

USE OF RESERVED FLOW FOR HYDRO PRODUCTION: RECENT ACHIEVEMENTS

L. Papetti, G. Frosio

Abstract:

When at the Reserved Flow it is possible to join a “head”, not less than one meter, we have a site which can be studied for an advantageous hydroelectric exploitation.

Modern technologies as well as unusual design solutions allow to transform the water “lost” as Reserved Flow in a new resource available downstream of weirs and dams of existing hydro power plants.

The paper focuses on “high” reserved flow (some cubic meters per second), and low head (more than 1 m) released by a river weir, showing how apparently similar situations and problems must be solved in different ways.

1 Introduction

The reasons for the recent development of the hydropower use of reserved flow mainly lie in the evolution of the law framework and of the available technologies, as well as in the availability of profitable tariffs for energy produced by small hydropower plants.

First of all, as regards the law framework, the main reference at EU level is the Water Framework Directive (WFD), which has imposed more severe restrictions on water uses with the aim of protecting water bodies; the adoption of the WFD at national law level may hinder the HP production development, making new water diversion authorizations more and more difficult to obtain and subjecting the existing ones to the obligation of releasing (or, sometimes, of increasing the current release of) the reserved flow. This new and unfavourable scenery, on the other hand, has roused a new way of considering the reserved flow: no more as a cause of hydropower production decrease, but as a source of constant flow available downstream of an existing hydropower diversion. Thus the reserved flow, in the presence of a “head” (that is a water level difference), can become a valuable opportunity to produce clean energy, combining the river ecosystem preservation and the RES development, with a relevant environmental benefit.

Secondly, as regards the technical progress, modern technologies and innovative design solutions allow now to realize hydropower schemes that were impossible up to a few years ago because of space and other requirements, mainly connected to the environmental impact of the plant.

Last but not the least, thanks to profitable tariffs for the energy produced by small hydropower plants (currently approx. 220 €/MWh, in Italy, for plants with nominal capacity up to 1 MW), the investment on this kind of plant is economically feasible.

The combination of these causes, i.e. constraints, innovations and tariffs, has caused the aforesaid development of hydropower plants exploiting the reserved flow; such

plants face both common and particular problems and accordingly have both common and particular features. This paper deals with these topics, focusing on low heads (a few meters) and high reserved flows (some cubic meters per second) released from river weirs, not only for hydroelectric purposes, but also for irrigation, etc. The abovementioned similarities and peculiarities are highlighted, referring in particular to the northern Italy scenery.

2 Hydropower production from reserved flow

2.1 Main problems and features

For low head plants, usually, many works are below ground level and close to rivers, where the water table is high, so that risky excavations under the water table level are often required. The solutions to this problem are sheet piles, micropiles (acting as deep foundations as well) and jet-grouting to reduce the seepage flow; moreover, provisional dikes (made out of river bed materials, to be eventually put back) can be built and reinforced with rocks or concrete blocks, to allow working in dry conditions, both upstream and downstream.

The plant dimensions must be small, particularly with regard to length, in order not to interrupt the flow continuity, since the reserved flow must be released where it once was. This requirement can be met thanks to current available technologies such as compact submergible hydroelectric units, with semi Kaplan turbine and synchronous generator. Another viable option is the Straflomatrix™ technology, implemented at Chievo plant, where a matrix of small Turbine-Generator (TG) units put in rows (the so called modules) should exploit the small available space in the best possible way. In the specific case of Chievo (described in detail later on) the matrix has one row, so it's a vector, of five TG units; the module also incorporates the draft tubes, the downstream power gates at the end of each draft tube, the Hydraulic Power Units (HPUs) for moving the gates and the in-field electrical cubicles. A further design solution is to install siphon intakes on the existing weir or spillway, with turbines either on the top or on the downstream side: this is the case of Sticchi plant, described later on, where two short siphon pipes, each one with a bulb TG unit at the end, are set on top of the existing spilling wall.

A new fish pass isn't usually necessary, as the existing one (if any) can be used, according to the plant layout: the important is to ensure the river continuity.

The environmental (specially visual) impact must be minimized by appropriate restoration works: local-stone facing, rip-rap protection, banks reshaping, bio-engineering works, reforestation with local plants.

The design of the plant layout must take into account the protection from the floods: a typical solution is to locate the new plant at the beginning of the headrace of the existing plant, so that, in case of floods, it is protected by the closing of the existing intake gates. Another viable option, once again described more in detail for Chievo plant, is to install removable hydroelectric equipment.

Trash and sediment management is crucial for low head plants: an intake screen is always needed, equipped with a trash rack cleaning machine and protected by floating log and debris booms upstream; effective flushing devices (such as sluice gates) must be provided for and carefully designed with respect to their hydraulic behaviour. The water available for the plant may be either the reserved flow (constant or modulated) alone or also the flow spilling over the existing weir.

The intake can be located both upstream and downstream of the existing intake works, anyway a protecting screen (with trash rack cleaning machine) is always needed. Accordingly, the plant head depends on the cases; it will often be, for instance, the water level difference between the existing weir or headrace (depending on whether the new intake is, respectively, upstream or downstream of the existing one) and the river downstream, but different situations are possible. Casnigo plant, for instance, conveys the water to be released downstream of the existing plant by an alternative path, shorter than the previous, so it suffers less head losses and thus it exploits a greater net head. The head available for Garletti plant, instead, is created (or rather increased) by the inflatable weir set on the existing fixed weir used for irrigation water diversion.

2.2 Case studies: two peculiar plant schemes

Sticchi, in central Italy: it is realised across the spillway at the beginning of the headrace of an existing run-of-river plant, which in turn exploits the flows released by a storage plant upstream. A short (around 13 m) conveyance system, consisting of two siphon pipes, takes water over the existing spilling wall to the two bulb TG units, one at the end of each pipe. The head is 7,50 m, while the available water is the reserved flow of the run-of-river plant plus the flow it releases when its capacity is exceeded.

Chievo, in the surroundings of Verona: it exploits a mean gross head of 3,60 m across a navigation lock (no more used, but still in perfect operation) where a very high reserved flow of 60 m³/s is constantly released. The basic concept at the basis of the project was to replace the downstream gate of the ship lock with a matrix (in this case a vector) of small TG units put in a row (a so called module). In the specific case of Chievo the vector has 5 units. The whole module, beside of the TG units, incorporates also the draft tubes, the downstream power gates at the end of each draft tube, the HPU's for moving the gates and the in-field electrical cubicles. The whole module can be lifted (and lowered) by an hoisting system in case of flood. An auxiliary hoisting system can lift one unit by one for maintenance.

The Straflomatrix™ technology allowed to meet all the requirements (technical, environmental and operational) of the project:

- minimum space occupation: the generating set (composed by five units in a row) was located inside the existing navigation lock instead of the downstream gate of the lock;
- compact construction: the steel module is composed by five Turbine-Generators units of the Straflo type. The generators are of Permanent Magnet type, allowing a very compact construction both in longitudinal and radial direction, which is essential for exploiting in the best way the small available space inside the lock;
- the steel module can be lifted and lowered in a few minutes, just like a gate, so the functionality both of the navigation lock and of the connected waterway for discharging water in case of flood events is preserved;
- the submerged steel module and the careful design respecting the historical existing structure allows a final “zero” impact realization, supplying energy to 4.000 equivalent families.

2.3 Conclusions

The use of reserved flow for hydropower production has proved technically and economically feasible, provided that the following general conditions are met:

- a certain and stable system of incentives is necessary;
- technical innovations are needed to widen the range of possible solutions.

3 Pictures



Fig. 1 - Why not make some energy out of this water?



Fig. 2 - Adige river as it looks now



Fig. 3 - Adige river as it will look after the implementation of the plant



Fig. 4 - Inserting a new plant with minimum visual impact: photo-simulation



Fig. 5 - Straflomatrix™ module



Fig. 6 - Straflo TG unit

Authors

Luigi PAPETTI,
Studio Frosio
Via P. F. Calvi 9, 25123 Brescia, ITALY
Phone: +39 030 3702371, FAX +39 030 396143,
E-mail: luigi.papetti@studiofrosio.it

Giovanni FROSIO,
Studio Frosio
Via P. F. Calvi 9, 25123 Brescia, ITALY
Phone: +39 030 3702371, FAX +39 030 396143,
E-mail: giovanni.frosio@studiofrosio.it

Luigi Papetti: hydraulic and chemical engineer, is involved in design and supervision of small hydroelectric plants since 1990. At Studio Frosio is in charge of the hydraulic design and of the environmental problems connected to small hydro production.

Giovanni Frosio: environmental engineer, graduated in 2009 with a thesis on a small hydropower plant in Africa. At Studio Frosio he's in charge of the hydraulic design and hydrological problems of small hydroelectric plants.