Recommissioning of the Bieudron powerplant

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Following the description of the rehabilitation of the pressure shaft at Cleuson Dixence, this paper describes the re-commissioning of the Bieudron power station and the adaptation of the Pelton units to the new operating conditions.

The 1269 MW Bieudron hydro plant was built between 1992 and 1998 in the Canton of Valais, Switzerland, and is one of the highest head schemes in the world. It is part of the Cleuson-Dixence development. With a maximum gross head of 1883 m, and three 423 MW Pelton turbines (supplied by Andritz) with an apparent output per pole of 35.7 MVA, the Cleuson-Dixence scheme holds three world records.

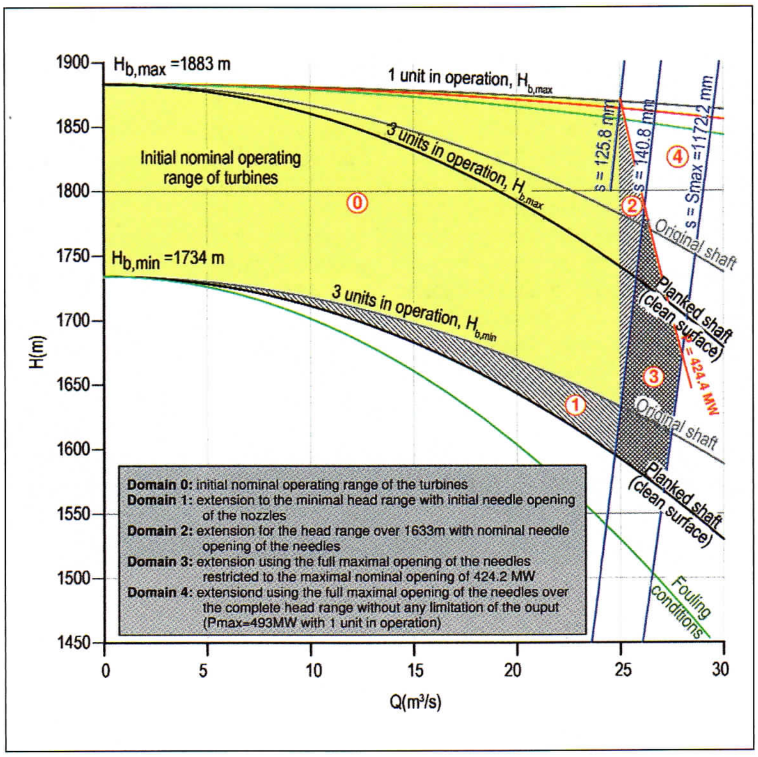
The original commissioning of the plant was in 1998. On 12 December 2000, a tragic accident occurred. The pressure shaft burst under a pressure of 120 bar, at about el. 1234 m, approximately 300 m downstream of Péroua. The accident caused the loss of life of three people, destroyed several houses, and also caused significant environmental damage.

1. Hydraulic considerations

The three Pelton units at the Bieudron powerplant, commissioned in 1998, were designed for the operating conditions shown in Table 1.

The average operation time was of 3100 hours at the time of burst of the pressure shaft in December 2000.

Fig. 1. Initial and new operating range of the Bieudron units.



1.1 Operating range after re-lining of the pressure shaft

The rehabilitation of the pressure shaft, described in the previous article, resulted in additional pressure losses for the entire waterway, which have increased from 101 m to 142 m after the relining to renew the condition, with a total discharge of 75 m^3/s. Incase head losses should increase for any reason, and with a view to adopting a cautious approach, further investigations have been based on a maximum head loss of 200 m. The operating domain of the turbines has thus altered, with a reduction in the output for the nominal discharge of 25 m^3/s. To address this situation, the owner of the scheme wants to keep open the possibility to increase the discharge of the units to take advantage, in the lower head range, of the available opening reserve of the existing nozzles.

With that aim, Andritz Hydro was asked to carry out a study to analyse following main issues:

- Definition of the new gross head range after relining of the pressure shaft.
- Definition of the efficiency characteristics in the lowered net head range. This analysis was based on the full homologous model test performed in the 1990s, as well as on the thermodynamic measurement campaigns carried out on site with three net heads and with the initial pressure shaft.

1.2 Possibilities of increasing the discharge with the existing nozzles

The initial operating range and the several studied extensions after relining are shown in Fig. 1.

1.3 Consequences of the new operating range

For each extension of the operating range, hydraulic and mechanical consequences for the turbine and their environment have been analysed and evaluated in detail.

For the turbines, a special care was taken regarding: performance, cavitation, hydraulic behaviour of the

Table 1: Original operating conditions of the Bieudron Pelton units

Maximal gross head (m)	1883
Maximal net head (m)	1869
	(with one unit in operation)
Nominal discharge (m^3/s)	25
Maximal output (MW)	424.2
Minimal gross head (m)	1734
Minimal net head (m)	1633
	(with three units in operation)
Nominal discharge (m^3/s)	3 × 25

runner with an enlarged jet diameter (domain 3) as well as their mechanical behaviour in overload conditions. For this last point, the original cast runners were studied by the FEM, using the latest tools and processes for transient hydraulic loading conditions. The resulting stress level was kept within the limits given in the initial specifications, and consequently the established inspection intervals were maintained.

The CFD study carried out in the same period indicated that local modifications of the runners were required to adapt them to the increased jet diameter, by increasing the cutout of the buckets. One of the initial runners was modified accordingly, to test them in the new conditions of domain 3, as the operation of the other two original runners and of the reserve runner remains restricted to domain 2. As the maximum nominal output of 424.2 MW is not exceeded, the design of the friction coupling of the runners remained unchanged as regards slipping and short-circuits. It is interesting to note that an extension to domain 4 would probably have required an increase in the friction coefficient by the application of corundum or another product. As the maximum output of the unit was maintained, no special study was required for the turbine shaft or rotor behaviour.

Regarding the waterways, consideration was given to the relined pressure shaft itself, the surge chamber, the upper butterfly valve and the spherical valves before each unit. To redefine new opening and closing laws for the operation of the nozzles and spherical valves, and because of the new conditions associated with the modified geometry of the shaft and new operating conditions, complete transient hydraulic calculations were necessary. The aim was to check that in normal and also exceptional conditions, the overpressure considered during the design would not be exceeded and that the level in the surge tank would remain within specified limits

2. Re-commissioning

Following the accident, Hydro Exploitation was mandated by the owner to take various measures which were required during the standstill period, as well as for the preparation of the re-commissioning, including maintenance activities and, as far as required, upgrading of the existing equipment.

After the rehabilitation of the pressure shaft, complete re-commissioning tests of the hydro plant were carried out between September 2009 and January 2010, under the responsibility of Hydro Exploitation in collaboration with Andritz Hydro and the others equipment suppliers.

2.1 Re-commissioning after nine years out of operation

During the long standstill period, several measures were taken to prevent the equipment from damage which could result from being idle. Working in collaboration, Hydro Exploitation and Andritz Hydro periodically activated the equipment with moving or rotating parts (such as motors, pumps, servomotors, valves); the components were run or moved for a short time, or at least for some strokes. The aim was to lubricate the bearings and bushes, to move the bearings into other standstill positions, and to prevent the dynamically acting seals from sticking. Functional checks were performed at the same time. As technology has been continuously developing, some items of equipment at the plant were replaced by state-of-the-art components. Advantage was also taken of the standstill period to carry out maintenance and corrosion protection work. Several quite large and heavy components were completely dismantled, checked, rectified or partly modified, and then re-assembled. At the end of the standstill period, all three units and their auxiliary equipment were upgraded and maintained in good condition e ready for the re-commissioning.

2.2 Transient calculations and technical limits

The maximum admissible pressure in the pressure shaft was fixed according to the relevant specifications. The minimum pressure limits in the waterways without the additional error margin, in the case of a simultaneous load increase of the three units were defined as follows:

- 10 m WC for the minimal pressure in the gallery and in the diaphragm; and,
- 8 m WC at inlet of the pressure shaft and valve to avoid air suction through the air admission valve.

The transient calculations were done by Power Vision Engineering (of Ecublens, Switzerland) using the SIMSEN softwaredeveloped by the EPFL [Nicolet *et al,* 2010[1]; Nicolet, 2007[2]]. The domain considered was set as follows:

- Gross head range varying form 1883 to 1734 m.
- For runners A, C and D which were not modified, limitation to 25 m^3/s (initial limit) in the net head range from 1868 m to 1633 m; limitation for the needle opening of 140.8 mm for lower net heads resulting from the relining of the pressure shaft (initial domain + domain 1).
- For runner B, modified with an increased bucket cutout width, limitation to 28 m^3/s, maximal output of 424.4 MW and full needle opening of 172.2 mm for net heads lower than 1670 m (domains 0, 1, 2 and 3).

As many as 288 recordings were carried out to check and optimize the operation of the scheme.

2.3 Quick shutdown of the units

Quick shut down tests made it possible to compare measurements with calculations and confirmed the excellent quality of the numerical model for the prediction of pressure amplitudes and the level in the surge tank, with an accuracy of 5 mWC corresponding to 3‰ of the maximal gross head. Only the pressure fluctuations by 0 discharge show some discrepancies (see Fig. 2) because of the non-simultaneous closure effect of the 15 nozzles as well as a difference on the initial condition of pressure due to the penstock head losses overestimation.

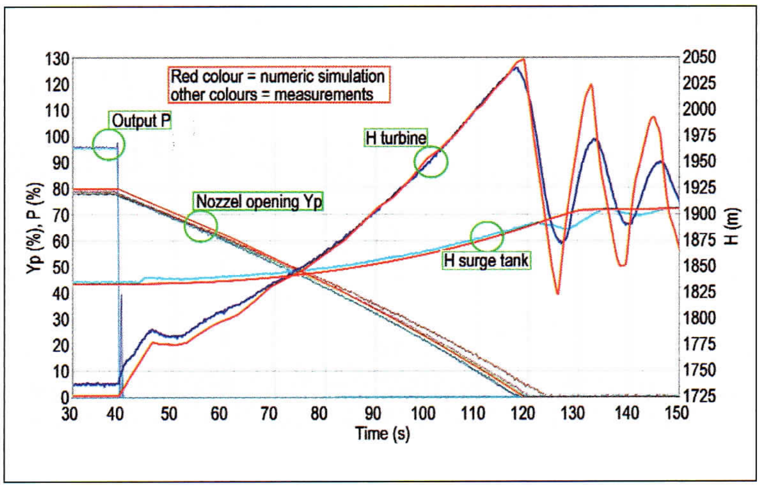


Fig. 2. Emergency shut down of three units by loads of 3 × 400 MW and comparison with calculations. Bieudron Units 1,2 and 3 on 1 December 2009.

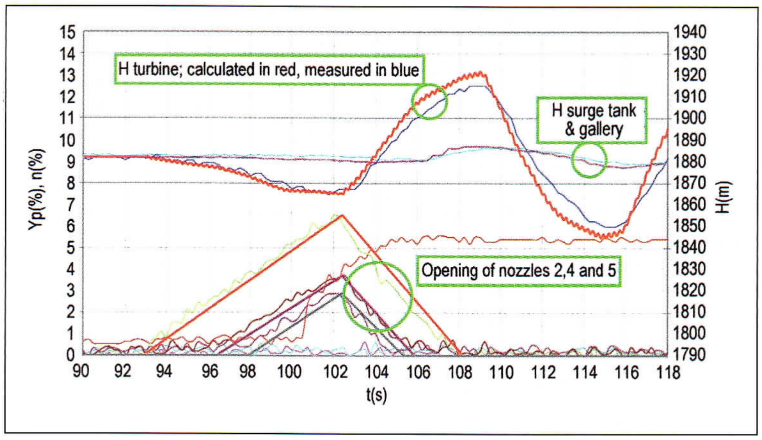


Fig. 3. Starting and closing within a reflection time of 9.5 s and comparison with the numerical simulation. Bieudron Unit 2, on 29 September 2009. Upper level at el. 2362 m.

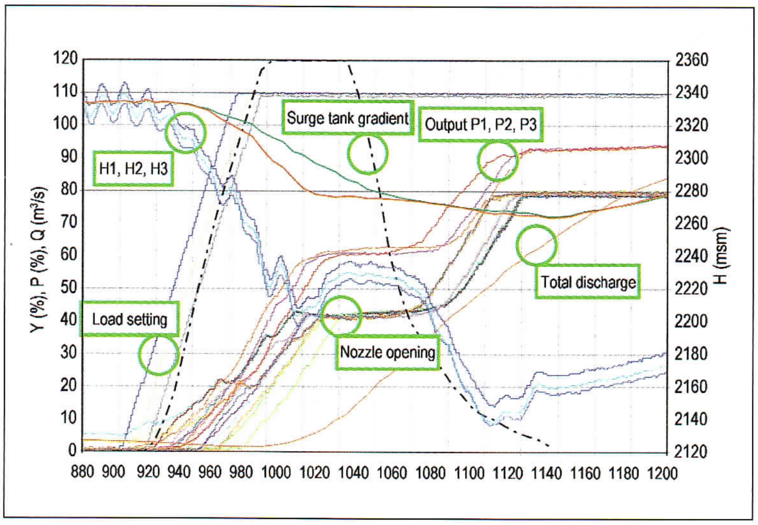
2.4 'Pic de Michaud'

A special case to be considered is the opening of the nozzles followed by an immediate re-closing with the reflection time, so called 'Pic de Michaud'. The starting of the unit induces a depression followed by overpressure. In the event that an emergency shutdown occurs at this moment, the overlapping of both waves leads to an overpressure of 280 mWC, that is, exceeding the maximal limit with a level 15 per cent higher than the maximum gross head.

Even if this case is quite theoretical, as it would involve startup of the three units at exactly the same time, a special process has been implemented to avoid this situation. The trick is to prevent the opening of another nozzle of the unit within 2.3 s after the opening of the previous one. This law has been installed in the control command and tested on site.

Several measurements have been taken by varying the time interval between startup and emergency shutdown and maximal amplitudes were recorded between 23 and 28.5 s. A systematic study was performed with the maximal upper level of 2364 m and three units in operation. Thanks to the opening time of the nozzles, the simulated maximum overpressure is now reached for re-closing after 11.5 s, but remains below the 10 per cent limit. A considerable reduction is thus achieved.

Fig. 4. Simultaneous load of the three units at 3 × 400 MW, surge tank gradient of 0.5 m.s^{-1}, 21 January 2010, upper level at el. 2330.4 m.



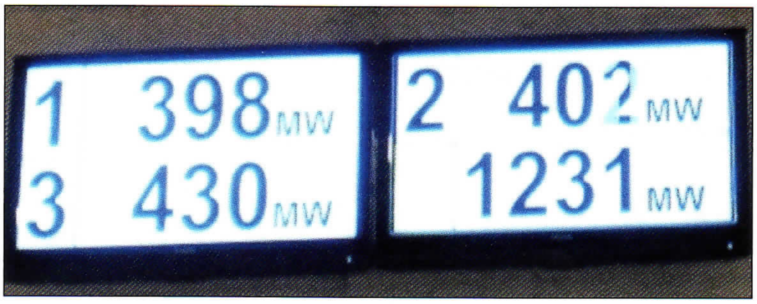


Fig. 5: Impressive figures on the power display board shortly before the full load plant rejection test.

2.5 Simultaneous load of the three units

A reduced level in the surge tank, together with the head losses of the diaphragm, can lead to very low pressure in the upper gallery as a result of simultaneous load of the three units. The head losses in the diaphragm play an important role and have been validated with loading the three units at 1200 MW (see Fig. 4)

A simultaneous start could lead to following problems:

- dewatering of the surge tank;
- depression in the upper gallery; and,
- excessive discharge at the water intake at the dam.

To avoid such a situation, the control command of the units has been programmed as follows:

- a slowdown in the loading of the units depending of the level gradient in the surge tank
- a freeze of the unit loading for levels below 2185.8 m, just above the upper level of the lower surge tank
- an increase in the loading sequence to 236 s (double the time for normal conditions) in case the level measure in the surge tank would not answer.

In these conditions, all safety criteria for the commissioning could be reached.

2.6 Full load plant rejection test

The most impressive highlight of the whole re-commissioning phase was the full load plant rejection test, with all three units running at the nominal maximum output. When the load rejection command was initiated at a total output of 1231 MW, an intensive thunder rumbled through the whole underground powerhouse caused by the enormous energy dissipation in the turbine housings. After 1 minute and 25 seconds, the thunder ceased completely and in the relative quietness that followed, the engineers checked the readings and the graphs to find that everything worked as foreseen.

3. Conclusion and acknowledgements

The re-commissioning of the Cleuson-Dixence hydroelectric scheme and the Bieudron Pelton units was challenging from both the technical and human points of view, combining the know-how and experience gained over decades by engineers from different horizons. Because of the exceptional technical requirements and in view of the accident, a special attention was devoted to safety.This goal, and a high level of confidence, could be achieved thanks to the expertise and positive collaboration of the companies involved, in particular Cleuson-Dixence Construction, Power Vision Engineering, Hydro Exploitation and Andritz Hydro. ◊

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Claude Bissel graduated in Fluid Engineering from the Electricity and Mechanical Engineering school of Nancy, France, in 1991. He worked as a research assistant in hydraulic machinery at EPFL in Lausanne, Switzerland, and then moved to the pump industry and joined Andritz Hydro, Switzerland, in 2001. As Project Manager for hydraulic developments, he was strongly involved in the layout proposals and the hydraulic design of Pelton turbines for new and rehabilitation projects. Since 2008, he has been Head of the Research & Development of Pelton turbines for Andritz Hydro.

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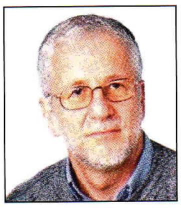

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