Evaluation of the reduction of pressure fluctuations in a branch of the SES water supply system after the installation of a Real-Time Control (RTC) system

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ABSTRACT

The Syndicat des Eaux du Sud (SES) in Koerich installed its first Real Time Control (RTC) System in early 2018, which now controls all but one of the basins in a branch of its water supply system (Garnich, Clemency, Dippach, Bertrange: the "Clemency Branch"). The SES distribution system is generally characterised by highly fluctuating flows, with an associated expectation that the stresses SES pipes are encountering may be relatively high. However, the Clemency branch is also characterised by low inflow heads in some basins, with associated supply issues under certain conditions. At the time of installation of the RTC it was expected that pressure fluctuations would be significantly reduced as a result. Pressure sensors in the branch are now available and it can indeed be observed that this is the case, mainly due to much more constant flows, even though one of the basins (Dippach) is not yet controlled. From the data it can be calculated that a reduction in average pressure difference between the controlled state and the uncontrolled state of 58% for Clemency, 42% for Garnich and 14% for Bertrange was achieved. RTC systems are now being installed throughout Luxembourg and this technology will play a considerable role in the water management of Luxembourg in the future.

1.0 INTRODUCTION

1.1 Description of the current system

The Syndicat des Eaux du Sud Koerich (SES) water distribution system is relatively complex and consists of spring catchments, deep wells, pumping stations, disinfection plants, water storage tanks, pipelines and additional installations [1,2,3]. In addition, the water systems of the 22 member municipalities must be considered. Furthermore, there are several large industrial customers in the area. The SES water distribution system has been further described in a previous paper by the authors[4,5].

Parts of the SES network are characterized by large fluctuations in demand. The typical daily demand profile resulting from residential areas is further exacerbated by the large industrial users which are in many cases directly connected to the network (without a buffering basin). These fluctuations have in the past required the installation of substantial piping, which enabled the SES to deliver large amounts of water in a short time. However, the resulting transient high flow rates are undesirable because these can result in significant pressure fluctuations and pressure surges in the network.

Since the first pilot study in the SES in 2016, it has been decided to focus on the, so called, “Clemency Branch”, which is a branch of the network that is fed from the main reservoir, the Rebierg top level reservoir also called Rebierg high (2000 m^3). The reason for this is that the receiving reservoirs are all on a high level with low differences in elevation.

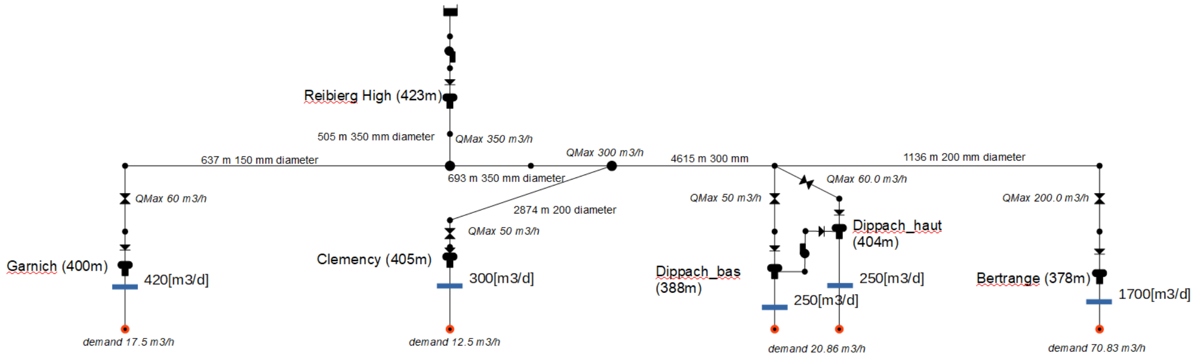


Figure 1: Schematic of the SES Clemency Branch distribution system

A schematic of the Clemency Branch is given in Figure 1. Here it can be observed that the main Rebierg reservoir is at 400 m altitude, while Rieberg High is at 423 meters. From Rebierg High, water is then distributed to Garnich (400 m altitude, 500m^3), Clemency (405 m altitude, 800m^3), Dippach bas (388 m altitude, 1200m^3), Dippach haut (404m altitude, 400m^3) and Bertrange (378 m altitude, 4000m^3). The length and diameter of the pipes as well as the average daily demand have, where applicable, been given in Figure 1.

1.2 Aim of the study

The aim of the study is to evaluate the installation of a Real Time Control system for the Clemency branch. Particular attention has been given to the pressure and flow fluctuations encountered in the system both before and after installation of the RTC.

1.3 Progress of the Real Time Control installation to date

The installation of the RTC system to date has progressed along the following stages:

a) Installation of a central computer with a SCADA system and the installation of local controllers at the basins Garnich, Clemency and Bertrange. This was done in January/February of 2018. Dippach did not receive a local controller since a new basin had been under construction. This construction has now been completed, however, to date, Dippach is not connected to the system.
b) Connection of the Clemency basin to the SCADA and the RTC on the 28th February 2018.
c) Connection of the Bertrange basin to the SCADA and the RTC software on the 12th March 2018.
d) Connection of the Garnich basin to the SCADA and the RTC on the 21st May 2018.
e) After training sessions with the responsible persons for the basins the range that RTC was allowed to operate within was extended (finished July 2018).

1.4 Real Time Control

The Real Time Control system as produced by RTC4Water is essentially a merging of three technologies: Model Predictive Control (MPC), Distributed Control Theory (DCT) and Self Adapting Network (SAN) technology. The DCT and SAN part of the technology are used to increase the overall resilience of the control system (failure recovery and network reconfiguration due to faults or maintenance) and will not be further discussed here. The MPC system has been extensively described in previous publications of some of the Authors [6-10].

The Real-Time controller produced by RTC4Water handles a variable set of objectives and constraints:

1. Homogeneity, the system tries to keep the autonomy of each tank homogenic
2. Achievement of a set point volume by the end of the day, which is set at the beginning of the day
3. Stay below the network wide Reserved Daily Capacity (RDC)
4. Minimise pumping costs
5. Avoid any reservoir level dropping below the fire reserve
6. Avoid any reservoir level increasing above the overflow level

Because of the influence of each sub-goal, the commanded volumes can still change and fluctuate rapidly. This clearly also has an influence on the pressure in the system.

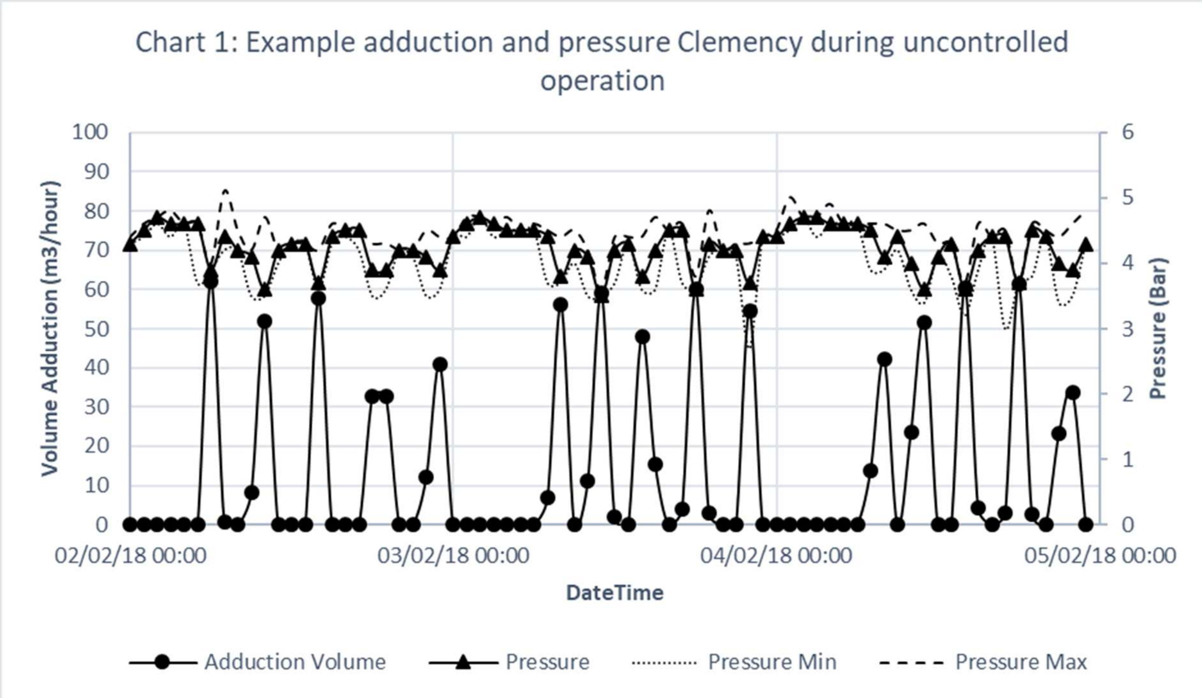
2.0 EXPERIMENTAL

An EPANET hydraulic network model was constructed for the Clemency Branch. This model was then fed with a standard daily profile to ensure its stability. This has been described in the previous paper. Once the SCADA and RTC were installed pressure and debit data was recorded and agglomerated to an hourly reading.

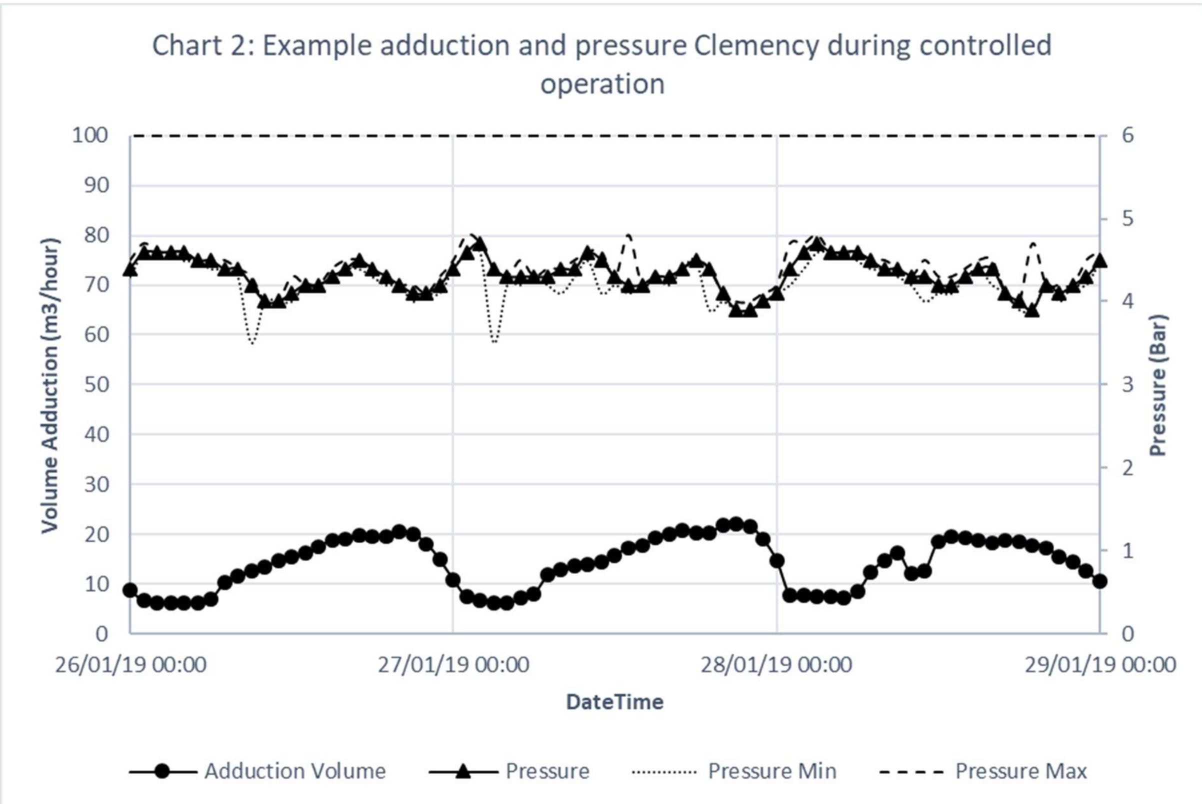
The difficulty with the comparison of pressure fluctuations before and after the installation of the SCADA and RTC system was that before this installation there was no data being captured. However, the SCADA and RTC were normally not connected simultaneously. So there is some data which is available that illustrates the uncontrolled state. The data collection period is from February 2018 to May 2019 to include 10343 datapoints for the Clemency and 9635 datapoints for the Gernich and Bertrange basins.

3.0 RESULTS AND DISCUSSION

In Chart 1, a few days of hourly flow-data is displayed together with its associated pressure data (hourly average, hourly minimum and hourly maximum pressure) before the RTC was providing any control. It can be observed that the valve would open, typically 5 times per day, and let water in at a rate of around 60 m3/hour. In the pressure data this is reflected in a pressure drop of between 0.5 and 1 bar. The local pressure at each basin is, of course, also impacted by activities at the other basins in the branch.



In Chart 2, the controlled behaviour can be observed. Here the RTC is not implicitly trying to keep the flow constant but is reacting to demand changes in a much more considered way. Here it can be observed that the inflow is much more constant than in Chart 1. In the pressure data this is also reflected. There are a few considerable peaks and troughs which can be observed in the minimum and maximum pressure data which cannot be explained by valve changes in the Clemency basin. It is assumed that these pressure changes are caused by valve changes in the other basins, especially in the still uncontrolled Dippach basin.



In particular, it can be observed that the pressure rarely drops to lower than 4 bar in the controlled state, while in the uncontrolled state it was regularly dropping to around 3.5 bar.

Similar profiles can be shown for the Garnich and Bertrange basins (see graphs 3-6).

Chart 3: Example adduction and pressure Bertrange during uncontrolled operation

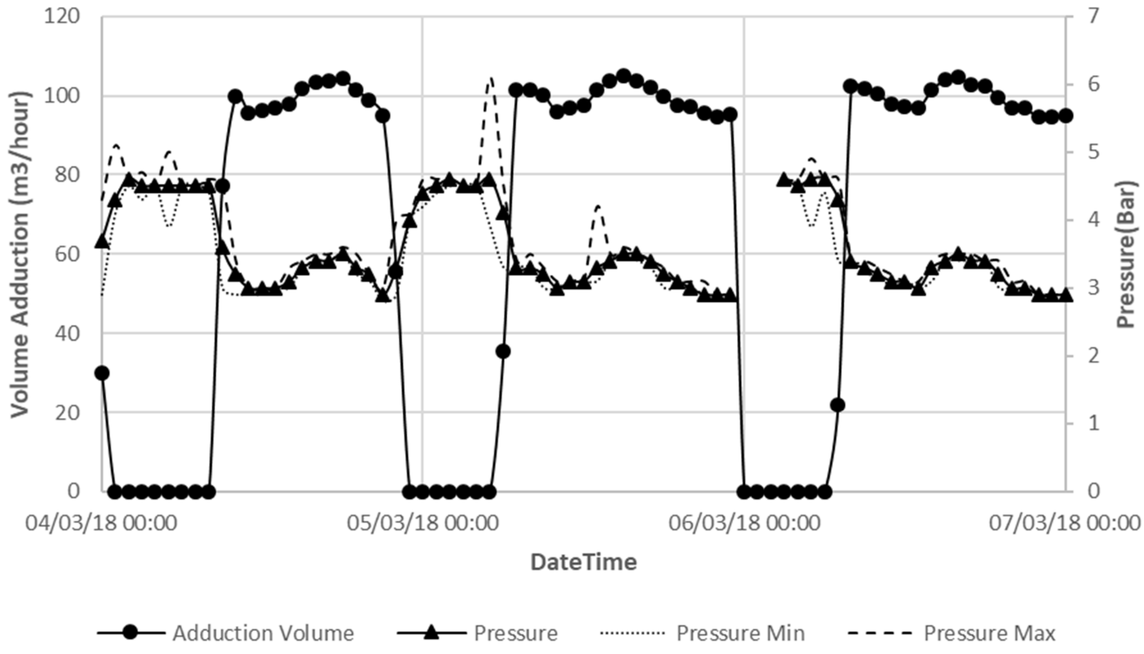
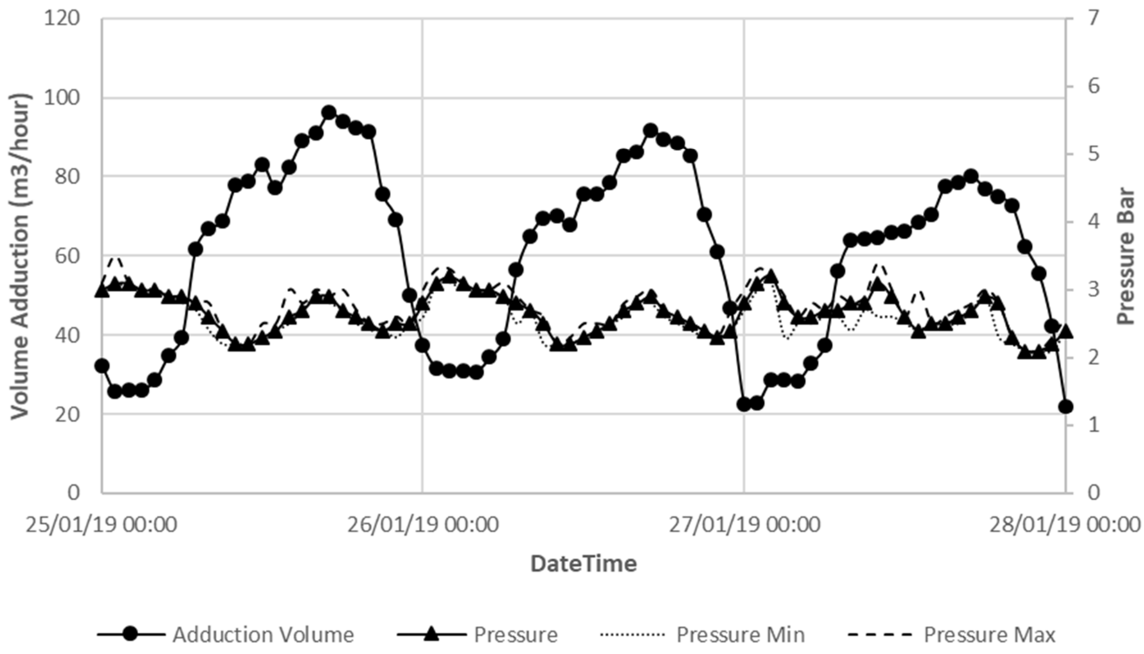
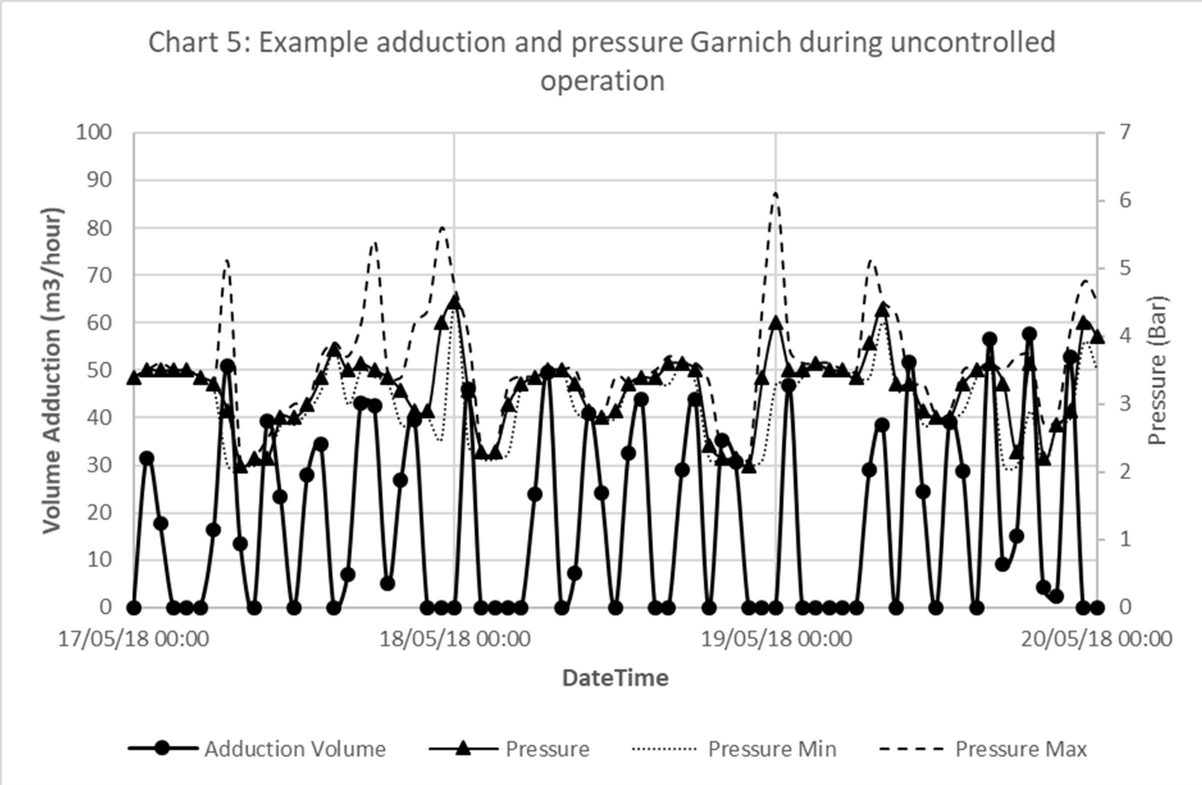
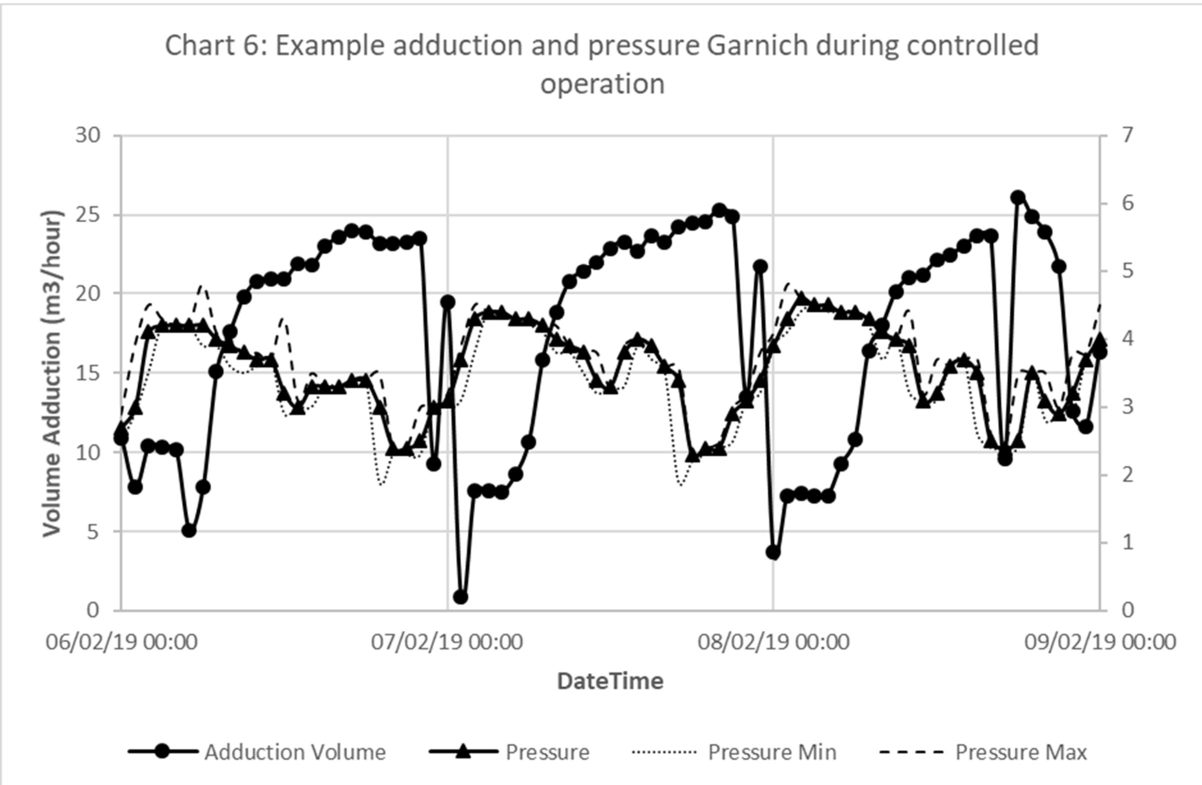


Chart 4: Example adduction and pressure Bertrange during controlled operation



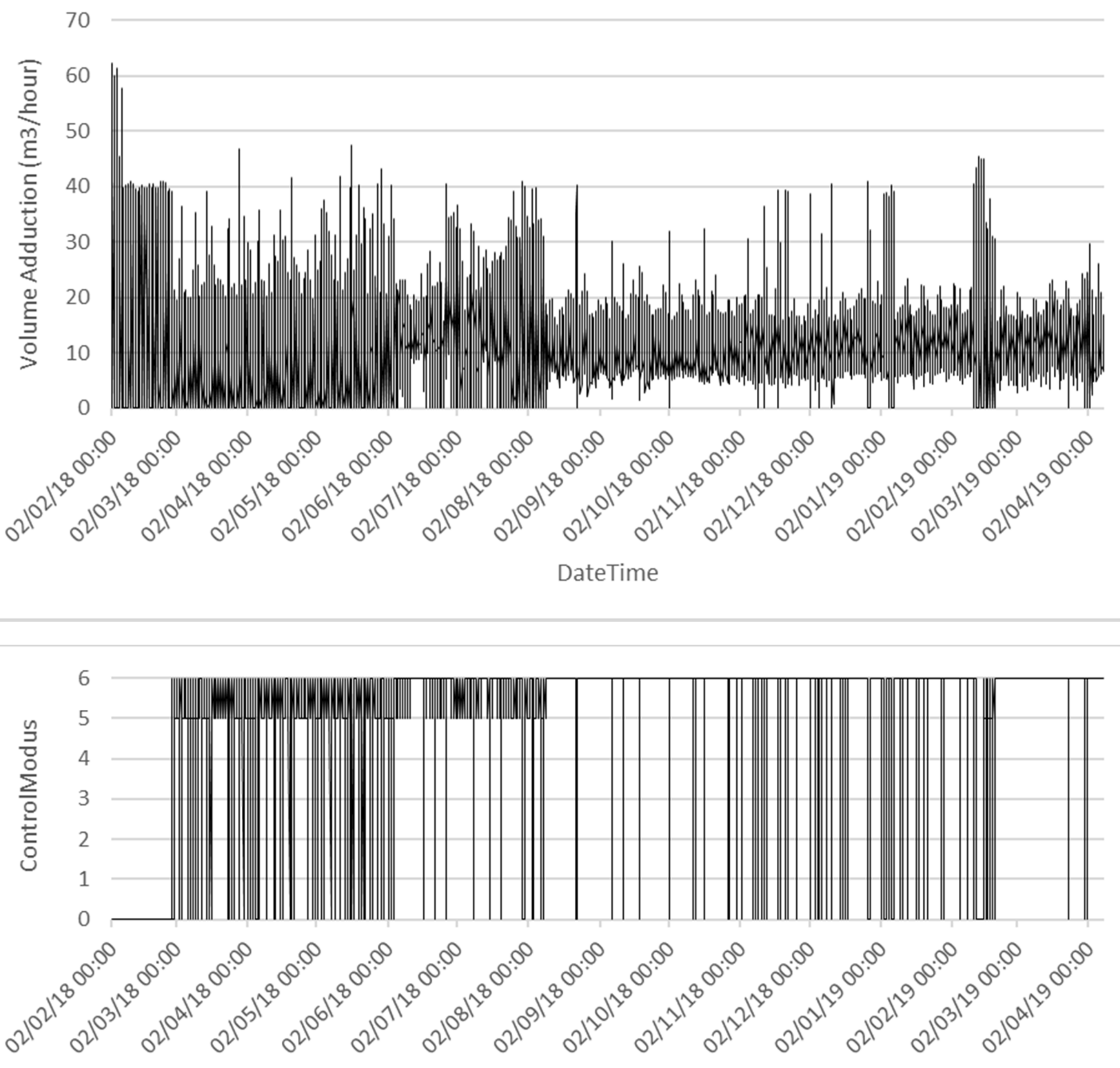




Also, here there is an observable reduction in pressure fluctuations. A positive aspect is that the RTC controlled state results in a positive effect on the water balance and eliminates a reduction in inflow when another basin opens. This effect can be seen in the uncontrolled data (peaks fluctuating in height).

Graph 6 shows the inflow of Clemency over the whole experimental period. This graph has a "bottom section" which shows the control modus.

Graph 7: The adduction of Clemency over the experimental period (431 days) with the control modus (bottom graph extension): 6=controlled, 5=at max level, 0=RTC offline



During this period the basin was in RTC control for 82% of the intevals, closed because the max level was reached in 11% of the intervals and "offline" in 7% of the intervals. Offline can be caused by failures in communication, by maintenance (an observable maintenance period is midway in February, because of basin cleaning) and any other failures in software and/or hardware. At the end of the experimental period the RTC controlled state reached 99% of the intervals. It can be observed that the reaching of the max level has a significant effect on the flow distribution and therefore on the pressure. However, during high demand periods (here in August 2018), the system considers that the importance of a full basin outweighs the importance of keeping a homogenous flow.

In order to attempt to introduce a figure on the improvement in pressure fluctuations, the following was calculated:

$$\delta P(h) = Max.Pressure\ (h) - Min.Pressure(h)$$

Where δP(h) is the maximum pressure difference (in meter) experienced in the hourly interval data. Then the following sums were calculated:

$$\sum \delta P(h) = \sum \delta P(h,c) + \sum \delta P(h,tl) + \sum \delta P(h,nc)$$

Where δP(h,c) is a pressure difference observed in a controlled interval, δP(h,tl) a pressure difference observed in a "top level reached interval and δP(h,nc) a pressure difference observed in a not-controlled, RTC offline interval.

For each state the average pressure difference was then calculated using the generic formula:

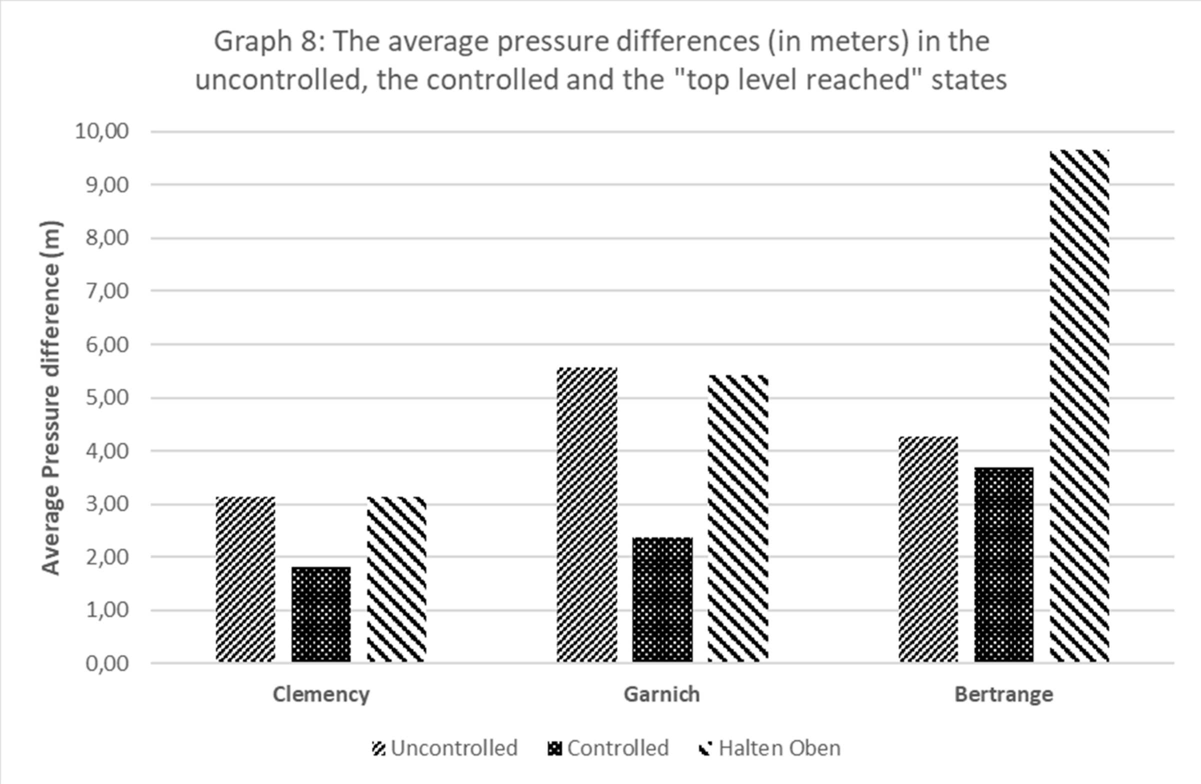
$$\overline{\delta P(h)} = \sum \frac{\delta P(h)}{n}$$

This resulted in the following table:

Table 1: The Average Pressure Differences for the controlled, the uncontrolled and the "top level reached" states

Basin	**Average Pressure difference (m)**		
	Controlled	**"Top level Reached"**	**RTC offline**
Clemency	1.81	3.15	3.14
Garnich	2.37	5.43	5.58
Bertrange	3.69	9.65	4.27

The same data can be converted into a bar chart (graph 8). It can be observed that the controlled state offers a substantial improvement in pressure difference. The fact that generally the pressure difference in the uncontrolled and the "top level reached" states are similar is probably due to the fact that both generally involve a valve closure. Interestingly the "top level reached" state for Bertrange results in a very high average pressure difference. This may be explained by a too rapid valve closure of a large valve (Bertrange is a large basin). This has to be investigated and the valve adjusted accordingly.



From the above data it can be calculated that a reduction in average pressure difference between the uncontrolled state and the controlled state of 58% for Clemency, 42% for Garnich and 14% for Bertrange was achieved. The small reduction for the Bertrange basin may be partly due to the fact that it is located on the pipe behind Dippach. Which means that the pressure fluctuation caused by the Dippach on/off control is still in the Bertrange pressure data.

Clearly, it has been a limitation that the last basin, Dippach, was not yet RTC controlled. Once this is the case another examination will be done to evaluate the performance further.

4.0 CONCLUSION

In a previous paper the flow and pressure were modelled in a section of the SES network and it was predicted that pressure differences should decrease by using a Real Time Control system. Now pressure and flow data from this section is available after installation of the RTC and it can indeed be observed that the pressure fluctuations decrease when the section is controlled. This is mainly due to much more constant flows, even though one basin is not yet controlled. From the data obtained it can be calculated that a reduction in average pressure difference between the controlled state and the uncontrolled state of 58% for Clemency, 42% for Garnich and 14% for Bertrange was achieved.

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