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

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ABSTRACT

The Syndicat des Eaux du Sud (SES) in Koerich will be installing its first Real Time Control System, which will have control of a branch of its water supply system (Garnich, Clemency, Pippach, Bertrange: the "Clemency Branch"). In the SES, the overall supply system is strongly hierarchical with at its centre, one, very large storage tank (Rebierg). This system is characterised by highly fluctuating flows, which can rapidly vary from almost zero to 1000 m3/hour in some pipe sections. There is therefore an expectation that the stresses these pipes are encountering can be relatively high. However, at present there are no (pressure) measurements available to confirm or quantify this assumption. The expectation is that the installation of the RTC4water's, RTC system on the Clemency branch will produce a dramatic reduction on pressure fluctuations, the pressures in the pipe and therefore the pipe stresses in this part of the supply system. This paper attempts to quantify this assumption using a modelling strategy, without having access to any real data, only by using the current layout of the system. The results are indicating that a reduction in pressure fluctuations can indeed be expected, although because the Clemency branch has low level differences between tanks, it is unlikely that pressure

fluctuations have a large impact on pipe stresses but rather improve water availability throughout the branch.

1.0 INTRODUCTION

1.1 Description of the current system

The entire Syndicat des Eaux du Sud Koerich (SES) system is relative complex and consists of spring catchments, deep wells, pumping stations, disinfection plants, water storage tanks, pipelines and additional installations [1,2]. Included are 28 kilometres of water mains that conduct water from the source to the pumping stations and 185 km water mains for carriage and distribution to the local storage reservoirs. In addition, the water systems of the 22 member municipalities must be considered. Furthermore, there are a number of large industrial customers in the area, such as the group Arcelor Mittal, a steel manufacturer.

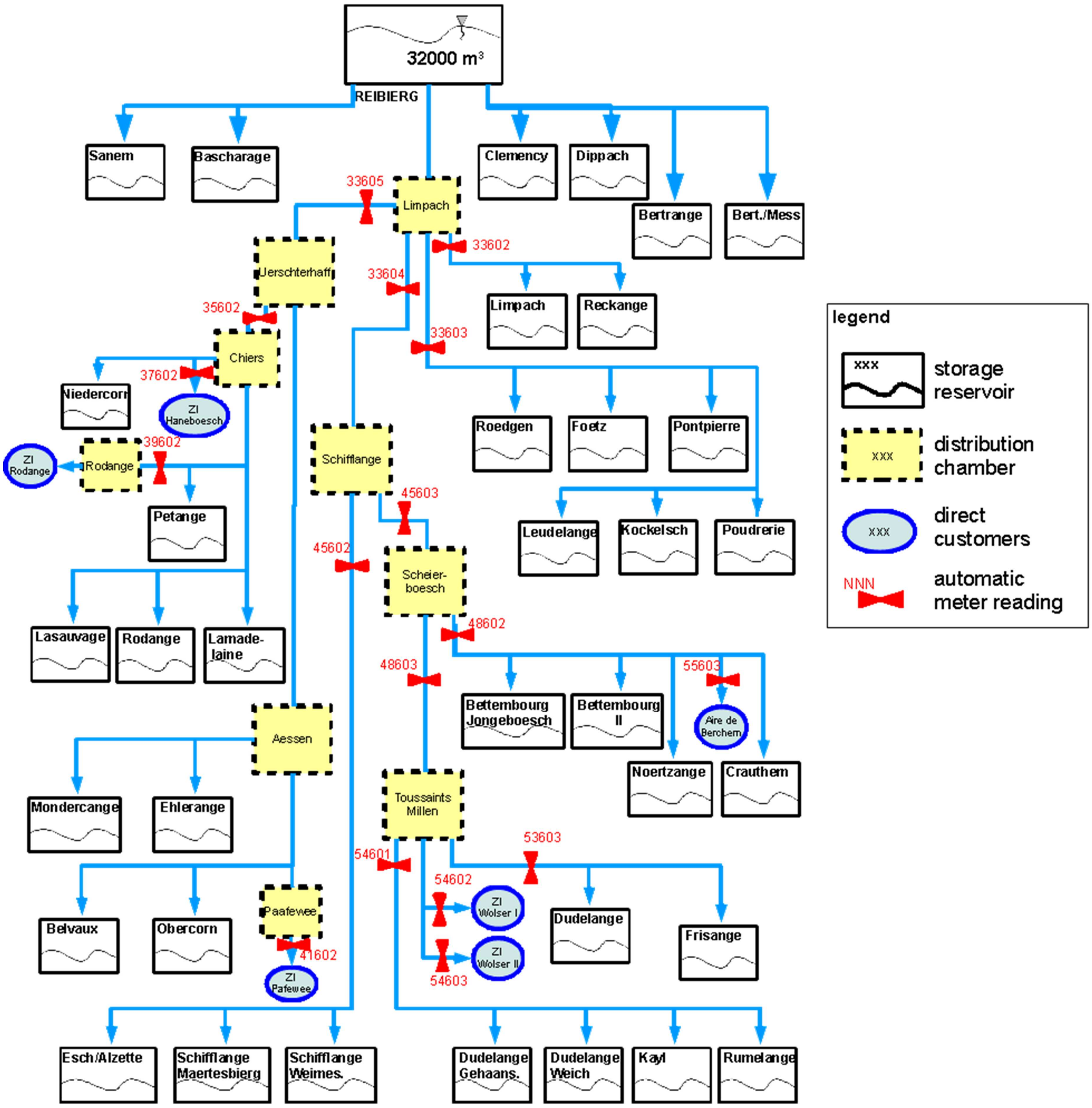


Figure 1: Schematic of the overall SES distribution system

A schematic of the distribution system is given in Figure 1. The system of catchments and wells that supplies almost half of the water needed is not shown here, neither is the water supplied by the SEBES[3], the water producer in Luxembourg[4]. However, this volume is relatively constant. From figure 1 it can be observed that the central storage basin(s) Rebierg (15000 m^3) plays a dominant role. Currently this is the only reservoir that is controlled by operators and used to absorb the effects of high customer demand or an exceedance of the reserved daily capacity (RDC). The remainder of the reservoirs are operated with a simple level control strategy that basically means that these tanks currently can be considered to be full at all times.

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 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 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.

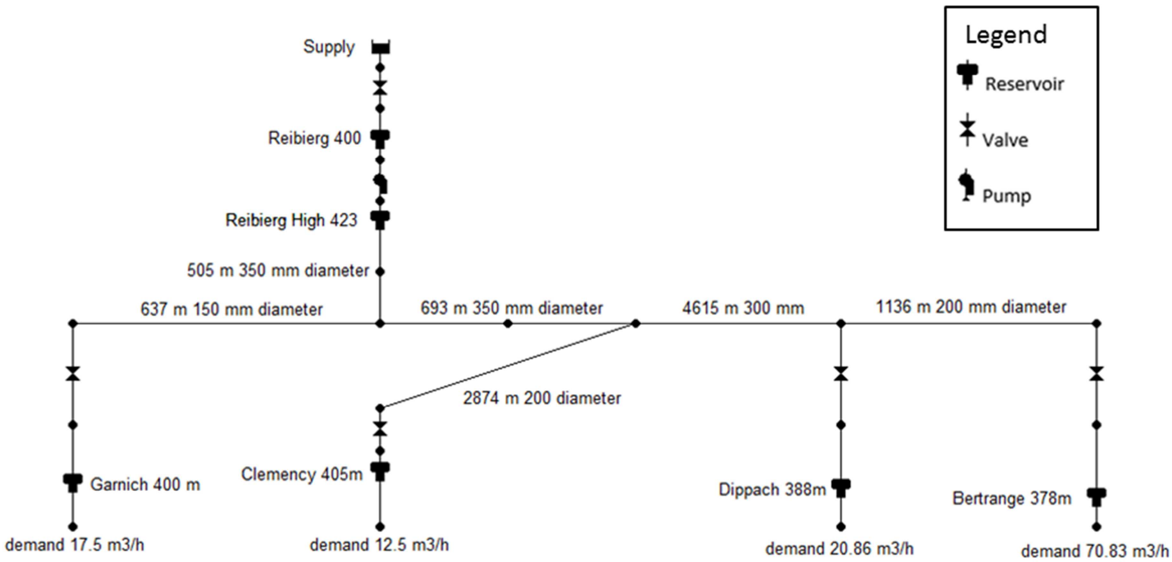


Figure 2: Schematic of the SES Clemency Branch distribution system

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 (388 m altitude, 500m^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 2.

1.2 Aim of the study

The aim of the study is to model the Clemency branch of the current distribution system, then develop a real-time controller for this system and redo the simulation with the output of the controller. An examination of the pressure fluctuations at the point of entry of the tanks, for both situations would then provide some indication of the reduction in pressure fluctuations to be expected.

1.3 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 [5-10].

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

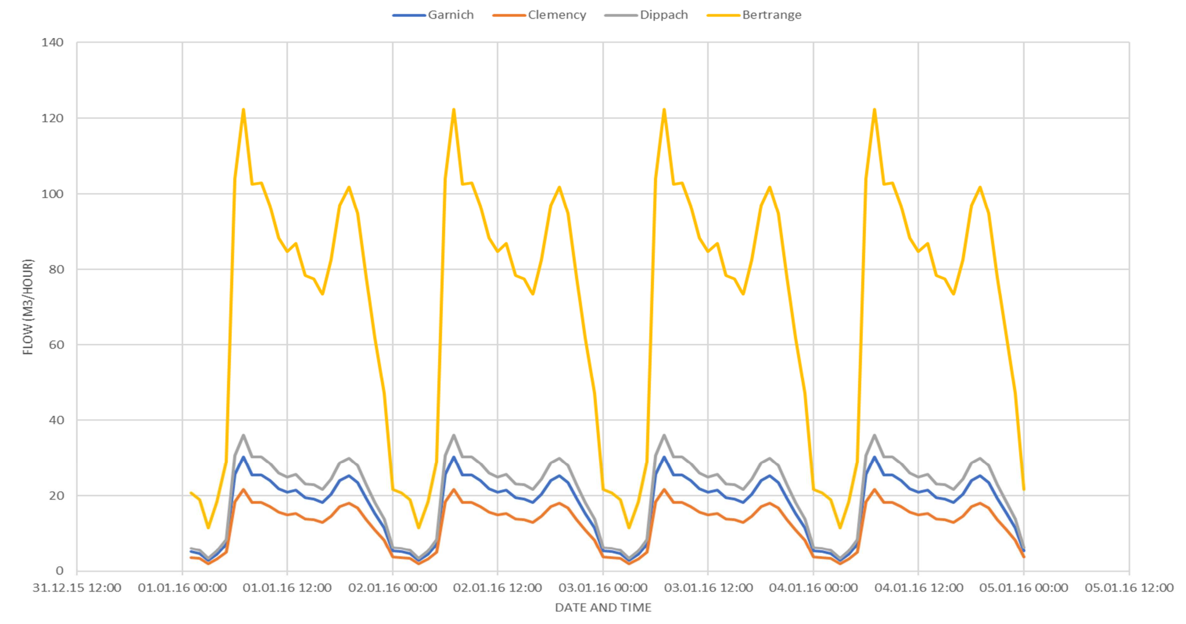
1. Homogeneity, the system tries to keep the autonomy of each tank homogenic
2. Reach the set point at the end of the day, which is set at the beginning of the day
3. Stay below the Reserved Daily Capacity (RDC)
4. Minimise pumping costs
5. Avoid any reservoir level dropping below the fire reserve
6. 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 of 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. This standard profile is given in Figure 3 for the receiving reservoirs. This daily profile is repeated 4 times (4 days) to make sure the controller is fully adjusted to the system.

FIGURE 3: STANDARD DAILY PROFILE USED FOR ALL EXPERIMENTS



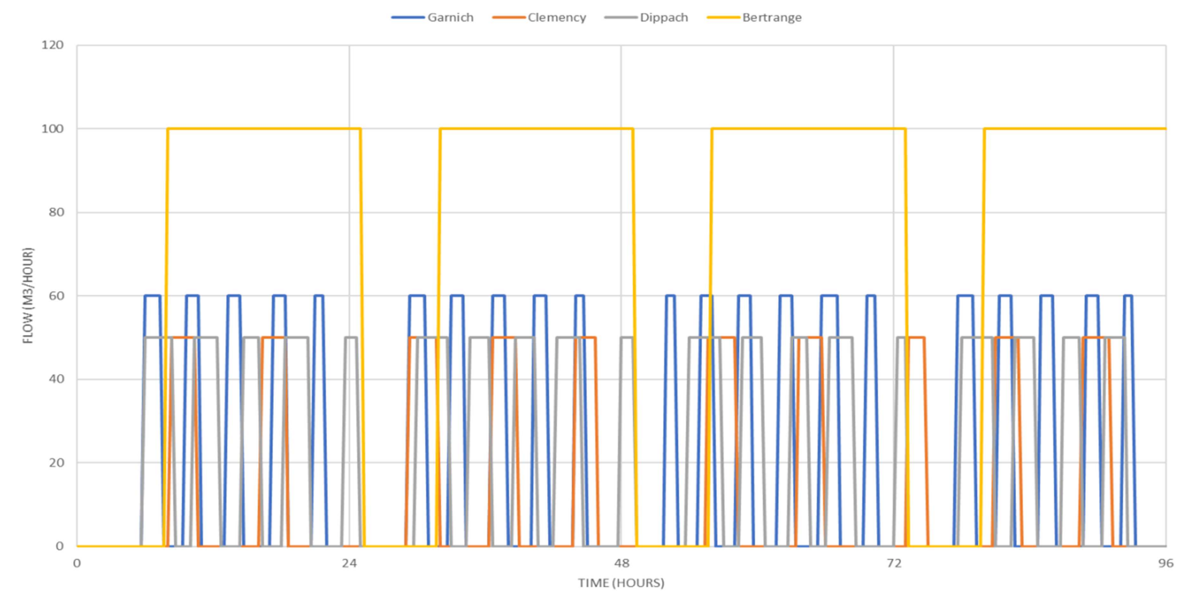
Simulations were then conducted on the model using a standard level control and the control provided by the RTC4Water controller. The results are displayed in section 3.

3.0 RESULTS AND DISCUSSION

3.1 Results of the conventional level control

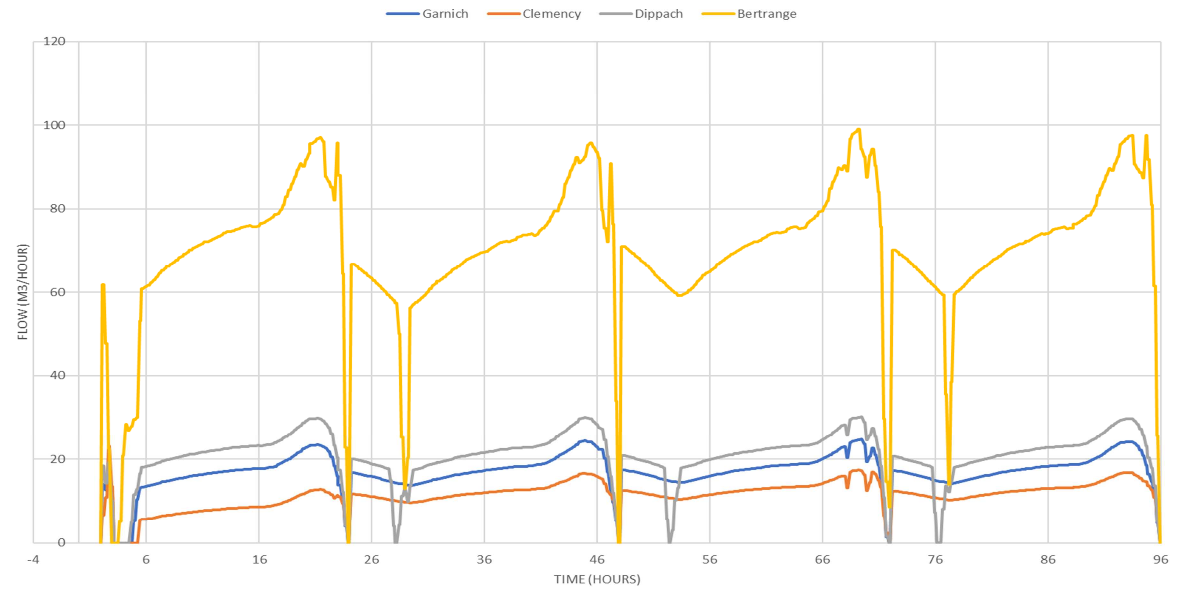
The flow fluctuations because of a level controller are unremarkable and predictable. The resulting flow patterns are shown in Figure 4.

FIGURE 4: SIMULATION TWO LEVEL CONTROL. THE FLOW INTO THE 4 RECEIVING RESERVOIRS OF THE CLEMENCY BRANCH



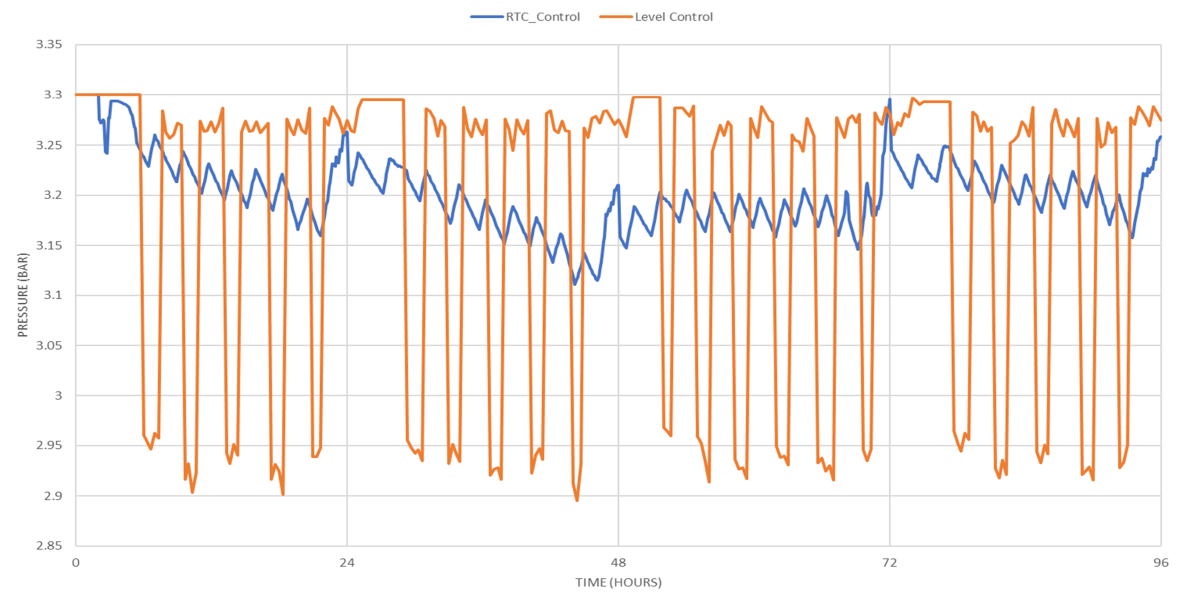
It is maybe interesting to discuss that the SES uses advanced flow control valves on some or their inlet valves and these valves are set-up to have a reduced maximum flow to already reduce pressure fluctuation. The Bertrange reservoir does employ one of these valves. The effect can be observed in figure 4: the Bertrange valve is open much longer and only once per day. Figure 5 similarly illustrates the output of the real-time controller. The controller aims to have a constant flow during the day, while maintaining homogeneity in the system. However, clearly,

FIGURE 5: REAL TIME CONTROL. THE FLOW INTO THE 4 RECEIVING RESERVOIRS OF THE CLEMENCY BRANCH



when the reservoir is full, the controller will close the valve (see objective 5 in section 1.3). A further characteristic of the controller is that it attempts to reach its set-point at the end of the day (see objective 2). Therefore, it is normally observed that the controller will command a steady output at the beginning of the day, while around midnight the volume commanded will fluctuate somewhat more.

FIGURE 6: REAL TIME CONTROL V LEVEL CONTROL. THE PRESSURE AT THE POINT OF INFLOW TO THE GARNICH RESERVOIR



When the modelled pressures are compared for the inlets of the four reservoirs the results as displayed in figure 6-9 are obtained.

FIGURE 7: REAL TIME CONTROL V LEVEL CONTROL. THE PRESSURE AT THE POINT OF INFLOW TO THE CLEMENCY RESERVOIR

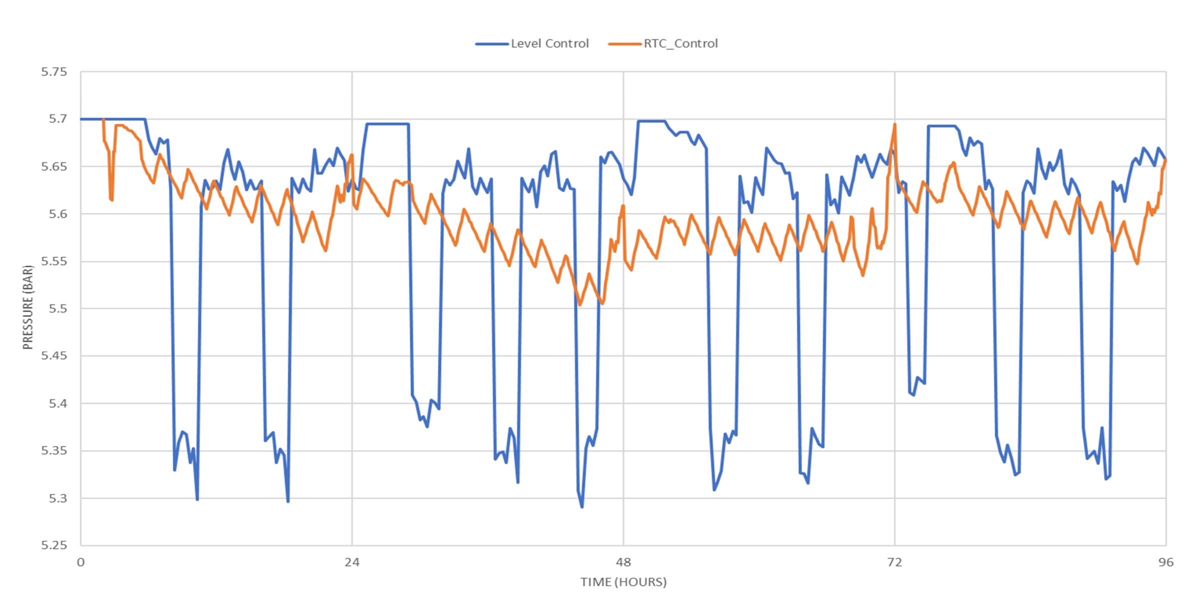
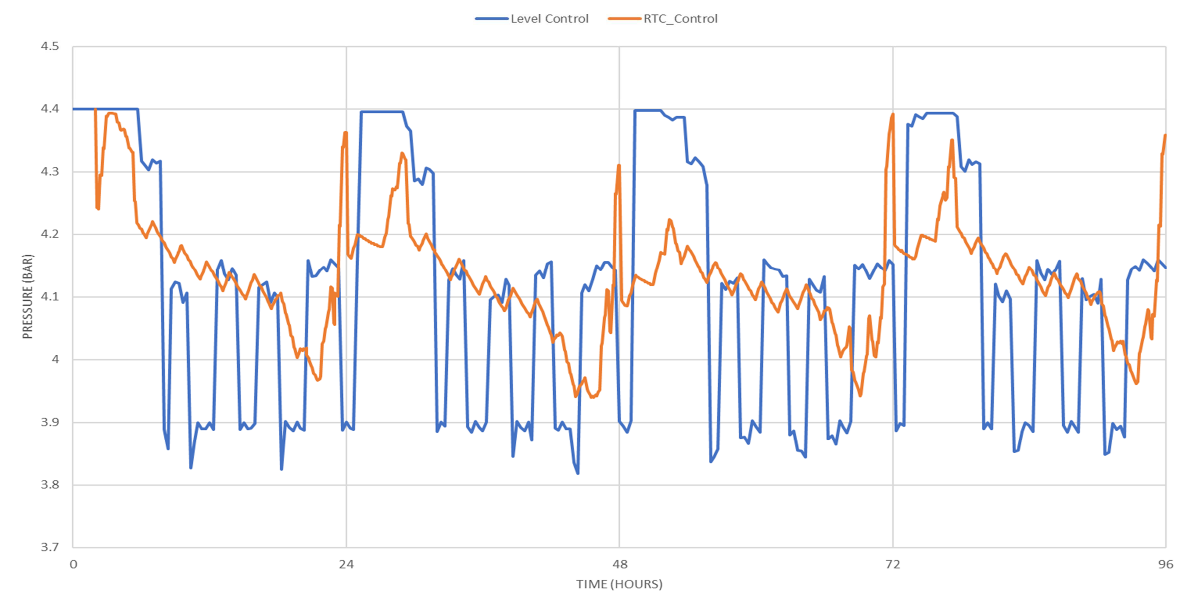
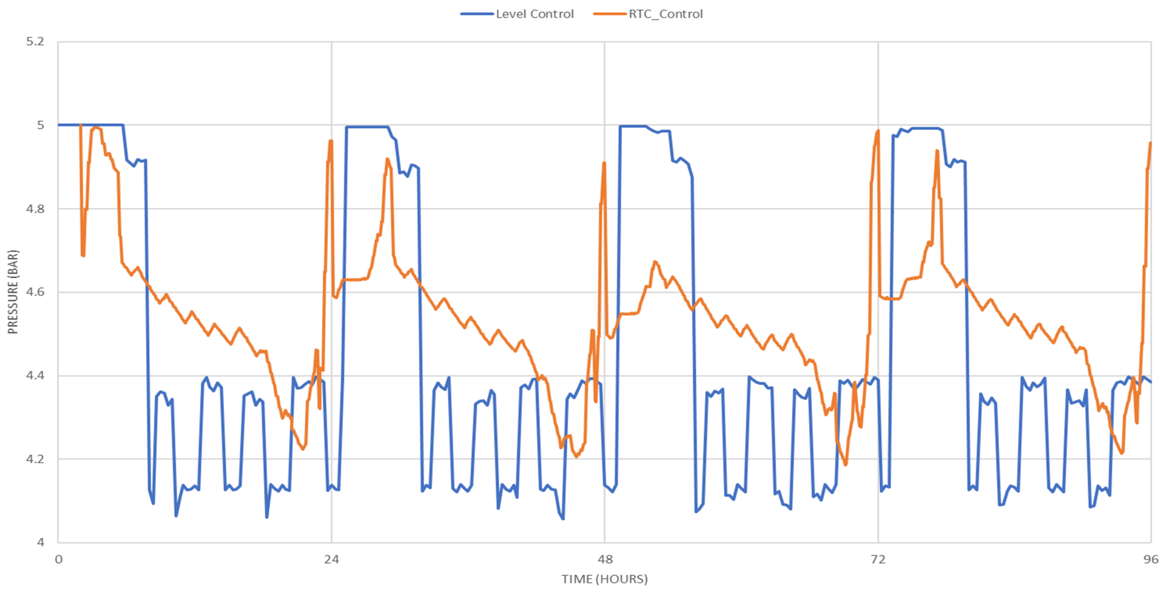


FIGURE 8: REAL TIME CONTROL V LEVEL CONTROL. THE PRESSURE AT THE POINT OF INFLOW TO THE DIPPACH RESERVOIR



When examining figure 6 to 9 it is clear that at all the inlets of the distributing reservoirs there is a substantial reduction of pressure fluctuations. However, the fluctuations in flow and pressure observed are still considerable and often happen around day-change. In principle, there is therefore still room for improvement from a pressure point of view. However, other constraints should not be discarded and a balance should be achieved. It is also not desirable to remove ALL pressure and flow fluctuations. The removal of virtually ALL fluctuations can, for instance, be achieved by including a standard profile in the predictions. This can and has been done in the past for other systems and for other reasons. One negative aspect is that an increased level of pipe and reservoir cleaning may be necessary because of an increased settling. Another may be that a natural airflow or air-exchange, which is the result of a changing water level, is reduced. This, in turn, may lead to a deterioration of the ceiling and walls of the reservoir, subsequently leading to a decreased water quality.

FIGURE 9: REAL TIME CONTROL V LEVEL CONTROL. THE PRESSURE AT THE POINT OF INFLOW TO THE BERTRANGE RESERVOIR



Furthermore, it is obvious that the pressure fluctuation reduction observed will not seriously improve the life of the system observed. This is because in this branch, which is relatively flat (i.e. has few altitude changes), pressure fluctuations were relatively low to begin with. Instead the reductions in pressure fluctuations will be more beneficial in securing the supply to the Bertrange reservoir when the other reservoirs demand water. The observed principle is however sound and pressure reductions will also be achievable in networks or network branches with much larger changes in altitude. In these systems, the the real-time controller will have a much more dramatic impact on the overall life of the system and could have a dramatic impact on the number of pipe bursts experienced.

3.2 Future work

The current control approach does not explicitly minimize the control-energy (actuator fluctuation). There is no such objective specified in the MPC objective function. In addition, the current implementation uses a decreasing control-horizon towards the end of the day witch results in higher dynamics of the controller activity at day-change. This are potential improvements the next generation of controller will be considering

4.0 CONCLUSIONS

The results are strongly indicating that a reduction in pressure fluctuations when utilising the RTC4Water Real-Time Control (RTC) software can indeed be expected. However, because the Clemency branch has low altitude differences between reservoirs, it is unlikely that pressure fluctuations have a large impact on pipe stresses but rather improve water availability throughout the branch. It is likely however that in other systems or branches the effect on system life can be increased and pipe bursts avoided.

5.0 REFERENCES

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