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“Hydroelectric power generation at multi-purpose irrigation dams using HYDROMATRIX® Technology”

1 Abstract

In the last 10 years ANDRITZ HYDRO and its customers have jointly and successfully developed and implemented 6 hydropower plants using the HYDROMATRIX® Technology in various existing structures ranging from irrigation and navigation dams to canals and ship locks.
Apart of a brief introduction of the technology, the paper describes the possible power plant arrangements which can be incorporated into the design of head works or dams at irrigation canals. These arrangements will be described based on already operating or currently constructed reference installations.
The main advantages and disadvantages of these arrangements with regards to power generation, flood release and cost will be outlined.

2 Introduction to HYDROMATRIX® Technology

The HYDROMATRIX® concept consists of a factory assembled “grid” of modules containing small propeller turbine-generator units, that can be grouped flexibly in various power plant arrangements. HYDROMATRIX® plants can be installed at existing dam and gate structures as well as in greenfield projects.
HYDROMATRIX® modules are shipped in pre-assembled condition to the power plant site where they are installed into the existing water passage. (See picture 1) The turbine-generator (TG) units are switched on and off using hydraulically operated sliding gates.

The design of the modules allows the lifting or removal from its operating position like a sliding gate. This enables the passage of flood water and simplifies inspection and maintenance work on the TG units. (see picture 2)

Picture 1: 5 x 5 Unit Module of Freudenau HYDROMATRIX® plant

Picture 2: TG-Unit (StrafloMatrix™ Type)

Projects that are not economically feasible with conventional plant designs can now be profitably developed by using this innovative approach. Six reference installations, each using the concept under different site-specific conditions, are now being successfully operated for up to 10 years.

3 Possible plant arrangements

3.1 Jebel Aulia - Retrofitting an existing irrigation dam for hydropower generation

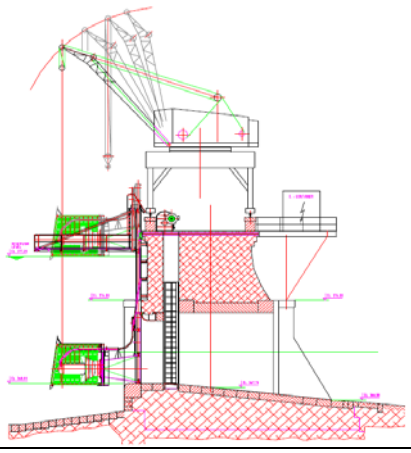
The Jebel Aulia dam is located on the White Nile. The dam was originally built for irrigation of the adjacent agricultural land and features 50 discharge openings which were originally equipped with manually operated stoney roller gates.

The HYDROMATRIX® power plant consists of 40 modules. Each Module is equipped with two submerged 380 kW Turbine-Generator Units arranged in one row. Each turbine has a 1.12 m diameter runner precision cast of aluminium bronze. The modules and associated 80 TG units were installed in front of the existing discharge openings and can be lifted for maintenance purposes by a newly installed gantry crane. The 690 V asynchronous generators were grouped in sections of 5 Modules and feed into one generator switchgear section and associated 690V/33 kV stepup transformer. Each section has its own unit control system and was installed inside containers which were placed on platforms along the downstream side of the dam.

For emergency power supply, a Diesel generator was installed. The existing stoney roller gates were retrofitted and equipped with motor driven hoists. The motors are operated with frequency converters to allow operation via a battery system.

ANDRITZ HYDRO supplied and delivered the entire electromechanical equipment which was installed by the customer under the supervision of ANDRITZ HYDRO personnel. Since it was possible to use the existing gate slot structures and to retrofit the upstream face of the dam with guiding rails for the Modules, very little civil construction work was required. The resulting cost savings proved to be one of the decisive factors for the realization of this project.

The plant was built in several lots with the first units being commissioned in 2002 and the final units becoming operational in 2005.



Picture 1: Sectional view of the Jebel Aulia dam showing a module in operating and lifted position

Picture2: Photo of the modules in raised condition

Relevance of the Jebel Aulia design for irrigation projects

The Jebel Aulia project is the classic example for adapting an existing irrigation dam structure for hydropower generation. The following preconditions have to be met to allow the incorporation of HYDROMATRIX® technology:

- The dam has to withstand the changed hydrostatic loads due to the hydropower installation
- The minimum available width of the existing gate openings shall be 2,20 meters per installed Turbine-Generator Unit.
- If the dam or headwork is also used for flood release a suitable the crane or hoist arrangement has to be chosen to allow lifting of the modules within the available lead time.

3.2 Chievo Dam - Hydropower generation and flood release in an abandoned shiplock

In Chievo, a district of the city of Verona in Italy, a dam and adjacent ship lock was built in the 19th century on the Adige river to establish the Camuzzoni canal. The abandoned ship lock downstream of Chievo dam is owned by Consorzio Canale Camuzzoni and was modified to harvest the unused hydropower potential of the abandoned lock without compromising its flood discharge capabilities. Picture 3 shows the lock in its original condition.

The core element of the Chievo Dam plant is the steel-fabricated module, which is located at the downstream end of the lock. The bottom part is formed by five drafttubes arranged in one row. On top of the draft tubes, a submersible equipment gallery houses the hydraulic power unit and the power cables. At the upstream side of the module there are five StrafloMatrix™ TG units with a unit output of 270 kW (at a head of 3.8 m) that can be switched on and off separately by opening or closing individual draft tube gates. The entire module can be lifted and lowered by a gantry hoist system under balanced conditions in order to evacuate the lock chamber prior to flood release. (See Picture 4)

Picture 3: The unused lock at Chievo dam. The gantry hoist and sliding gate are located at the downstream end .

Picture 4: The Chievo dam HYDROMATRIX® plant seen from the upstream side. The Module is lifted out of the lock´s water passage. On the right side of the lock wall, the upstream entrance of the newly constructed fish ladder can be seen.

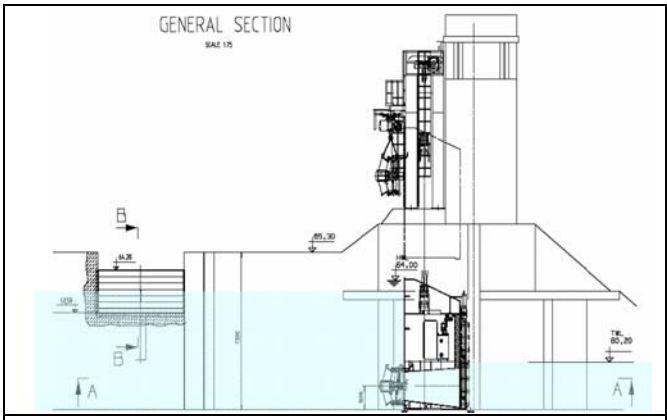
The HYDROMATRIX® plant at Chievo dam in Verona was successfully commissioned in the fall of 2009. With a capacity of 1.35 MW and an average yearly energy production of 12 GWh it meets the energy needs of around 10.000 households.

Relevance of the Chievo dam design for irrigation projects

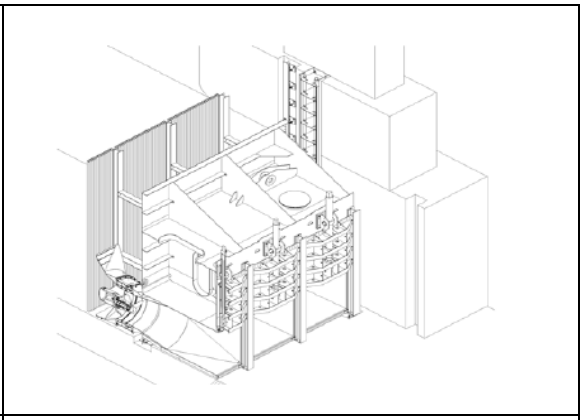
The integrated module design as employed at Chievo can also be incorporated into new or existing dams or headworks if the following conditions are met:

- Dam structure is suitable with regards to stability and strength to withstand the hydraulic forces which are transferred into the structure via the guiding rails and sill plates of the Module and to allow the installation of a crane or hoist system for lifting the Module.
- There is adequate space to incorporate the Module steel structure into the existing water passage
- A radial gate or other closure device is available to block the water flow on the upstream side of the module to enable the lifting of the module in balanced condition.

Since the weight of the Module depends on the width of the water passage, the hydrostatic load and the head differential, the clear width of the existing water passage shall not exceed 18 meters and the gross head should be in a range of 4 to 5 meters. This results in a module outfitted with 7 to 8 units which still has manageable dimensions and weights to allow land transport and use of standard type gantry cranes or hoist systems.



Picture: Sectional View of the Chievo Dam design



Picture: Isometric view of the Module showing the StrafloMatrix™ TG-Unit, draft tube and draft tube gate

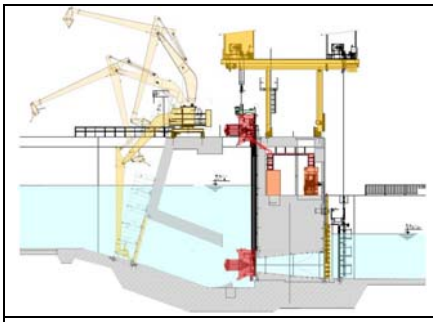
At new irrigation constructions, there is the possibility to avoid the need for a separate gate structure by designing the module as a roller gate. Due to the sturdy design of such a gate which is capable to be closed under the full head differential, the maximum width of the gate structure should however be limited to 12 meters which would allow a five TG-Unit arrangement similar to the one employed at Chievo dam.

3.3 Ashta I & II – HYDROMATRIX® in a Greenfield Application

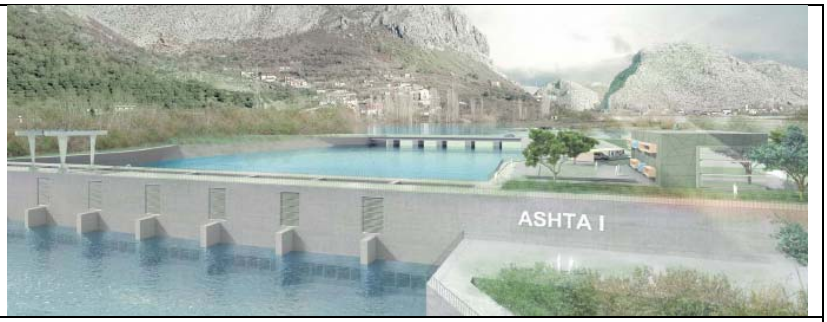
The Ashta I & II Hydropower Project is located on the Drin River near the city of Shkodra in Albania and comprises two power plants of similar design. Ashta I is located next to an existing weir. It includes an intake trashrack along with a trashrack cleaning machine. The tailrace of Ashta I consists of a 6 km long canal connecting the two plants and an additional diversion channel connecting the plant with the Drin River. With the exception of the trashrack, the Ashta II plant has a similar arrangement to Ashta I and its tailrace will be connected with to the Drin River by a short canal.

Each power plant is equipped with forty-five HYDROMATRIX® TG units mounted at the upstream face of a concrete gravity dam structure. The TG units are arranged in one row in front of the dam structure and can be raised individually for service purposes.
The accompanying draft tubes are embedded in the newly constructed dam structure.
The hydraulic and electrical equipment is installed in an underground gallery located above the draft tubes.

Water flow may be stopped separately for each machine by a sliding gate on the downstream face of the dam structure. In the event of gate maintenance, the same lifting crane as for the TG-units will be used.



Picture 7: Sectional view of Ashta I plant configuration



Picture 8: Architectural rendering of Ashta 1 (seen from the downstream side)

Technical Data	Ashta 1	Ashta 2
Plant capacity:	24.03 MW	45.14 MW
Head:	4.98 m	7.53 m
Speed:	300 rpm	375 rpm
Unit Output:	534 kW	1,003 kW
Runner diameter:	1,320 mm	1,320 mm
Number of units: 5	45	45

Relevance of the Ashta I& II plant design for irrigation projects

The design of Ahsta I & II is one of the most economic approaches to build a drop structure for hydro power generation. Due to ist shallow setting the construction of the retaining wall requires only little excavation. The prefabricated draft tubes are self-supporting and simplify the remaining forming work of the retaining wall.

In case such retaining wall is built as a drop structure of an irrigation canal and the canal may require more discharge capabilities during flooding this can be realized by adding one or more separate radial gate bays adjacent to the retaining wall.

4 Summary

The existing reference hydropower plants using the HYDROMATRIX® concepts are a testimony to the flexibility of technology. The module arrangements can be modified to fit into existing structures or to meet the needs of multi-purpose dam projects which want to combine the needs for irrigation with the potential of hydropower generation.

References

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