hydroelectric stations completely immersed in water but movable, are now in operation. Invisible and nearly without any noise emission, they fulfil today’s expectations for environmental protection.

Besides a large number of industrial representatives, ordinary people interested in hydro power, came as well to witness the premier of the first movable power station in action. They were not disappointed. Its concept is most convincing due to its functionality as well as offering other ecologic advantages.

Within about one year after ground was broken, all civil structural work of the power station had been completed, but hardly anything is visible above ground.

The station is completely submerged, operating quietly beneath the water level. This represents an absolutely new, innovative concept, realized over a period of five years of research and development. Experience was also gained in the economic and ecologic utilization of hydro power stations at ultra low head sites.

Such low head sites can be found almost anywhere – they are generally known and identified. Worldwide, numerous such unexploited sites, offering heads of less than 5 meters, exist. With this new concept, many of them can now be developed without extended head or tailrace sections, and therefore may be approved and sanctioned quicker by the authorities. For utilizing larger flows, correspondingly larger structures and plant components will be necessary. Low-head installations are quite sensitive to head losses, which can happen due to back-up and raise of the tail water level. A partial or full blockage of trash racks, many designed with a net spacing of 20 mm and less, has to be faced, due to debris coming down the river, which must be re-directed and
guided around the power station. In addition, today's environmental mandates are demanding solutions regarding fish habitat. Fish must be able to pass without risk near the surface or at the ground. These requirements and stipulations set by the license issuing Agency make low-head hydro plants, using traditional designs and techniques, relatively expensive, calling their profitability into question.

Therefore, aiming for a well-adapted technology was the guiding factor: Minimize building expenses, provide safe flow discharge even at flood conditions, simplify the disposal of debris accumulation.

These requirements lead to a common, standardized design of power house, trash rack screen, adjustable weir, turbine and generator – inclusive of intake and discharge passage. Such design must be reproducible and the civil works must simple to exclude most-any risk during construction.

The answer to these questions was as follows:

- Construction of a simple trough structure, possibly within the weir itself,
- A power house that can be lifted, allowing the bed load to move underneath, control the weir crest and enable fish to travel downstream,
- A standardised unit comprised of equipment and power house, wherein all plant components are optimal adjusted to the system requirements.

The solution was the movable power station. A station that almost can’t be heard or seen. Another advantage point this design offers, comes from the “ejector effect”, which emanates from different flow velocities at the draft tube end. This effect is well known amongst hydraulic Engineers, however, it is hardly utilized in standard applications. The ejector effect permits extraction of residual energy at higher discharge rates, thereby obtaining extra power output.

Of course, of most importance is a compact machinery unit, characterized by an efficient turbine design, on the basis of the HSI Kaplan bulb turbine as well as an efficient generator design without the need of a gearbox.

For some years now, “permanent magnet-excited generators” (PMG) have found an application in the field of hydro power. This generator type had been used with bulb turbine units at first and put to the
The test results from these pilot plants confirmed the expectation of significant efficiency improvements fulfilled, due to avoiding losses within the exciter system. Even more important is the exceptionally slender body form of PMGs, i.e. they can be built at smaller diameters. Additionally, no cooling is necessary for the field windings or the electronic circuits of the exciter. The result represents a type of generator, which is robust enough to stand the comparison with an induction generator, however lighter in weight and more compact, rendering advantages in efficiency at the same time.

The PMG used for the movable power station can be connected to the mains without the need of a separate transformer. As already mentioned, the first bulb generators for immersed design were tested along with a turbine housed inside a conventional power house. The positive outcome experienced, was essential for the decision to use them also for the movable power house. Of highest importance were corrosion-resistant materials for the permanent magnets, offering small variations only in field strength, at varying temperatures. The generator voltage can be adapted to suit the local voltage level of the mains. The design of the pole shoes and the damper cage provides optimum protection against demagnetization and guarantees an optimal voltage curve.

This leads to an extremely smooth run and in association with low-loss dynamo sheet materials to high efficiencies (over 96% - already obtained at only 15 % of nominal power). Besides all these features, a continuous control of the inner bulb pressure monitors the shaft seal condition (generator shaft = turbine shaft).

The hydraulic machine is a double-regulated Kaplan Turbine from the current production series, which shows its best advantage in the middle and low head range. The turbines of the movable power station are known for their outstanding solid construction and ease in installation and maintenance, besides their basic features, such as high efficiency and long life expectancy. The first unit with a water-cooled permanent magnet generator powered by an HSI Turbine has been in operation since 2007. At a speed of 214 rpm, a generator efficiency of more than 96% has been measured. The next step was the installation of the first movable power station at 1.7 meters head and a nominal flow of 4 m³/sec. A maximum output of 55 kW is thereby achieved. It was essential to examine the hydrostatic buoyancy of this relatively small movable power station and to test the newly designed bow-shaped screening system in front of the unit, but also the ejector effect and the flow pattern around the unit.
Based on the experience gained there, a chain of power stations was projected in Southern Germany. The first one with a nominal capacity of 550 kW was connected to the mains in the summer of 2010, another one is at the stage of installation.

Already during construction of the 550 kW station, further advantages of its concept became evident. The trough structure could be built within a half-year construction time and the control room was erected during the same period. The movable power station itself was assembled at the manufacturer’s works as a complete unit and under went dry-run performance testing, including the generator test run, the setting of wicket gates and runner blades, the newly developed bow-shaped trash rack cleaner with synchro-run monitoring feature, the flushing flaps mounted on top of the power station and testing of all sensoring equipment.

Control and communication systems as well as full automation are most essential at power stations. Important are diagnostic, decentralized inputs and outputs for the programmable logic controller as basis for remote sensor diagnostics. To reduce the wiring between the control room and the moveable power station all measuring and control signals from the decentralized I/Os towards the PLC are transmitted via LAN. The double optic fibre cable not only assures good availability, it also prevents over voltage situations.

After successful conclusion of all tests at the manufacturer’s plant, the unit was transported to its place of destination in two pieces of 8 and 10 meters lengths, respectively. On site, both pieces were reassembled and lifted into the ready-made trough structure using two cranes, with 350 tons lifting capacity, simultaneously.
According to the Project manager – “this was a precision job, requiring millimetre accuracy, but it worked perfectly right from the beginning”. Even then, things advanced well. Less than four weeks passed after the lift-in until first commissioning took place.

Since then, the experience gathered during operation fulfilled supplier’s and operator’s expectations. Despite the small gap between the screen bars at the intake – only 15 mm wide - small head losses are experienced through the screen. The cleaning system works efficiently and fast, the debris is transferred promptly through the movable flaps. Regulation of the upstream water level, by means of the weir flaps and the lifting device of the power station, work excellent. The overall efficiency that was promised is observed. The ejector effect experienced with the surrounding flow even exceeds expectations.

Neighbours and visitors alike are particularly happy about the fact that no machine noise disturbs the smooth purling of the river. The machine can hardly be heard.

With a gross head of 3.2 meters, the power station is designed for a nominal flow rate of 20 m³/sec. At the generator terminals a power output of 550 kW is achieved. The generator is rated at 600 kW as a power increase is expected at larger discharge rates.

Such high power values are achieved by this plant, when conventional low-head turbines already drop off or must even be shut down, due to tail water back-up. With a back-up of 45 cm and a flow rate of 55 m³/sec. a conventional plant would lose more than 20% of the power produced. With the moveable hydro station and the flow passing beneath it and above, the ejector effect even increases the power passing up to 8% above its rated value.

The first plant is now in operation for some time. Apart from energy production, ecologic improvements are also achieved with this plant. The continuous fish passage upstream and downstream enables migrant fish like salmon to pass the power station without problems. Following the latest scientific knowledge, such large steel casing housing turbine, generator and screen, which can be moved by hydraulic cylinders, offers the best possible conditions for the protection of fish and water. Even ground dwelling fish, as e.g. eels, can pass by without any troubles. Consequently, the ecologic production of electricity and the ecologic upgrade of the river, show up on the positive side of the investment. The moveable power station is a ground breaking system, destined for environmentally friendly production of electric power from regional sources without CO₂ emission, using the latest technological developments. The next hydro station downstream is going to be commissioned within these days.

In cooperation with

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