Commissioning of Nant de Drance: delayed load rejection and hydraulic short-circuit operation transient tests

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Abstract: The commissioning of the Nant de Drance pumped storage power plant (PSP) was recently completed in the heart of the Swiss Alps. This latter is equipped with six reversible variable speed pump-turbines corresponding to a total power of 900 MW. This highly flexible power plant is designed to provide control power to contribute to the stability of the European Electric Power System. In this context, Hydraulic Short-circuit (HSC) operation, which allows the PSP to operate at the same time a turbine in parallel to a pump to further extend the overall operating range, can be of interest. However, this requires that the plant is capable of operating in this mode, which was not originally foreseen, and to ensure that it does not lead to more critical load cases than those considered in the design stage. During the commissioning, a specific test campaign was realized to test this particular operating mode. This paper presents an overview of site tests to validate the behavior of the plant during delayed load rejections and hydraulic short-circuit operation. In addition, the monitoring of the plant's hydraulic transients through the use of the Hydro-Clone digital twin, which allows real-time comparison of simulation results and measurements, is presented.

1 Introduction

The commissioning of a hydraulic power plant is obviously a key phase to ensure that all systems and components are designed, installed and tested in accordance with the operational and safety requirements of the plant. Among the myriad of points to be tested, hydraulic transients are a particularly important topic because of the associated forces and stresses that impact equipment and structures. It is therefore of upmost importance to verify that the real prototype complies with the assumptions considered during the engineering phase (pipe roughness, localized losses in valves and diaphragms, unit behavior, etc.). For this purpose, the pressures and levels reached during the operation commissioning tests are compared with the values of the projective transient simulations used during the design phase according to the assumptions made for these load cases. This allows to corroborate that these assumptions are adequate, and to perform possible model calibration and related additional verifications, to ensure that in the extreme load cases the operation will have the required safety.

In order to meet these challenges during the commissioning of the Nant de Drance pumped storage plant (PSP), the use of the Hydro-Clone® digital twin, which enables a real-time comparison between the simulations results and the measurements,

proved to be a major asset. This real-time monitoring system allows for a rapid assessment of the power plant's behavior during the commissioning phase, which is a valuable tool for reducing commissioning time by shortening the decision process after each test. In addition, the system also allowed offline simulations to be run in parallel with the ongoing transient tests to simulate various load cases and verify the hypothetical behavior of the plant under different operating conditions.
In this paper, an overview of the specific on-site tests to validate the plant behavior during the delayed load rejections and hydraulic short-circuit (HSC) operation are presented. The methodology used to ensure that the HSC, which was not originally foreseen in the engineering phase of the Nant de Drane PSP, does not lead to more critical load cases than those considered for the design is also briefly outlined.

2 Presentation of Nant de Drance PSP

Nant de Drance is a pumped storage plant owned by ALPIQ (39%), SBB (36%), IWB (15%) and FMV (10%), whose construction began in 2008, equipped with six Francis pump-turbines corresponding to a total power of 900 MW. It is located 600 meters underground, between the Emosson (1930 masl) and Vieux Emosson (2225 masl) reservoirs, and has a storage capacity of 20 GWh. The plant offers flexible power generation, playing a key role in stabilising the Electric Power System throughout Europe and in safeguarding Switzerland’s power supply. The facility consists of two independent adduction systems each supplying three units, placed in a cavern at a level of 1695 masl. On the high pressure side, each of the waterways consists of a 200 m long concrete-lined pressure tunnel, followed by a 425 m high concrete-lined vertical pressure shaft and a 130 m long steel-lined manifold. The low-pressure section of the waterway consists of a steel-lined manifold followed by a concrete-lined headrace tunnel approximately 1’300 m long. Each supply system is designed originally to operate in either pump or turbine mode.

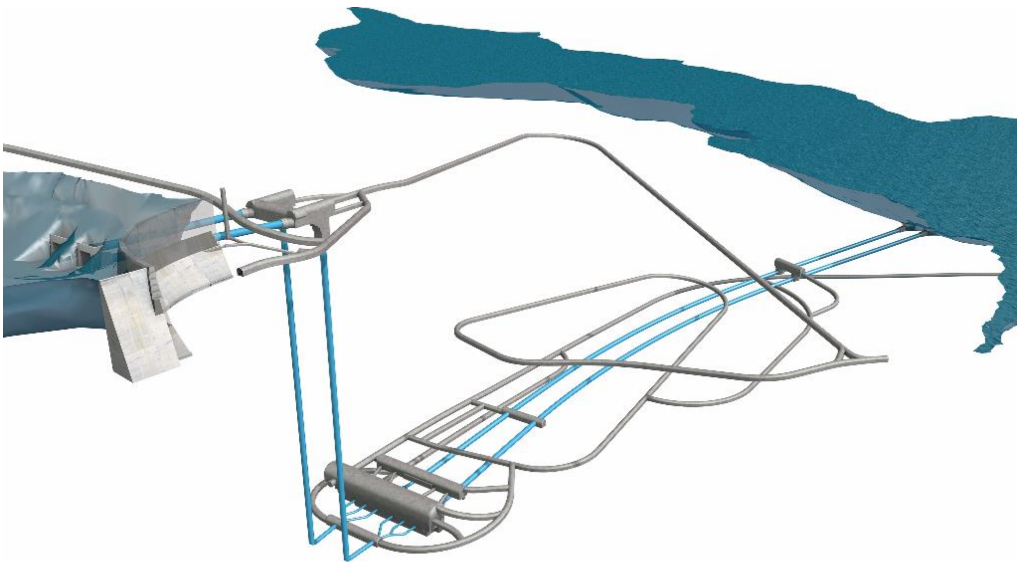


Figure 1. Overview of Nant de Drance pumped storage power plant with the two independent waterways.

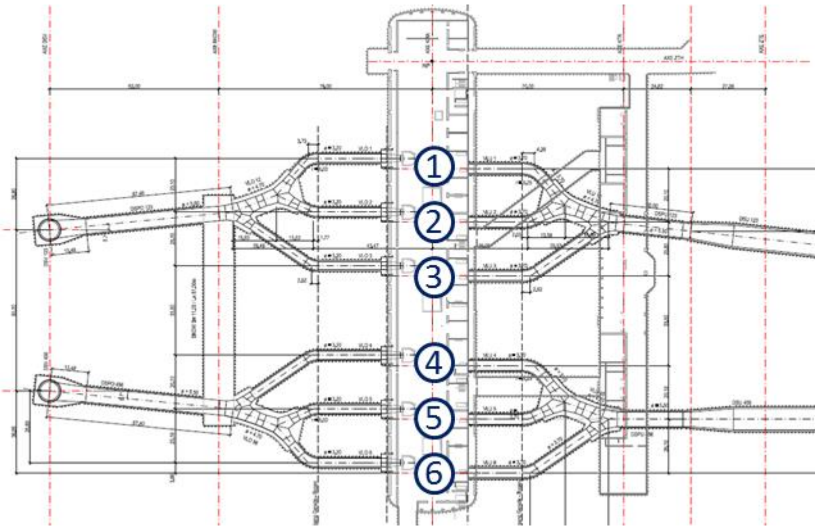


Figure 2. Manifold of units 1-2-3 (top) and units 4-5-6 (bottom) of the Nant de Drance power plant

Due to the important gross head variations and to ensure flexibility in the pumping input power, the plant features 6 high-head single-stage reversible variable speed units, coupled with 175 MVA doubly-fed induction motor-generators (DFIM) with nominal rotational speed of 428.57 min^{-1}. The allowable speed variation of -10.6% and +7% allows the units to operate with a head between 250 and 395 mWC, with a maximum flow per unit of 60 m^3/s in turbine mode and 56 m^3/s in pump mode [1].

3 Real-time monitoring with Hydro-Clone

Hydro-Clone is an innovative Real-Time Simulation Monitoring System (RTSM) based on a well calibrated and validated digital model of the hydropower plant capable of reproducing in real-time any dynamic behavior of the plant based on the boundary conditions measured in situ, i.e. a digital twin [2], [3], [4]. This system allows continuous diagnosis of the health of a hydro power plant (HPP) by digital cloning of the main hydraulic and electrical components of the plant using SIMSEN software. The Hydro-Clone general concept is illustrated in Figure 3a. The system manages the tasks of real-time acquisition and transfer of boundary conditions and measured quantities to the SIMSEN model, as well as data processing and diagnosis of the HPP health status. A custom-built archival storage system and an associated database allow for the display and analysis of previous results. As such, the digital twin can identify unusual events, for which measurements and simulations are no longer in agreement. This can be used to detect a sensor failure, but also potentially more serious events such as unintentional water hammer caused by an improper turbine shutdown sequence. The schematic implementation of the Hydro-Clone in the existing measurement chain of the powerplant is illustrated in Figure 3b with the data workflow. This comprises the data exchanged between the Hydro-Clone computer and the HPP SCADA system at a sampling rate of 10 Hz using the MODBUS TCP protocol, as well as eventual additional signals coming from other programmable logic controllers (PLC) with higher sampling frequency for the pressure signals, dispatched in the powerplant.

(a)

(b)

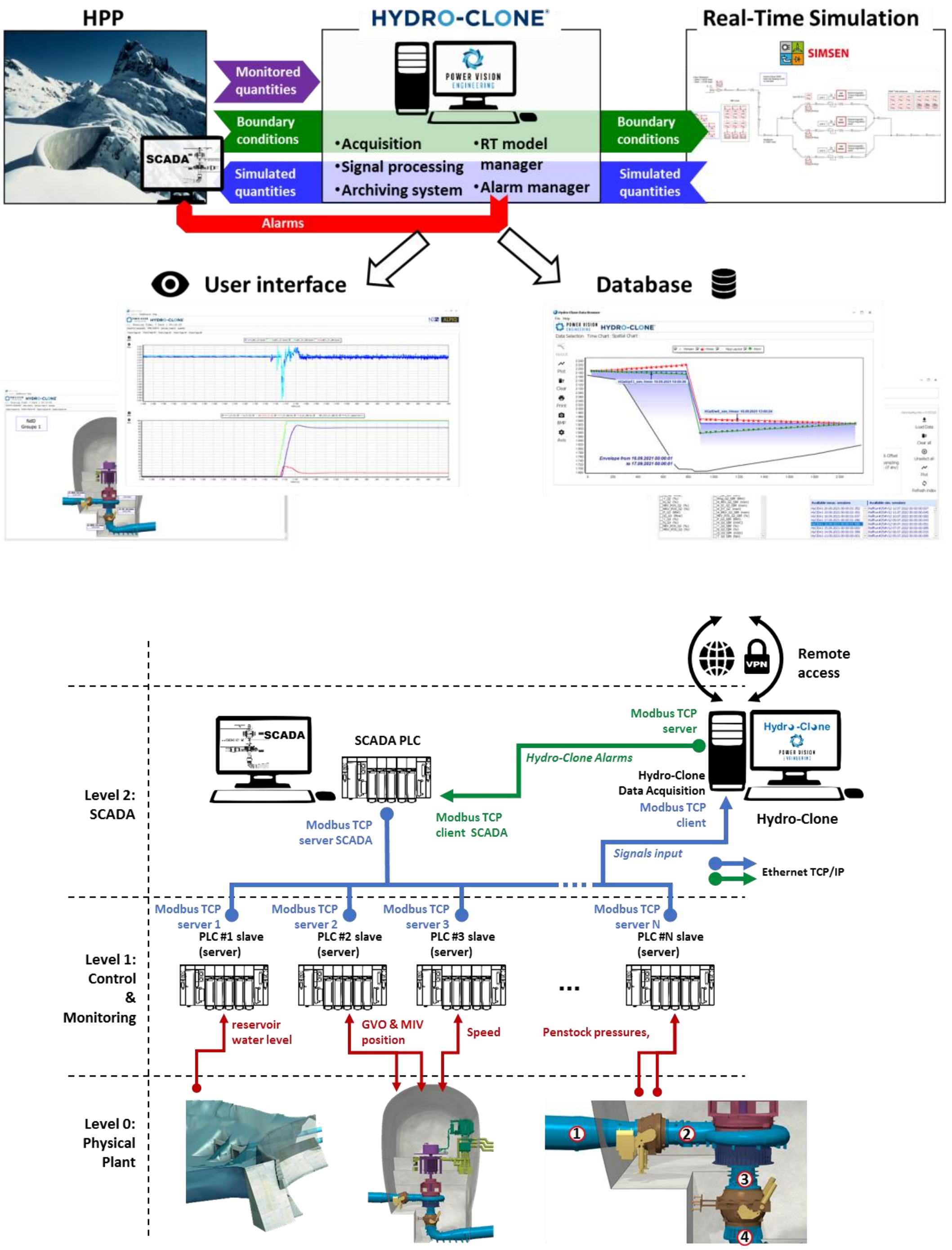


Figure 3. (a) General concept of Hydro-Clone system based on real-time simulation. (b) Schematic diagram of the implementation of the Hydro-Clone in the measurement chain of the power plant and architecture of the Modbus TCP network for data exchange.

The immediate benefit of this digitalization is that it allows the non-measured/non-measurable quantities, such as pressures throughout the water conduits, to be monitored at any time without the physical installation of additional sensor [5]. The analysis and comparison of simulated and measured quantities allows the health status and behavior of all essential system components to be assessed at any time and to estimate the non-measured/non-measurable quantities in the entire system. In

the case of Nant de Drance PSP, a dedicated SIMSEN model was used for each of the independent waterway, as illustrated in Figure 4a. A comparison of the measured and simulated pressure upstream the MIV during the emergency shutdown (ESD) in turbine mode as well as in pump mode from 100% power of a single unit is shown in Figure 4b and Figure 4c. The good agreement between the measurements and the simulation for the overall time evolution of the mean pressure is clearly visible. The measurement feature however some significant high frequency pressure fluctuations induced by the reversible pump-turbine itself which are not simulated by 1D models, as already reported in other pump storage power plant [6], [7].
Figure 5 depicts an overview of the Hydro-Clone user interface implemented for the Nant de Drance PSP. The interface typically features some synoptic diagram showing real-time values of measured and simulated data, as well as some customable time charts showing the evolution of the monitored quantities. In addition, the digital clone provides also the ability to visualize in real time the evolution of the piezometric head in the headrace tunnel and the penstock.

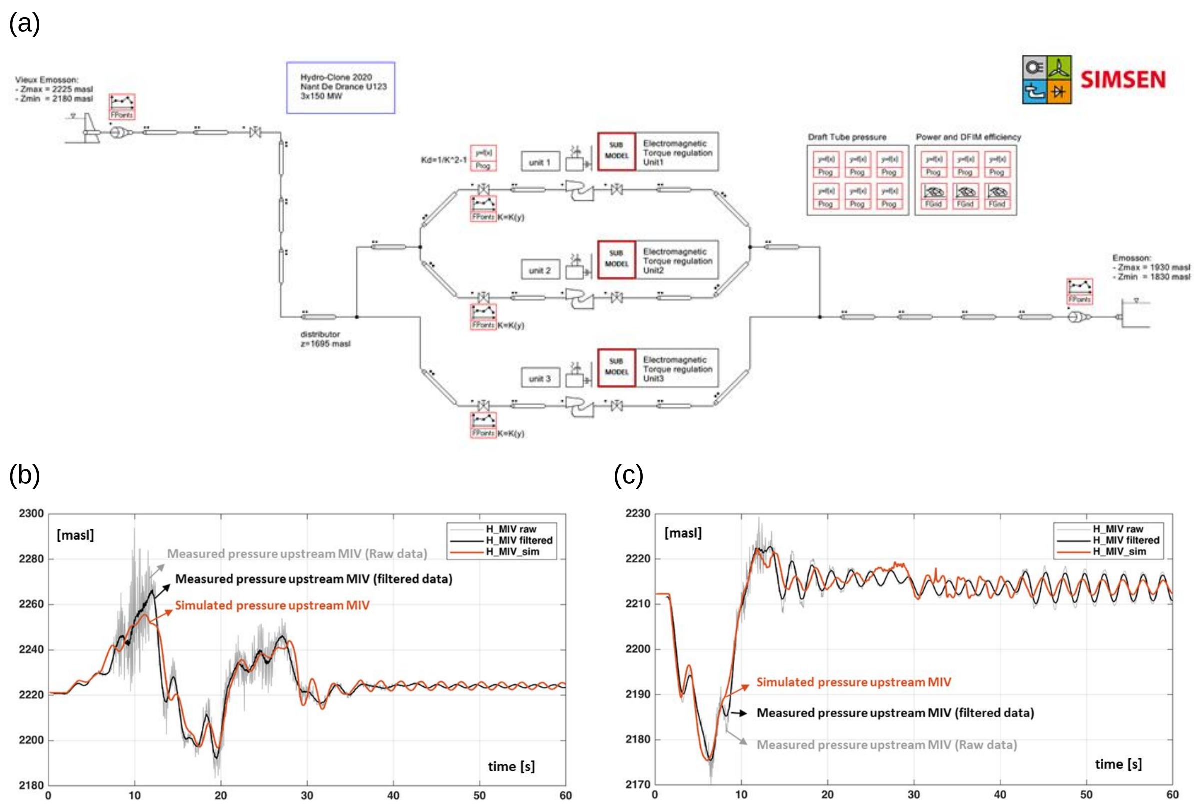
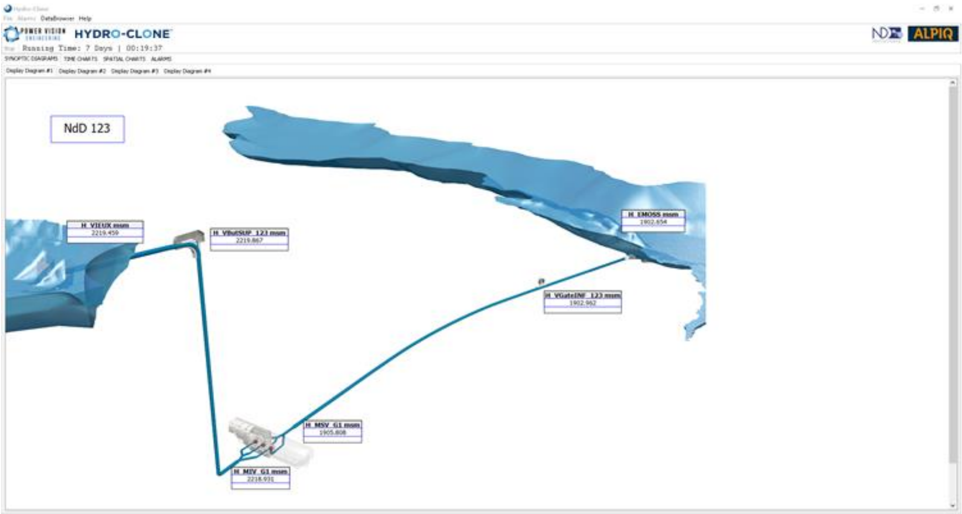


Figure 4. (a) SIMSEN model of the Nant de Drance PSP for the water of units 1-3. Comparison of the measured and simulated pressure upstream the MIV during the emergency shutdown of one unit in turbine mode (b) as well as in pump mode (c) from 100% power.

(a)



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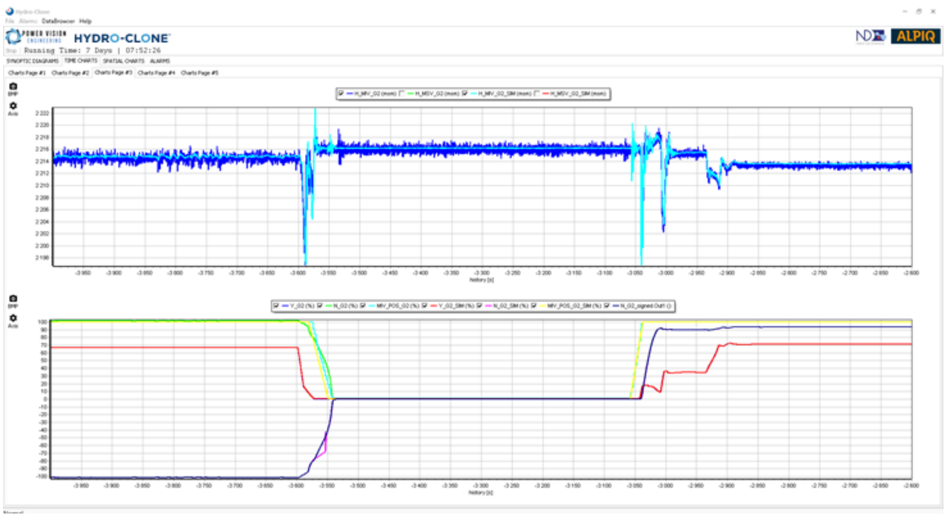


Figure 5. Screenshots of the Hydro-Clone user interface at Nant de Drance. (a) Synoptic diagram showing real-time values of measured and simulated data, (b) time charts showing the evolution of the pressure upstream of the MIV and the parameters of unit 2.

4 Results of commissioning campaigns

4.1 Delayed load rejection transient tests

The delayed load rejection is the situation when one of the unit is tripped with a slight delay as compared to the other units connected with a common manifold. Due to the pronounced S-shape characteristic of high-head reversible pump-turbine, which has already a strong influence on the transients during a standard trip of the unit, the interactions of the adjacent units during an asynchronous load rejection can lead to dramatic increase of the pressure and hydraulic forces experienced in the waterway [8]. In the case of the Nant de Drance with three interconnected pump-turbines per waterway, this risk was identified and well taken into account during the design phase [1]. Based on extensive transients calculations, it was decided to impose the simultaneous closing of the upstream spherical valve (MIV) in case of a load rejection to prevent any shaft torque overload during the eventuality of a delayed load rejection [9].

Due to the high sensitivity of the transients to the pump-turbine trajectory within its 4-quadrants characteristic during an ESD, especially to how deep the unit can make an excursion into the reverse pump region of the S-shape, the delayed load rejection tests for units 1-2-3 and 4-5-6 were scheduled during plant commissioning. However, given the importance of this topic and even though the transient calculations indicated that the units could withstand these tests under any conditions due to the positive effect of the MIV closure, it was decided to perform these tests under conservative head conditions, with prior transient calculations. The purpose of these tests was not to check on site the worst case under the worst conditions, but rather to confirm that the real power plant behaviour was consistent with the simulation. The delayed load rejection tests were therefore performed at a head conditions close the minimum head. The methodology to carry out these tests and to choose the delay to be implemented was the following: first, predictive simulations were performed the day before the test with head conditions in the simulation as close as possible to the intended on-site test. Figure 6 shows a typical example of these projective simulations results, with a systematic variation of the time delay between the load rejection of U1 and the simultaneous trip of U2 & U3. By simulating more than 50 scenarios, it was possible to identify the most critical delay for the maximum pressure in spiral case, respectively for the minimum draft tube pressure. Under the particular test conditions shown in Figure 6, it is thus predicted that a delay of 5.5 s for the trip of unit 1 leads to the worst overpressures in the spiral case of the pump-turbine, while a delay of 3 s results to the lowest pressures in the draft tube. These two delay values were then tested on site, and the behavior of the units was closely monitored using the real-time simulation from Hydro-Clone.

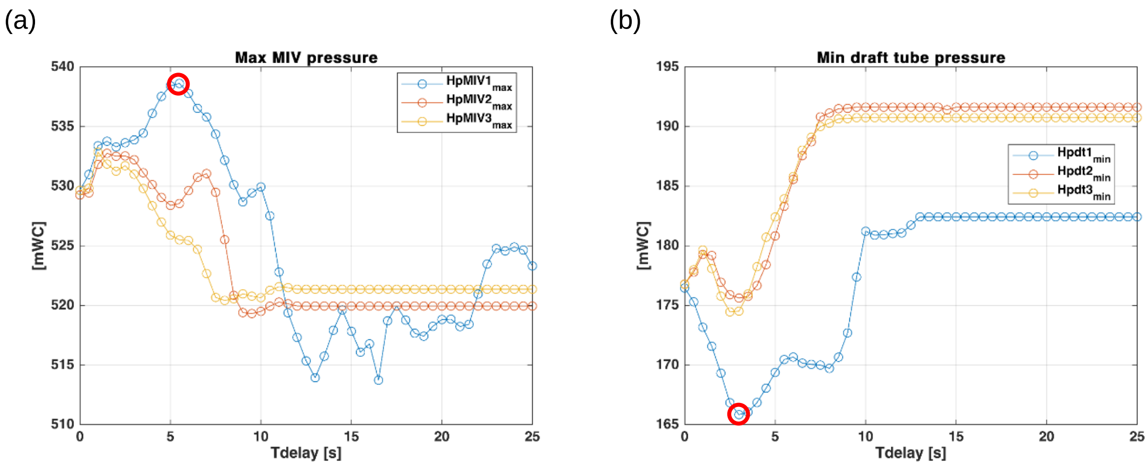


Figure 6. Predictive simulations with the delayed load rejection of U1 showing the time delay influence on the max MIV pressure and min draft tube pressure. (a) Most critical time delay for max spiral case pressure is Tdelay=5.5 s. (b) Most critical time delay for min draft tube pressure is Tdelay=3 s

The comparison between measured and simulated values during the delayed load rejection of U1 with a time delay of 6 s is shown in the Figure 7. As can be observed, the overall qualitative temporal evolution of the quantities compared between the measurements and the simulation shows a very satisfactory agreement, both in terms of overspeed and pressures. This good match between the measurements and the 1D simulation model for delayed charge rejection is an interesting result in itself. Indeed, it has already been reported that the S-shaped region of the 4-quadrant feature can be strongly affected by the presence of cavitation, so that a Thoma number-dependent hill chart model can be necessary to improve the correlation between the measurement and simulation results [10]. In the case of Nant de Drance, the high submergence of the units (135 m when the lower reservoir is at its minimum level) probably prevents the occurrence of such effect during delayed load rejections. It should however be mentioned that if the mean value of the simulated and measured pressure are in good agreement, the extreme values of pressure are too optimistic in the simulation as compared to the measurement, due to high frequency pressure fluctuations induced by the reversible pump-turbine itself which are not taken into account in the 1-D simulation, such as rotor-stator interaction (RSI), broadband fluctuations resulting from stochastic phenomena, flow separations and possible cavitation [6]. This is however a general feature experienced during the ESD of all pump-turbine with a pronounced S-shape 4-quadrant characteristic, as shown in Figure 4b, and not an effect specific to delayed load rejection tests.

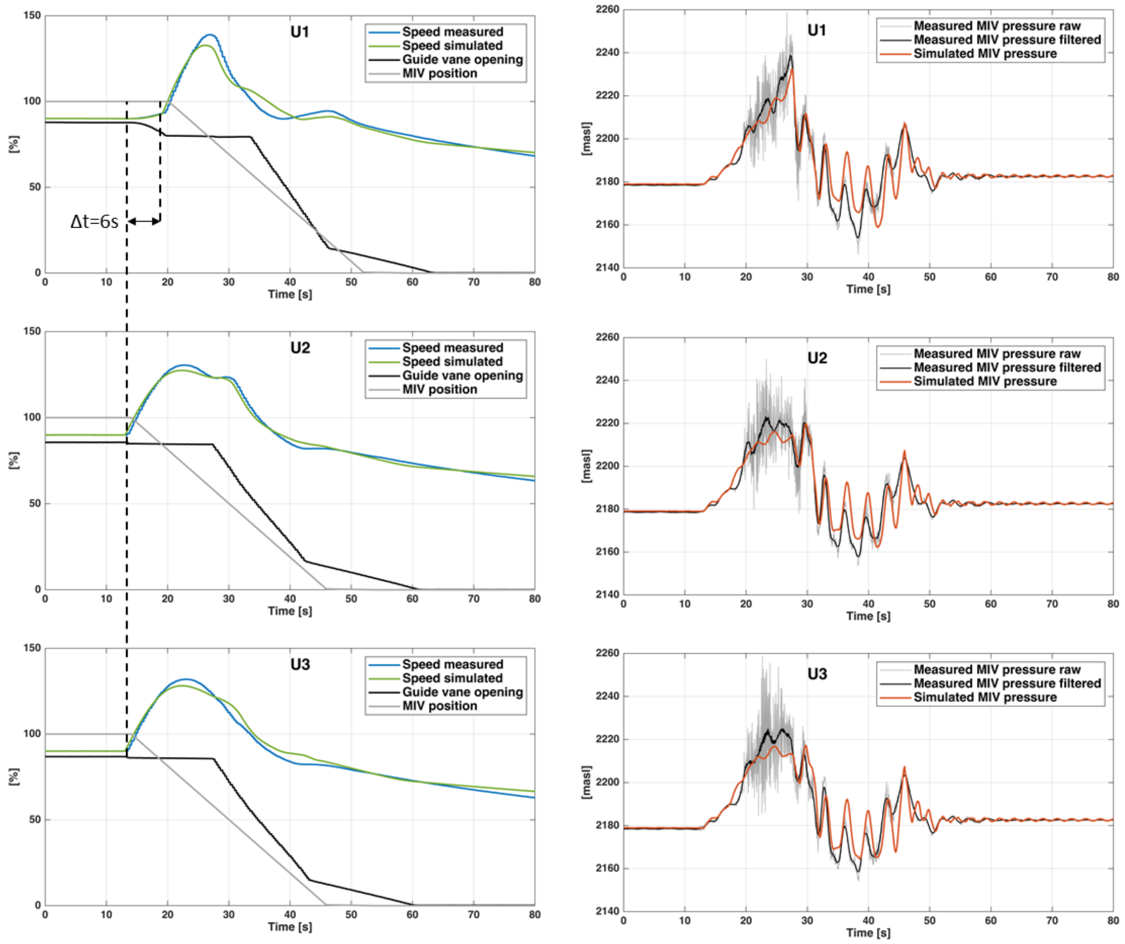


Figure 7. Comparison between measures and simulated values during the delayed load rejection of U1 with a time delay of 6 s. Left: rotational speed and guide vane position, Right: resulting pressure upstream the MIV.

The Table 1 shows the comparison between the predictive simulated values, the simulated values by Hydro-Clone in real time and measurements. As it can be observed, the predictive simulations are in line with the tests results. However, the measured mean values, i.e., the average value around the pressure fluctuations, are about 7m higher and lower for the MIV and draft tube pressures, respectively. This small deviation implies a difference between the simulation and the measurements in the trajectory of the unit's characteristic during the transient (trajectory through the S-shape of the characteristic). These small discrepancies in the trajectory are explained by the slight differences in the evolution of the rotational speeds between the measurement and the simulation visible in the Figure 7. The typical appearance of the trajectory of each unit within its 4-quadrants characteristic is illustrated in the Figure 8. Since the transient pressures are highly dependent on these trajectories and excursions in reverse pump mode, small differences between the theoretical characteristic and the actual behavior can be inferred. Nevertheless, in all cases tested, all quantities remained within the permitted limits, so that the safe operation of the power plant could be validated.

Table 1. Comparison of predictive simulations with real-time Hydro-Clone simulation of delayed load rejection and measured mean extreme values.

Quantity	Time delay	Predictive Simulated value (raw data)	Hydro-Clone real-time Simulated value (raw data)	Extreme mean measured value (average value around pressure fluctuations)
Max MIV pressure	6 s	2232.8 masl	2232.5 masl	2239.0 masl
Min DT pressure	4.3 s	1858.6 masl	1857.3 masl	1850.0 masl

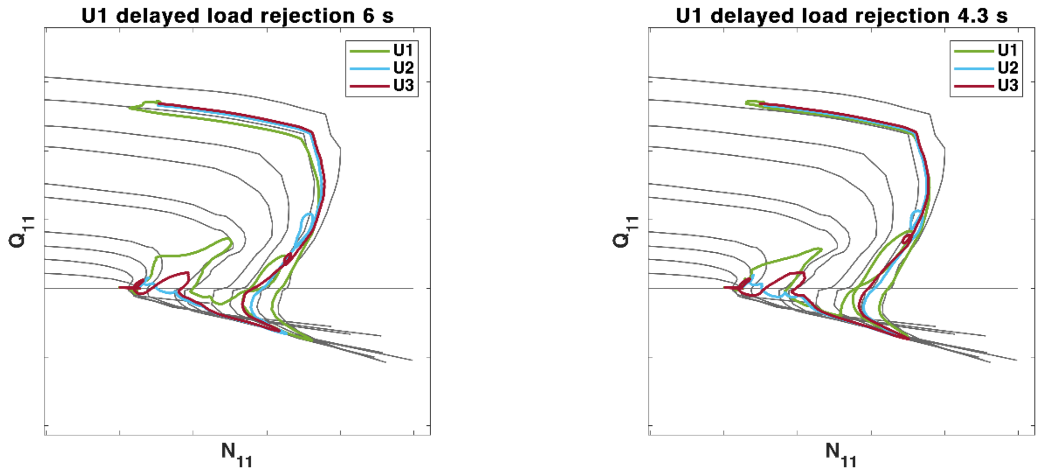


Figure 8. Trajectory in the N11-Q11 characteristic during the delayed load rejection of U1 with t=6 s and t= 4.3 s, as tested on site during the commissioning phase.

4.2 Hydraulic short-circuit operation

The hydraulic short-circuit (HSC) consists in operating at the same time a turbine in parallel to a pump. HSC allows to extend the operating range of the power plant, which can be particularly interesting to provide more ancillary control services in terms of primary and secondary control reserves. However, this requires that the plant is capable of operating in this mode, which was not originally foreseen in the case of Nant de Drance, and to ensure that it does not lead to more critical load cases than those considered in the design stage. Although during HSC the units operate in their regular operating area, so for the individual unit, it is not an extraordinary operating condition, HSC leads to specific load cases so that different studies must be undertaken to obtain a power range without any risk. Following the roadmap described in [11], the following aspects were carefully examined and tested prior to release this mode of operation:

- **Hydraulic transient behavior:** an important point related to the safety of the hydraulic power plant is the verification of the hydraulic transient behavior of the units and the interactions with the hydraulic circuit occurring in case of normal, quick or emergency shutdown and this for normal, exceptional and accidental operating load cases. Using the 1D SIMSEN model, numerous load cases were simulated to identify the potential hydraulic transient issues, such as extreme pressure along the conduits and overspeed.
- **Flow in bifurcation:** in HSC operating mode, the flow paths in the waterways of the power plant are different compared to the pump or turbine modes. CFD studies were therefore carried out to assess the risk of hydraulic instabilities in bifurcations, induced by unfavorable flow patterns, such as recirculation, vortices, flow instabilities, pressure fluctuations, cavitation or vibrations in bifurcation structures. The Figure 9 illustrates the streamlines of one of the simulated condition in the downstream manifold. The CFD study revealed that no significant flow induced pressure fluctuations were to be expected during HSC mode, nor any cavitation in the bifurcations.

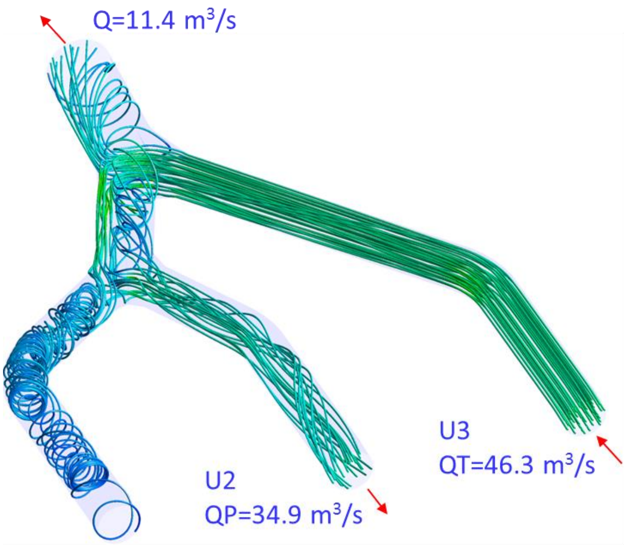


Figure 9. CFD of the flow structure in the bifurcation when operating in HSC mode with 2 units. In this configuration, the U3 is in turbine mode while the U2 is in pump mode.

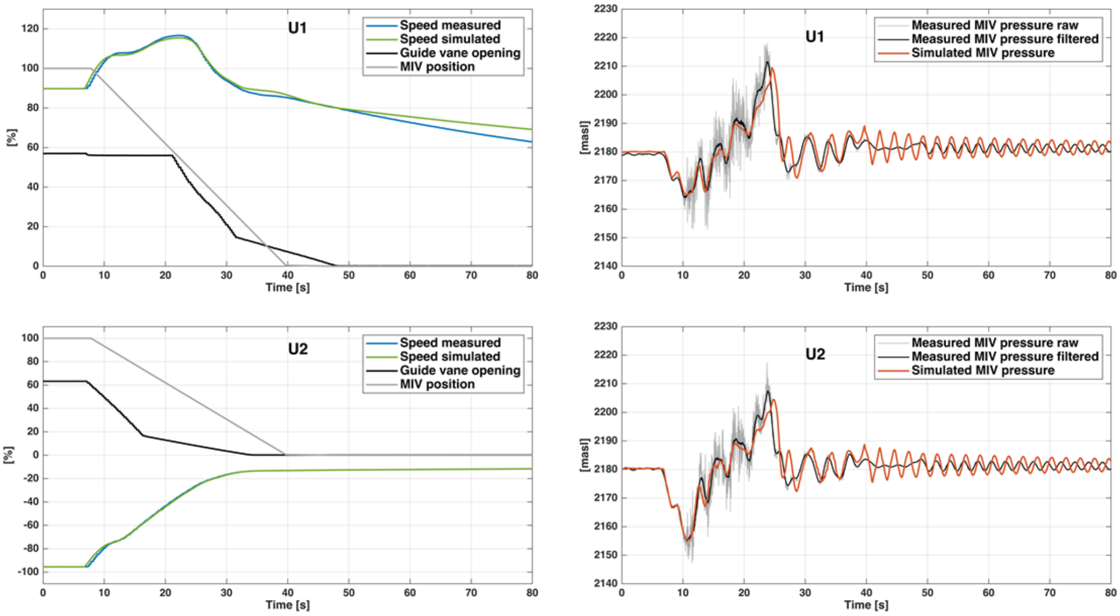
- **Performance of the hydraulic machines:** the possible flow disturbances induced by the junctions could alter the flow pattern at the turbine and/or pump inlet, which could lead to vibrations, cavitation or a reduction in efficiency. These effects were evaluated with site measurements, by comparing a fingerprint of the unit behavior obtained in normal operating mode and a variety of HSC mode by stepwise change of the power of the pump or the turbine.
- **Heating of the water:** as during HSC mode, part of the flow can circulate in a closed loop between the turbine and the pump, it can lead to overheating of the water. This aspect was tested by fully circulating the water at full pump load and high turbine load for a sufficiently long period of time, without exchange of water with the reservoir, and verifying that the process heat could be removed by the units' cooling water circuit.
- **Interference between the units:** the trip of the pump or the turbine can have a negative impact on the adjacent unit such that it is important to verify the stable governing behavior of the remaining unit. The impact of the transient behavior of a hydraulic machine on the other units was investigated by performing some dedicated on site tests, which were closely monitored using Hydro-Clone as detailed hereafter.

To verify the accuracy of the simulations of the SIMSEN 1D model, which was used to predict the transient hydraulic behavior in HSC operating mode, site tests were conducted starting with one unit in turbine mode and one unit in pump mode, while the remaining unit was at rest. As usual, these tests were also monitored and simulated in real-time using the digital twin Hydro-Clone. The Figure 10 shows the transient behavior of the U1 in turbine mode and U2 in pump mode during the simultaneous emergency shutdown of both units. In this case, the turbine was initially operated at 100 MW while the pump was set at its mid power corresponding to 125 MW. As it can be seen by the evolution of measured and simulated rotational speeds and pressures, the behavior of the units is very well reproduced by the simulation. The corresponding N11-Q11 trajectory in the 4-quadrant characteristic of each unit during the ESD is also represented. These tests supported the findings of the hydraulic transient study in HSC, which showed that the hydraulic transients are compatible with plant safety.

In addition to the simultaneous ESD test, it is also important to verify the stable governing behavior of the units in hydraulic short-circuit mode when one of the adjacent unit is tripped. This type of event can potentially lead the remaining unit to enter an unstable operating zone through the following mechanism:

- The trip of one of the unit induces a net head variation on the adjacent unit;
- In case of a turbine ESD, the net head of the adjacent pump is increased during the transient, leading to a decrease of the N11, and the possibility to enter the pump hump zone;
- In case of a pump ESD, the net head of the adjacent turbine is decreased during the transient, leading to an increase of the N11, and the possible excursion in the turbine S-shape region.

(a)



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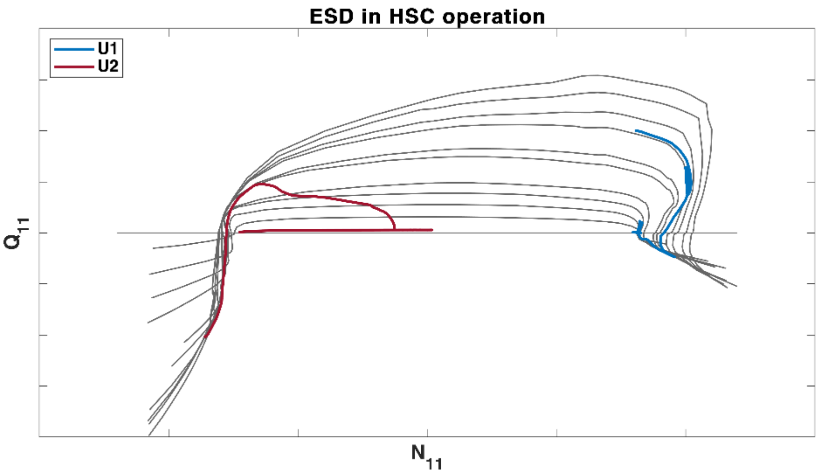

Figure 10. (a) Transient behavior of the U1 in turbine mode and U2 in pump mode during the simultaneous emergency shutdown of both unit, with the rotational speed and guide vane position on the left, and resulting pressure upstream the MIV on the right. (b) Corresponding N11-Q11 trajectory of each unit during the ESD.

To test this particular aspect, a specific test campaign was carried out to verify the interference of the units. The focus was put on the behavior of the unit that remains in operation, when the adjacent unit is tripped with the aim to verify whether the remaining unit can enter the potential unstable region. Figure 11 illustrates the interference test in the case of a trip of U1 in pump mode at mid power, while the U2 is operated in turbine mode at the minimum power. As anticipated, the trip of the pump unit induces a net head variation on the adjacent unit, resulting in an increase of the N11 value of the turbine. However, during this particular test, it can be observed that the turbine remains away from the S-shape region, as shown by the N11-Q11 trajectory of the U2. It is worth mentioning that the behavior of each unit as well as the transient pressures are very accurately predicted by the real time simulation that was used to monitor these tests. This test also allowed to check and validate the proper behavior of the turbine speed controller to keep the unit at the desired operating point after the perturbation.

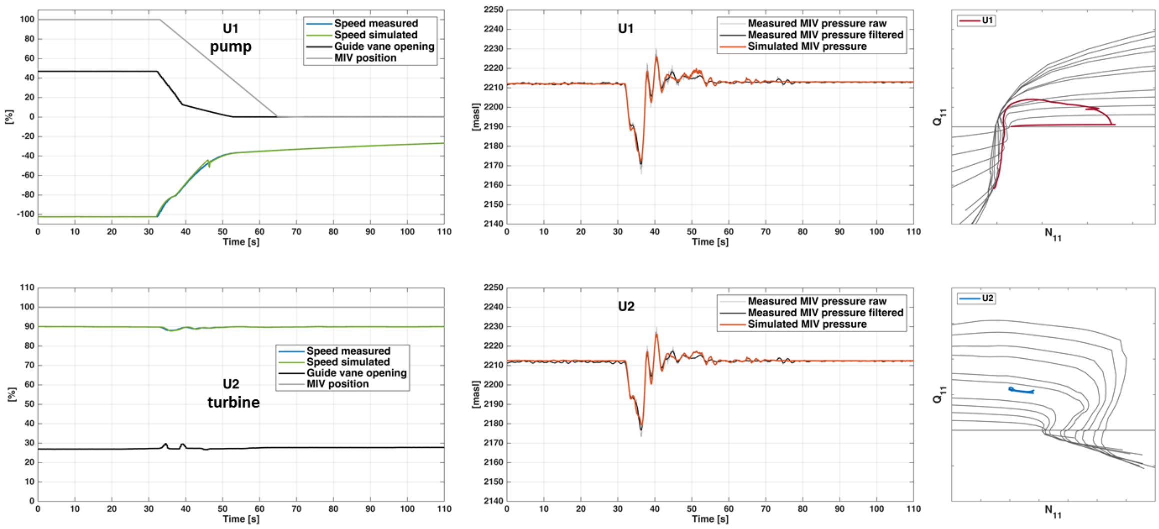

Figure 11. Interference test in hydraulic short-circuit operation, ESD of the U1 in pump mode while the U2 is operated in turbine mode. Left: the rotational speed and guide vane position, middle: measured and simulated pressure upstream MIV, right: N11-Q11 trajectory.

The interference test in hydraulic short-circuit operation when the U1 in turbine mode is tripped while the U2 is operated in pump mode close to the minimum power for the actual head of the test, is represented in the Figure 12. As expected, the trip of the turbine unit induces a net head variation on the adjacent unit in pump mode. As a consequence, the turbine ESD induces an increase of the pump net head, yielding to a decrease of its N11, and the possibility of entering in the pump hump zone. This behavior is all the more pronounced when the initial operating point of the pump is close to the hump zone, i.e. at minimum power. This situation is observed in N11-Q11 trajectory of the pump unit in the Figure 12, where it can be seen that the pump operating point makes a large excursion along the Q11 axis, which is expected when entering the pump's hump zone. In this particular test however, the unit remains outside the limit of the pump dissipation quadrant since the discharge does not become positive, which was precisely the goal of this test that was also simulated in advance. Altogether, during all the tested configuration, the pump showed a good and stable governing behavior during the interference tests.

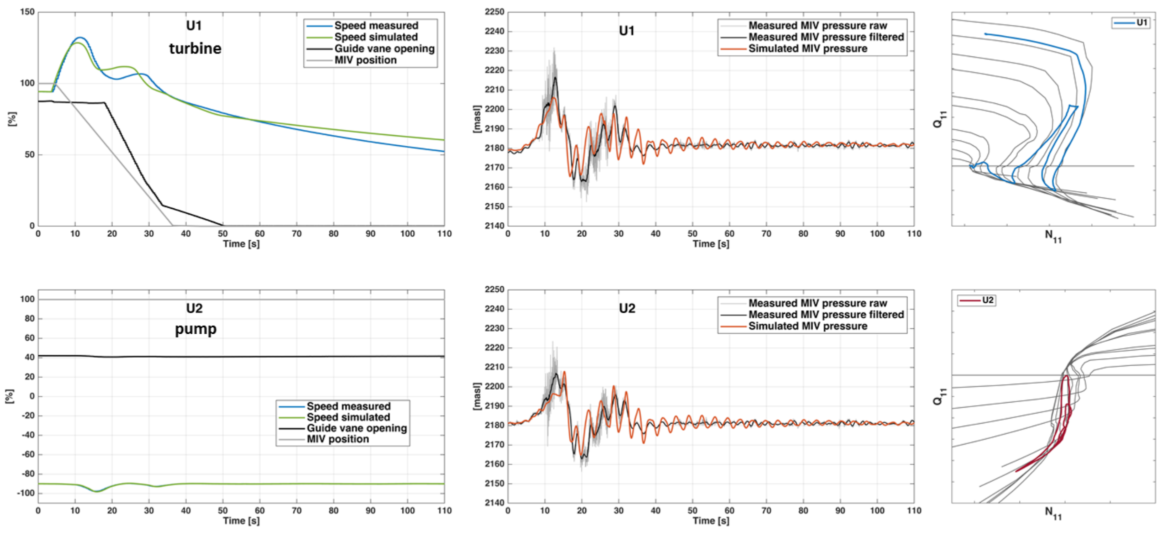

Figure 12. Interference test in hydraulic short-circuit operation, ESD of the U1 in turbine mode while the U2 is operated in pump mode. Left: the rotational speed and guide vane position, middle: measured and simulated pressure upstream MIV, right: N11-Q11 trajectory.

5 Conclusions

The commissioning of the 900 MW Nant de Drance power plant was successfully completed this year, allowing to start commercial operation on July 1st, 2022. The behavior of six variable speed reversible pump-turbines was thoroughly tested, as well as their interaction in the different operating modes. In particular, delayed load rejections have been tested and revealed that the overall time evolution of the quantities compared between measurements and simulation shows a very satisfactory agreement, both in terms of overspeed and pressures. In addition, careful research and testing was conducted to release the hydraulic short-circuit mode of operation, which was not originally planned. The HSC mode is a great asset to further increase the flexibility of the plant by expanding the achievable power range. All these tests validated the compliance level of the extreme values with the admissible limits during the different operating modes thereby ensuring the safety of equipment and people during the new operation of the plant.
The use of the Hydro-Clone real-time simulation system during the commissioning phase of the Nant de Drance power plant has proven to be an effective way to evaluate the hydraulic transients and thus ensure the safety of the plant during hydraulic transient tests. Thanks to the straightforward and direct comparison between the results obtained with the simulation model and the on-site measurements, the digital twin proved to be an efficient way to reduce the commissioning time by shortening the decision process after each test.

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Stephan Kolb graduated in 1996 with a MSc degree in Mechanical Engineering at the University of Stuttgart, Germany. Afterwards, he joined the Institute of Fluid Mechanics and Hydraulic Machinery of the same University and worked in research projects. In 2001, he joined Andritz Hydro and worked in the Governor and Automation Department in Ravensburg, Germany. In 2007, he took the role as the deputy project manager for the new construction of a Run of River Powerplant and later was appointed as the Head of Mechanical Engineering Department for the Atdorf Pumped Storage Project (1.400 MW) at Schluchseewerk AG. From 2014 to 2020 he worked for AF-Consult Switzerland Ltd in the Hydropower Unit as Project Manager Electromechanic where he was responsible for the electromechanical equipment of the Nant de Drance Project. In 2020 Mr. Kolb joined Alpiq AG to become a Senior Mechanical Engineer in the Electromechanical Engineering department.

Jean-Daniel Dayer graduated in Electrical Engineering from the University of Applied Science, in Yverdon-les-Bains, Western Switzerland. He worked for more than 20 years as system and project engineer at Grande Dixence and other power plants in the canton of Valais. He contributed to the initial implementation of Bieudron in the period 1994 to 1998 as design engineer of the control and supervisory systems. He then joined HYDRO Exploitation SA as Project Manager. He is currently working in hydraulic support at ALPIQ AG, Business Division Energy Switzerland.

Eric Vuignier graduated in electrical engineering from the ETHZ, the Swiss Federal Institute of Technology in Zurich, Switzerland, in 1987. He joined ABB as project manager for the control systems of the HVDC PIE project in California. In 1996 he joined the FMV company where he was group manager for generator and project manager for the dispatching center in Chippis. In 2003, he was at the head of the Automation & Control unit of Hydro Exploitation SA in Sion. In 2011, he joined Alpiq as head of electromechanical support for the hydraulic assets of the Alpiq group. In 2012 he joined the technical commission of the NDD project and since 2018 he is responsible for the groups for erection and commissioning on site for the NDD project and member of the project management.

Dr Yvan Michellod graduated from the EPFL, the Swiss Federal Institute of Technology in Lausanne, Switzerland, and received his master's degree in electrical engineering in 2004. Then, he participated to the Differential-Delay-Line European Spatial Observatory project in relation to the Exoplanet survey, while realizing his PhD at the Automatic Control Laboratory of the same school (PhD 2009). He also received his EMBA degree from the Lausanne Business School in 2015. Since 2009, he is working for HYDRO Exploitation SA in the field of hydroelectric generators and motors, as well as voltage regulation. He is also regularly in charge of refurbished or new hydro power-plant commissioning activities, including, since 2018, the commissioning of Nant de Drance.

Alain Sauthier graduated from the EPFL, the Swiss Federal Institute of Technology in Lausanne, Switzerland, and received his master's degree in mechanical engineering in 1993. He then worked as a development engineer at ABB Kraftwerke AG and ALSTOM Power Ltd, as an operating engineer at Energie Ouest Suisse SA and Grande Dixence SA, as head of the mechanical unit at HYDRO Exploitation SA and finally as head of operations at Electricité d'Emosson SA. He then joined the Nant de Drance project in 2013 as deputy director, responsible for the equipment of the plant under construction. Since 2021, he is senior asset manager at Alpiq AG and managing director of Nant de Drance SA.