

Chievo small hydro plant - from the obligation of environmental flow to the opportunity of renewable energy production

Stefano Rizzi	Luigi Papetti	Giovanni Frosio
Andritz Hydro Unipersonale s.r.l.	Studio Frosio – Studio Associato di Ingegneria	
Via Daniele Manin, 16/18 - 36015 Schio (VI), Italy	Via P.F. Calvi, 9 – I – 25123 – Brescia (Italy)	
Stefano.rizzi@andritz.com	luigi.papetti@studiofrosio.it	giovanni.frosio@studiofrosio.it
www.andritz.com	www.studiofrosio.it	www.studiofrosio.it

1. Abstract

In October 2009, after 7 years from the first meeting and a long authorisation procedure lasted 4 years, the new Chievo hydroelectric plant was put into commercial operation.

Chievo plant is located at a “dam” (actually it’s a moveable weir) completed in ‘20s last century (an older weir was there since 1860) to divert water from Adige river (the second more important river in Italy) for operating through Canale Camuzzoni (a large headrace channel flowing through Verona city) Tombetta powerplant (now equipped with three vertical Kaplan turbines and four Permanent Magnet Generators vertical bulb turbines – Ecobulb® - with a 10 MW total installed capacity) located in the vicinities of the centre of Verona.

To Tombetta plant was imposed a reserved flow of 60 m³/s - due to health and “dignity of the city” reasons, in order to avoid that the water left in river downstream of the weir was too low - very high if compared to the natural mean flow of the river (180 m³/s) and the rated flow of the plant (110 m³/s).

As effect of the weir an average gross head of 3,80 m was created.

In 1991 a first project to exploit the head and flow rate available was envisaged. The technology available at that time allowed only for installation of conventional Kaplan turbines requiring big excavations and earth handling, special foundations, so that the project was never implemented due to high costs and risks, beside of an undoubted environmental impact.

Thanks to new technology development in low head turbines design - Straflomatrix™ system - the opportunity of exploiting the head and reserved flow at Chievo dam could be taken at beginning of the century.

Straflomatrix™ allowed to meet all the requirements: technical, environmental and operational, of the Chievo project.

- Minimum space occupied by the plant: the generating set (composed by five units in a row) was located inside an existing navigation lock (no more used, but still in perfect operation) 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, essential for exploiting at the best the small space available.
- The steel module can be lifted and lowered in few minutes just like a gate. In this way both the functionality of the navigation lock and of the connected waterway for discharging water in case of flood events are preserved.
- The submerged steel module and the careful design respecting the historical existing structure allows a final “zero” impact realization, supplying energy to equivalent 4.000 families.

Furthermore some other important features of Chievo:

- New fish passage made in pre-casted concrete elements and removable steel weirs to facilitate erection and future maintenance
- Complete modification of the automation hydraulic node of Chievo. The new system must at the same time keep constant the level upstream of the dam to maximise the new plant energy production and allow for the diversion of water in the Canale Camuzzoni. The task was fulfilled by modifying the nine existing intake gates – already hydraulically operated – from the former *on-off* operation to a regulating function through modification of the hydraulic power units, the installation of a position transducer at each gate and a radical automation modification
- Vertical screen with hydrodynamic profile made by GRP bars, mounted and lifted with the module

The main parameters of the plant are:

- Gross head: 3,80 m Net head: 3,30 m
- Rated flow: 56,7 m³/s Rated output: 1.298 kW
- Expected energy production: 10,0 GWh/y

2. General background

In '20s last century (an older weir was there since 1860) a “dam” (actually it’s a moveable weir) was completed to divert water from Adige river (the second more important river in Italy) for operating through Canale Camuzzoni (a large headrace channel flowing through Verona city) Tombetta powerplant (now equipped with three vertical Kaplan turbines and four Permanent Magnet Generators vertical bulb turbines – Ecobulb® - with a 10 MW total installed capacity) located in the vicinities of the centre of Verona.

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As effect of the weir an average gross head of 3,80 m was created.

3. The existing Chievo dam

Chievo dam is actually a weir equipped with 7 sliding gates 12 m net span each. On the right side a ship lock is located. This ship lock was never put in operation: only some small boats passed through it since 1922 when it was built.

Before the realisation of Chievo plant the water level at the dam was not regulated, but it depended on the flow rate diverted by Tombetta plant at which forebay the water level is kept at a constant value as usual.

The variation of water level was rather large approx. 3 m, from 61 to 64 m a.s.l, according to the Tombetta plant flow rate.

4. New technologies available

At the end of 2002 the idea of exploiting reserved flow at Chievo dam came back into fashion (the first idea dated back 1991), thanks to the development at the end of '90s of a technology able to exploit low heads at existing weirs (Hydromatrix®).

That's why the Chievo dam owner and operator, Consorzio Canale Camuzzoni, decided to start a deeper investigation of the possibility of realising a plant inside the ship lock; this is the first photo-simulation of the new plant:

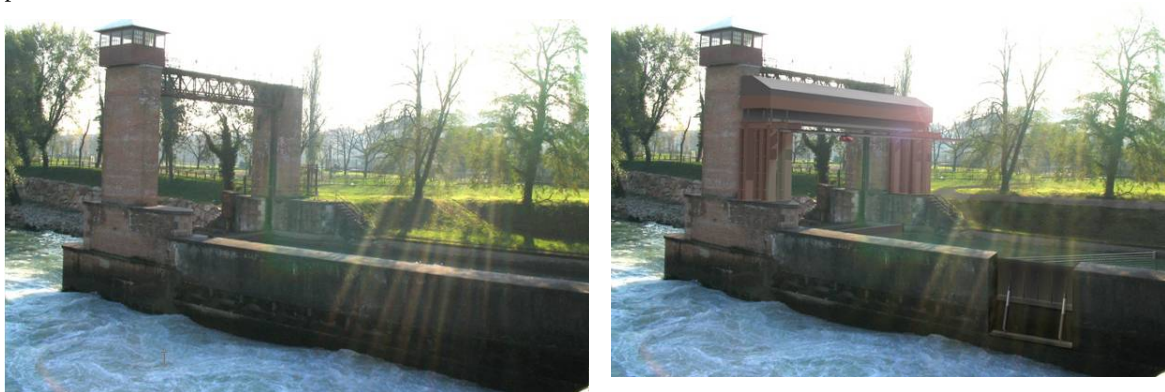


Figure 1 - Photo-simulation of the plant before (left) and after (right) the plant realisation

The plant layout has been modified several times during the development of the project.

Those modifications described in more detail in the following paragraphs didn't affected the overall concept of the plant that the authorisation procedure couldn't start.

5. Basic boundary conditions

The development of the concept had to take into account some basic boundary conditions and main issues:

- Floating debris management
- Trash management
- Water level and flow rate regulation of the hydraulic node (Canale Camuzzoni intake-Reserved flow downstream of the weir-Flood management)
- Connection to the grid
- No modification of flood management due to the new plant
- Fish passage

6. Solution adopted

The basic concept of the project was to replace the downstream gate of the ship lock with a matrix (in this case a vector) of small Turbine-Generator [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 TG units, incorporates also the draft tubes, the downstream power gates at the end of each draft tube, the Hydraulic Power Units [HPU] 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.

That's the concept.

To get the final goal several different solutions have been envisaged and thanks to the long time required to get the authorisations an optimisation of the project was possible.

After many adjustments along the project development, the final solution adopted was:

- StrafloMatrix™ (Straflo turbines) coupled to permanent magnet generators
- Conventional Trash Rack Cleaning Machine (TRCM) located against the module with rack lifted in case of flood with the module – vertical bars made by GRP with hydrodynamic profiles
- Hoisting system and the module incorporated in the existing piers of the downstream gate, but with a supporting frame similar to the existing one (removed)
- Problems: none (up to now)

7. Main technical issues

- Minimum space occupied by the plant: the generating set (composed by five units in a row) was located inside an existing navigation lock (no more used, but still in perfect operation) 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, essential for exploiting at the best the small space available.
- The steel module can be lifted and lowered in few minutes just like a gate. In this way both the functionality of the navigation lock and of the connected waterway for discharging water in case of flood events are preserved.
- The submerged steel module and the careful design respecting the historical existing structure allows a final “zero” impact realization, supplying energy to equivalent 4.000 families.

Furthermore some other important features of Chievo:

- New fish passage made in pre-casted concrete elements and removable steel weirs to facilitate erection and future maintenance. The fish passage is partially interred. Four holes in the roof of the passage allows for sunlight to enter the passage and guarantees its efficiency.
- Complete modification of the automation of hydraulic node of Chievo. The new system must at the same time keep constant the level upstream of the dam to maximise the new plant energy production and allow for the diversion of water in the Canale Camuzzoni. The task was fulfilled by modifying the nine existing intake gates – already hydraulically operated – from the former *on-off* operation to a regulating function through modification of the hydraulic power units, the installation of a position transducer at each gate and a radical automation modification.
- Vertical screen with hydrodynamic profile made by GRP bars, mounted and lifted with the module
- Optimisation of the floating debris management at the node: tuff booms were installed at the Canale Camuzzoni intake. To avoid the floating bodies stopped by the booms, the upstream gate of the ship lock is kept partially immersed. To flush downstream the floating bodies the first sliding gate of the weir has been modified cutting the top at installing in place of it a low flap gate. When the amount of floating trash is excessive it can be flushed downstream by opening the flap gate.

Actually, the real innovation which allowed the exploitation of reserved flow at Chievo dam is represented by the StrafloMatrix concept. Once solved the problem of the generating set, all the other issues come downstream as a consequence, even though those issues are in some extent as crucial as the units themselves for the global efficiency of the plant.

8. StrafloMatrix™ peculiarities

The Hydromatrix® concept is a patented technology utilizing an array of small propeller type turbine-generator units (“TG-Units”). These TG-Units are arranged in a matrix-type configuration to utilize the existing civil structure and to fit into an existing water passage. The TG-Units are mounted onto a steel structure, also called a Module. The Module design is integrated into the existing civil structure, requiring only minor modifications, if any, to the existing structure and allowing continued operation of the Locks and Dam. In one of the various possible configurations, the Module contains only the TG-Units (see Figure 2 and Figure 3).



Figure 2 – Module at Chievo Dam housing 5 TG-Units in horizontal configuration. Module shown in lowered position from upstream side, gantry crane to lift Modules, total plant output 1,25 MW



Figure 3 - Turbine Generator Unit at Chievo Dam

In another application, the module may also house the complete electrical and auxiliary equipment for the power plant itself (see Figure 4 and Figure 5).

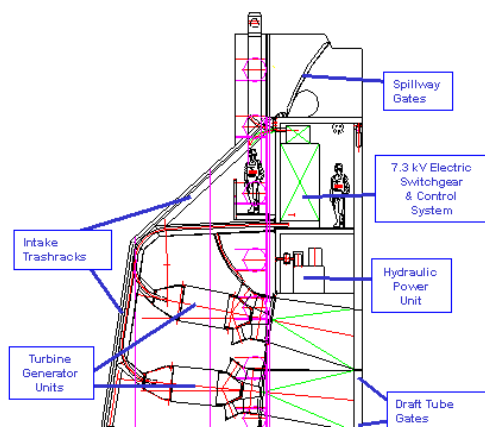


Figure 4 - Cross Section of a Module housing 34 TG-Units and complete electric switchgear equipment

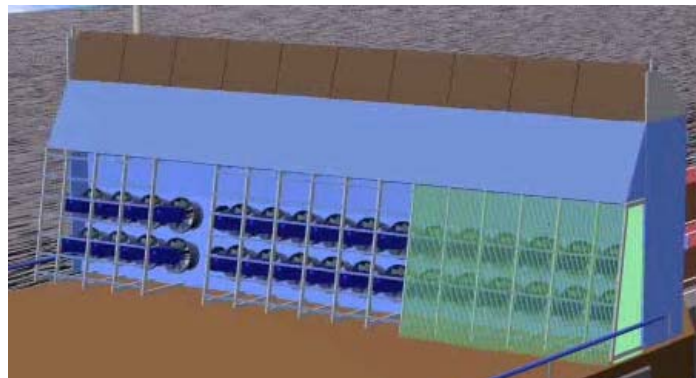


Figure 5 - Module (seen from upstream side)

Turbine –Generator Units

The design of the Turbine-Generator- (TG-) Units is derived from Andritz Hydro's classic concepts for small compact hydro turbines. With the ongoing developments and the specific needs for each application, Andritz Hydro has created two types of TG-Units, all using an unregulated propeller type runner with fixed stay vanes:

- The HYDROMATRIX® TG-Unit equipped with a low or medium voltage asynchronous generator or a medium voltage synchronous generator featuring a rotor with permanent magnets
- The StrafloMatrix™ TG-Unit equipped with a medium voltage permanent magnet synchronous generator

StrafloMatrix™ TG-Unit

The unique feature of this innovative system is the generator rotor, which is integrated into the turbine runner design, where the outer edge of the turbine blade supports the generator rotor with both turbine and generator rotor spinning under flow as a single unit.



Figure 6 - StrafloMatrix™ TG-Unit

This configuration allows to significantly reduce the length of the unit in the direction of flow, thus enabling applications where such space is limited. The StrafloMatrix™ operates synchronously with the power distribution grid, which is advantageous for applications where induction generators may not be acceptable.

1. Main figures

The main parameters of the plant are:

- Gross head: 3,80 m
- Net head: 3,30 m
- Rated flow: 56,7 m³/s
- Rated output: 1.298 kW (measured on site)
- Expected energy production: 10,0 GWh/y
- Overall cost: 9 M€
- Gross payback time: ~ 6 years.

2. Conclusions

Chievo plant realisation demonstrates that:

- Getting an optimised technical solution can require a lot of time and effort (the best is the enemy of good).
- Hydropower is a mature technology but R&D widened the range of exploitation of water resources not even considered as worth considering since few years ago.
- Exploitation of reserved flow for hydro production can give a marginal but not negligible contribution to RES production with negligible environmental impact.

The Authors

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

Stefano Rizzi: in the hydro field since 1994. Within the Italian branch of Andritz Hydro, he is currently

- Product manager for Compact Hydro sector (units up to 20 MW)
- Responsible of Electrical Engineering department
- Vice president and member of the Company managing team

Giovanni Frosio: environmental engineer. At Studio Frosio he's in charge of the hydraulic design and hydrological problems of small hydroelectric plants.