# French pilot virtual tests

## Deliverable DB4.2

**Real-time pollution-based control of urban drainage and sanitation systems for protection of receiving waters**

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| Document Title: **LIFE RUBIES DB4.2 – French pilot virtual tests** |
| **Partner responsible: LYRE** |

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| Authors : **LYRE, SUEZ SMART SOLUTION** | Date: **July 2026** |

| Modifications (dates) |
|---|
| October 2023: First version |
| July 2026 : Addition of elements regarding pre-production tests - last validated and FINAL version |
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General

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# 1 Introduction

**Sub-action B.4-3: Virtual testing (3S, LYRE)**

Prior to run the RTC solution on the real field, it is required to perform some virtual test. This sub-action will lead to the configuration and adjustment of the RTC algorithm.

The adjustment will mainly concern maximum levels in pipes and storage tanks for CSO pollution control while keeping some spare capacity for flooding control emergency, valves and pumps thresholds and MV curve interval control horizon.

Deliverables DB1.1, DB2.1, DB2.2 and DB4.1 describe the strategies implemented to guarantee protection again flood and CSO while considering for rainfall forecast uncertainties, hydraulics and quality model uncertainties, data measurement or communication failure, system infrastructure failure. They also describe strategy to switch from a quality based control (pollutant flux based) to hydraulics-based (volume based) control to guarantee that quality-based control (more difficult to anticipate) cannot lead to worst CSO pollutant mass spill than the hydraulics-based RTC (see DB4.1).

The goals of these tests are to control that they are correctly applied and fit the objectives. The tests will be performed using historical radar and short term forecast data of at least 6 months. This period will allow to guarantee that the LIFE RUBIES solution: 1) is a no risky strategy regarding flooding and CSO (no increase compared to baseline), and 2) brings a certain amount of benefits in terms of CSO pollutant mass saving compared to this baseline.

The diagram below reminds the operating infrastructure of the complete system deployed at MEL.

The first tests consist in checking that each communication link is operational and providing the appropriate data. Then, the methodology consists in testing sets of modules, whose size will increase until the complete loop is reached.

Some of these tests involve operational modules directly and will therefore be detailed in the DB4.3 deliverable, while others can be tested in a virtual or offline environment. As this deliverable is dedicated to virtual testing, it will focus on this part.

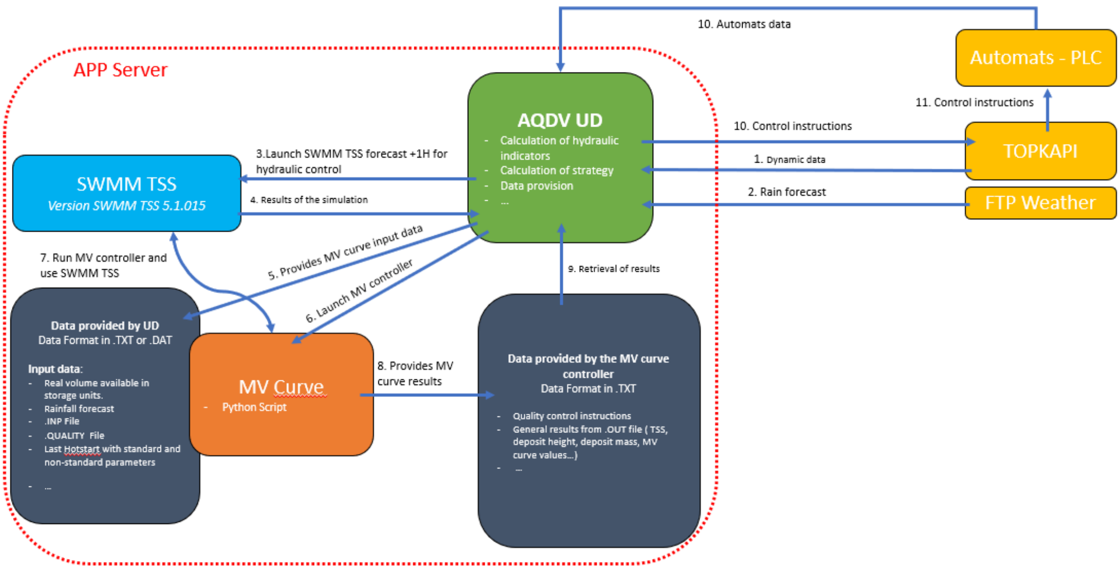



**Figure 1 Relational model of the operating infrastructure**



General

# 2 Online unit testing of AQUADVANCED® – Topkapi – Local site chain

Just after AQUADVANCED® UD deployment, Suez Smart Solutions and MEL checked all connectors between AQUADVANCED® and MEL's existing infrastructure, as shown below :

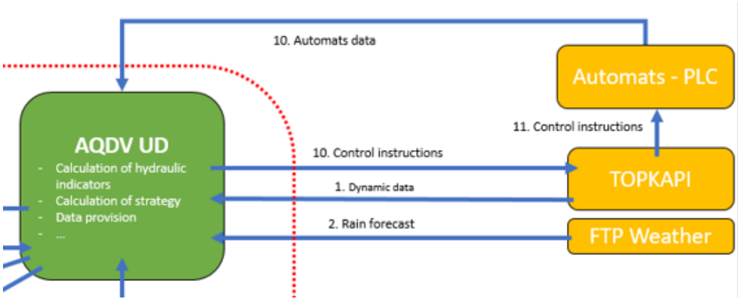



**Figure 2 : Zoom on "field" connectors linked with AQUADVANCED®**

Those operational tests were directly carried on the operation environment so as to validate data communication between all concerned modules:

- Exchange between AQUADVANCED® and the SCADA (Topkapi) => the purpose was to validate the possibility for AQUADVANCED® to read and to write data with the SCADA (and PLCs connected with the SCADA) :

| | |
|---|---|
| Numéro de consigne Vanne VS1 | 2252 |
| Vanne VS1 - Autorisation GD (opérateur) | Oui |
| Consigne / scénario - AQDV pour Vanne VS1 - mode 101 | 0 |
| Consigne / scénario - AQDV pour Vanne VS1 - mode 102 | 5 |
| Consigne / scénario - AQDV pour Vanne VS1 - mode 103 | 17 |
| Vanne VS1 - Disponibilité pour faire la Gestion Dynamique | Oui |
| Vanne VS1 - Fonctionnement demandé par AQDV | 101 |
| | |
| | |
| API ---> TPK ---> TPK | |
| Vanne VS1 - Retour mode de fonctionnement depuis API | 101 |
| Vanne VS1 - Alarme Gestion Dynamique impossible | Non |

**Figure 3 : Topkapi table with examples of AQUADVANCED® exchanged variables**

- Exchange between AQUADVANCED® and the subscribed weather data provider => the purpose was to validate that all radar data are correctly copied from Météo France FTP server to MEL AQUADVANCED® server :

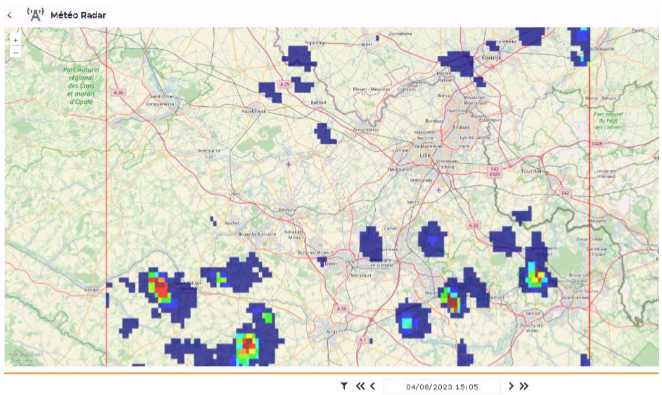



**Figure 4 : Example of radar data collected from Météo France FTP Server**

All technical specifications of those connectors are already described in deliverables related to the task A (chapters linked with the IT architecture) and all associated and other operational tests will also be described in the coming deliverables « DB4.3 French pilot operational tests ».

# 3 Virtual test algorithm

## 3.1 Simplification and optimization of hydraulic model

As a reminder, the process requires the use of a hydraulic and quality model, called SWMM TSS (blue module of the operating infrastructure), to predict the behavior of the network over the coming hours. To be compatible with real-time constraints, the SWMM TSS model must be able to simulate 24 hours of predictions in less than 5 minutes.

As described in deliverable A1.3, the model has undergone an initial simplification. However, as the TSS quality module took longer to calculate than the hydraulic model, it was necessary to carry out a further simplification phase.

The TSS simulation duration for 1 day took about 45 minutes or more in a system with small processor. The table below gives a quick view of the impact of the new simplification phase. The second simplification was further worked on to achieve the 5minutes time. This is explained in subsequent sections.

**Table 1 Last hydraulic model simplification process**

| Simplifications | Simulation duration |
|---|---|
| Initial model with first simplification | 45min |
| Second simplification | 30 min |
| Third simplification | 15 min |
| Further work on third simplification | 5 min |

When a model encounters computational instabilities, this leads to longer calculation times. Most instability are from small pipe/conduits so to achieve the adequate simplification, we merged small connected pipes. Thereby reducing the nodes by 13 percent, i.e., 3390 nodes reduced to 2936 and links from links from 3589 to 3135.

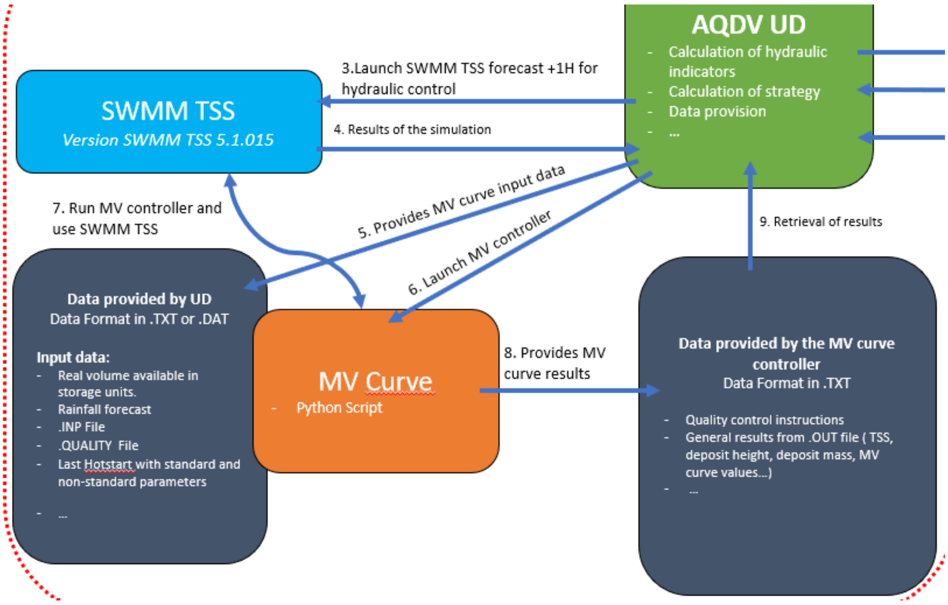
We also modified the calculation parameters to optimize them, while ensuring that these modifications did not lead to instabilities or calibration degradation.

Finally, as the simplification work had been carried out on our personal computers, the last step was to test the model's performance on the MEL server to ensure that the specifications were still met. This was indeed the case.

## 3.2 MV Curve algorithm loop

The figure below shows the relationship between the quality controller (orange module) and AQUADVANCED® UD (green module).

This phase of virtual testing involved testing the loop between the MV curve controller and AQUADVANCED® in an off-line environment.

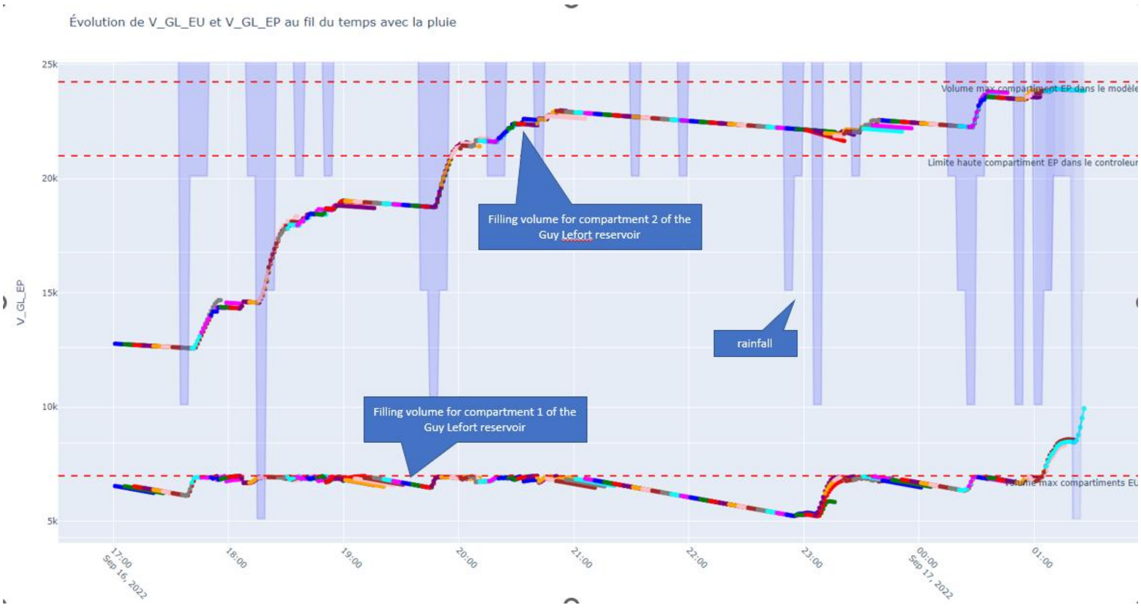



Before being connected to the real-time modules of the system (links number 5, 6, 9), temporary scripts were created to simulate the exchange of data and setpoints between AQUADVANCED® UD and the controller. This makes it possible to test the module offline, without any impact on the real network. These scripts involve:

- create rainfall forecast files in the appropriate format and data depth from historical data (link 5)
- Create the other input data required by the controller, normally supplied by AQUADVANCED® (initial conditions, latest version of SWMM TSS model, etc.) (link 5).
- Create a script capable of launching the quality controller every 5 minutes with new input data, as AQUADVANCED® will do in real time (link 6).

A virtual reality hydraulic model was also created to apply the control rules provided by the controller. This approach makes it possible to analyze the results obtained and ensure its performance.

The figure below illustrates an example of virtual reality results during a 2-days rainfall events. Guy Lefort's two compartments can be seen filling up over time, with the different colors representing successive simulations carried out every 5 minutes. Data continuity between simulations is validated. This exercise is based on several typical historical rainfall events that have occurred over the past 2 years.




At this stage, all tests have been carried out on a reduced hydraulic and quality model, centered on the Guy Lefort reservoir, to guarantee rapid calculations and to iterate modifications more efficiently. Once the controller code and the quality calibration of the overall MEL model has been finalized, we will be able to use virtual reality on the full perimeter.

Finally, a temporary version of the controller was deployed on the MEL server to ensure that it ran correctly (independently of the other modules). The missing Python extensions have been installed, and the controller is now ready to run on the production server.

# 4 Virtual Test of the complete Life RUBIES Loop

Following the successful testing of the individual system modules in a virtual environment, the final step was to test the complete control loop in a pre-production environment.

The objectives of this phase were to:

- validate the overall communication mechanism between the Quality Controller and AQUADVANCED;
- configure and test new AQUADVANCED views dedicated to quality control;
- monitor calculation stability and execution times.

## 4.1 Consistency Checks

The purpose of these tests was to verify the ability of the Quality Controller and AQUADVANCED to exchange data reliably in both directions.

The main objectives of this verification phase were to ensure that:

- the values transmitted from the Quality Controller to AQUADVANCED are correct, including expected ranges and units;
- the values transmitted from AQUADVANCED to the Quality Controller are correct, including expected ranges and units;
- data are received at the appropriate time to enable calculations and control actions to be performed when required.

## 4.2 Monitoring of calculation stability and execution time

The purpose of these tests was to verify that:

- calculations remain stable and operate continuously, 24 hours a day;
- execution times are compatible with the requirements of real-time control.

The initial objective was to provide updated control rules every five minutes. However, testing showed that this target could not be achieved due to the computation time required by the quality model.

The Quality Controller must calculate 24-hour hydraulic and water quality forecasts. As the model is relatively large, computation times are close to ten minutes. As a result, the following decisions were made:

- update the quality control instructions every ten minutes, while maintaining the hydraulic control loop at a five-minute update frequency running in parallel;
- optimise the calculation loop to reduce execution times;
- simplify the virtual reality simulation so that only the functions required for online real-time control are retained. All other processing stages can be performed offline for analysis purposes.

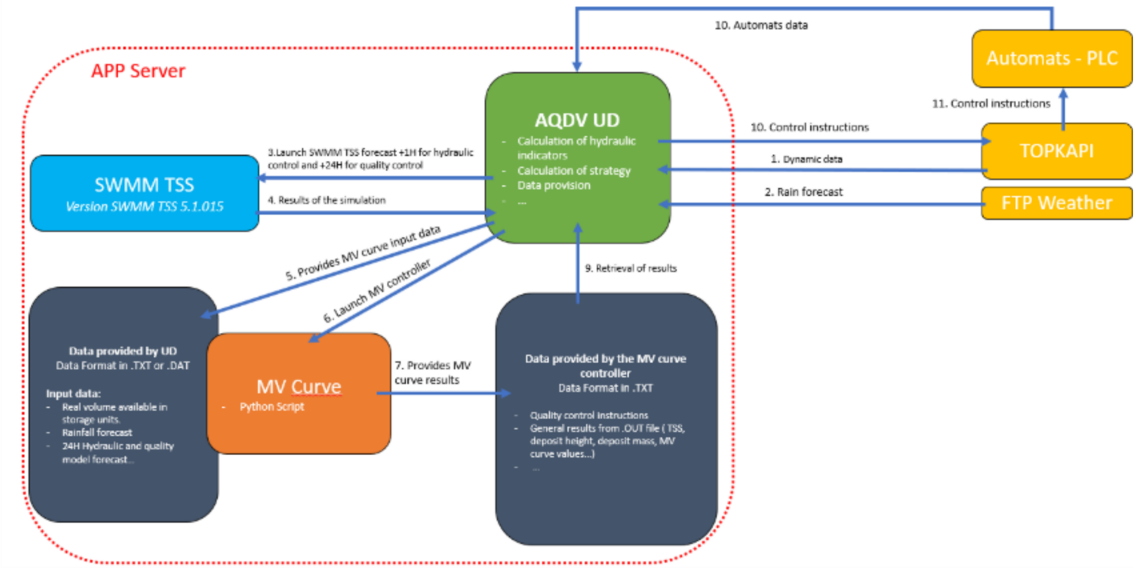



**Figure 7: New architecture schema of the communication loop**

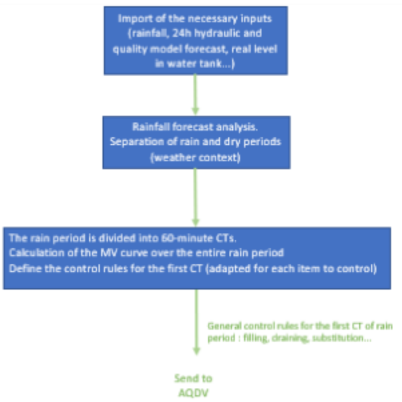



**Figure 8 : New calculation process of the real-time quality controller**

## 4.3 Configuration of Monitoring Views

To facilitate the checks described above, several monitoring views were created to visualise and analyse the results.

One view was designated as the official quality control dashboard available to all operators. In addition, a number of more advanced views were developed within the workspace to allow detailed analysis, comparison and troubleshooting when required. These views are intended for expert users.

4.2.1 Official quality overview

The deployment of the Quality Controller in the pre-production environment also provided an opportunity to configure and test a new view dedicated to quality control monitoring.

This view allows users to visualise:

- the MV curve associated with the most recent rainfall event;
- historical control rules;
- future control rules predicted by the Quality Controller.

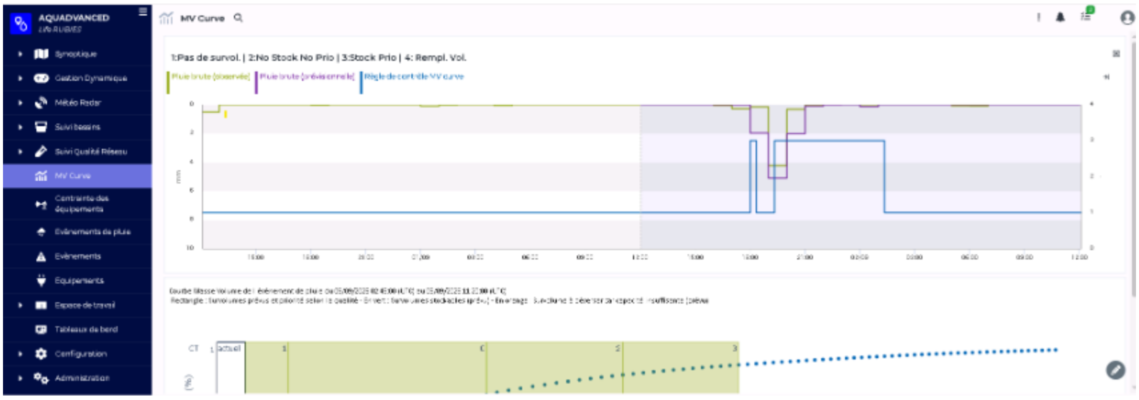



**Figure 5- Example of MV curve views**

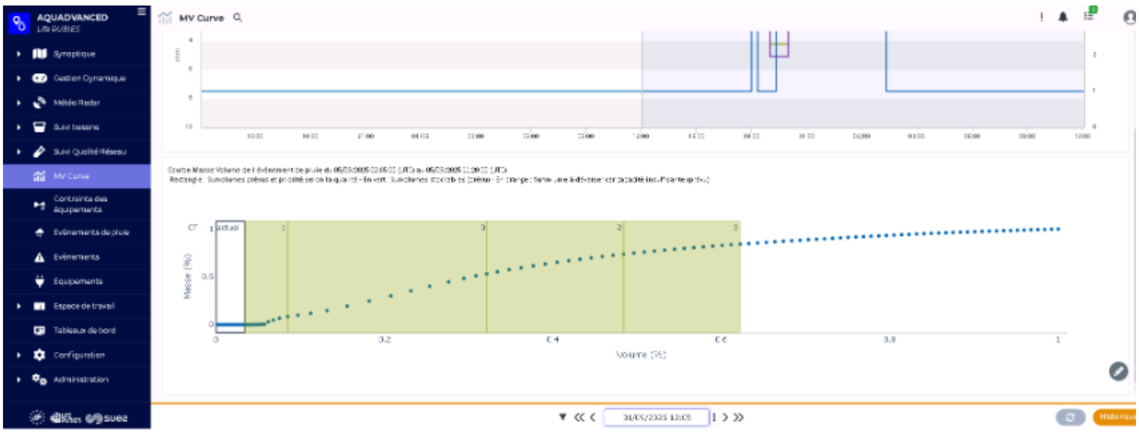



**Figure 6: Example of MV curve views**

### 4.2.2 Advanced quality views

Several advanced views were implemented within the workspace to support detailed monitoring of the Quality Controller outputs. These views make it possible to:

- compare quality control rules with hydraulic control rules;
- investigate the parameters leading to inconsistent or unexpected control rules in order to understand their causes and, where necessary, correct the code.


**Figure 5 : Extract from the advanced monitoring view used for the detailed analysis of individual rainfall events and the behaviour of the Quality Controller.**

AQUADVANCED also makes it possible to replay historical situations and rerun simulations using past data. This capability allows verification that code modifications produce results consistent with expectations.

This iterative process was carried out over several months, with daily monitoring, particularly during and after rainfall events, until stable and satisfactory performance was achieved.

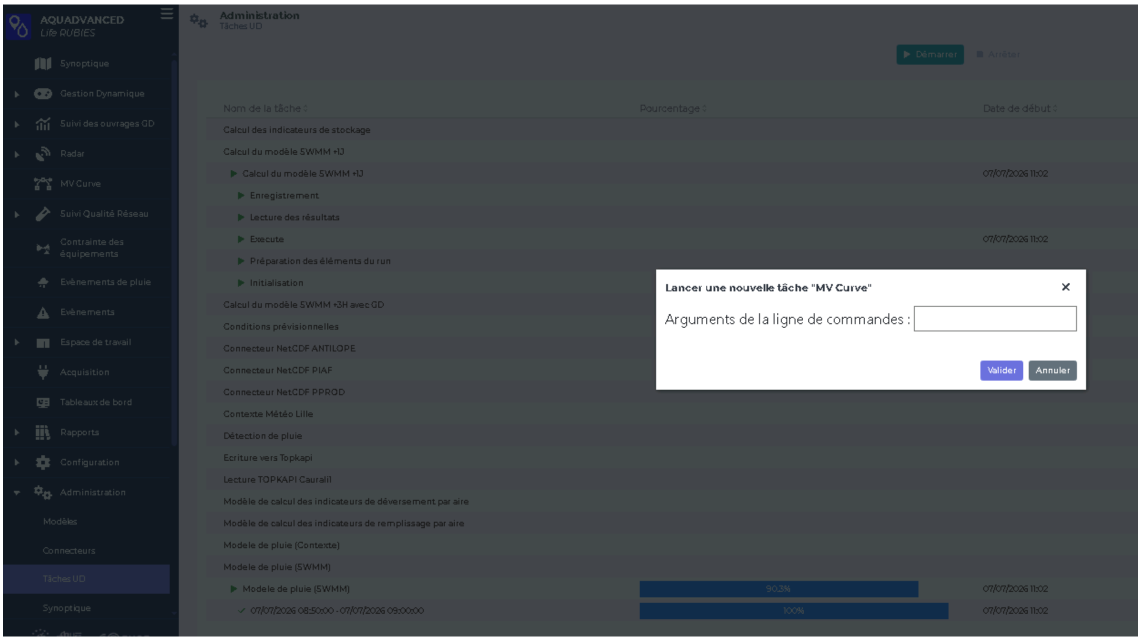



**Figure 6 : View allowing to replay historical situations**

At the conclusion of these iterative testing and optimisation phases, the following key outcomes were obtained:

- stable computation times suitable for real-time control requirements;
- continuous generation of control rules with no calculation failures or execution errors;
- control rules consistent with the expected operational behaviour of the system;
- dedicated monitoring and analysis views allowing efficient assessment and troubleshooting of system performance.

These results provided sufficient confidence in the robustness and reliability of the solution and confirmed the successful completion of the virtual testing phase.

The project could therefore move forward to the operational testing phase (see Deliverable DB4.3 *French Pilot Operational Tests*).