REDUCING BURSTS AND BACKGROUND LEAKAGE WITH PREDICTIVE PRESSURE CONTROL

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ABSTRACT

Pressure management is widely recognised as the foundation of effective leakage control in drinking water distribution systems. Conventional pressure management strategies primarily aim to reduce average network pressure, which lowers leakage flow but does not necessarily minimise pressure fluctuations. Recent research indicates that pressure variation—particularly daily—is a dominant driver for pipe fatigue and bursts.
This paper presents a predictive pressure control approach that targets leakage reduction and burst prevention by reducing pressure variability while maintaining compliance with minimum service level requirements. The method combines demand forecasting with learned hydraulic relationships to determine optimal pressure setpoints in advance, enabling smoother and more stable network operation. Unlike fully measurement-based control strategies, the proposed approach does not rely on continuous real-time critical point measurements and is therefore robust to delayed communication or temporary sensor failures.
The approach is operational at several drinking water utilities. Results show that predictive control achieves pressure levels comparable to advanced measurement-based control, while significantly reducing pressure fluctuations. This operational behaviour is expected to reduce background leakage, lower burst frequency, and contribute to extended asset lifetime.

KEYWORDS: predictive control, pressure management, leakage reduction

INTRODUCTION

Non-revenue water (NRW) remains one of the main challenges for drinking water utilities worldwide, particularly in distribution systems characterised by ageing infrastructure, pressure variability, and complex operational conditions. Pressure management is widely recognised as a key pillar of real loss reduction, as emphasised by the International Water Association (IWA). By reducing excessive pressure, leakage flow rates can be lowered and the occurrence of new bursts can be mitigated.
Conventional pressure management strategies typically focus on reducing average pressure levels through fixed or time-based pressure setpoints. While effective in lowering leakage volumes, these approaches often fail to adequately control pressure fluctuations, which are increasingly identified as a critical factor influencing pipe fatigue and burst frequency. Literature consistently highlights the role of pressure variation as a key driver for pipe fatigue and burst occurrence. Studies by Lambert, Martínez-Codina et al., and Rezaei et al. show that cyclic pressure loading and large daily pressure ranges significantly increase burst frequency.

This paper builds on these findings by presenting a predictive pressure control approach that explicitly targets pressure stability in addition to pressure reduction. The approach is rooted in operational experience from Netherlands drinking water utilities and aligns with the growing need for robust, data-efficient control strategies that can be applied in diverse network conditions, including those commonly found in Brazilian water systems.

OBJECTIVES

The main objectives of this paper are:

- To describe a predictive pressure control concept aimed at reducing both background leakage and burst occurrence.
- To compare predictive control with conventional pressure management strategies in terms of pressure level and pressure variability.
- To assess the expected impact of calmer pressure regimes on leakage, burst frequency, and asset lifetime based on established pressure–leakage and pressure–burst relationships.
- To discuss practical implementation aspects and applicability for drinking water utilities.

METHODOLOGY USED

The proposed methodology is based on predictive control of pressure setpoints using forecasted demand and learned hydraulic relationships. Instead of only reacting to real-time pressure measurements at critical points, the controller determines optimal pressure setpoints ahead of time, based on expected system behaviour.
Core elements of the methodology include:

- Short-term demand forecasting using historical flow patterns.
- Estimation of head-loss behaviour through grey-box or data-driven relationships between flow and pressure.
- Calculation of pressure setpoints that ensure minimum pressure requirements at critical points while minimising excess pressure.
- Gradual and smooth adjustment of pressure setpoints to reduce pressure variability and transients.

The approach can be applied to systems with variable speed pumps or pressure reducing valves. Optional feedback from pressure measurements can be integrated to enhance robustness, but continuous real-time measurements are not a strict requirement. This makes the method resilient to delayed communication or temporary sensor unavailability.

RESULTS OBTAINED

The predictive pressure control approach has been implemented and evaluated in multiple operational cases, including pilots at Netherlands, Argentinian and Italian drinking water utilities.

The Figure 1 and 2 and Table 1 show the differences between pressure control with only feedback and pressure control using predictive control for Echt. Figure 1 and Figure 2 show the control over a full day with feedback and predictive control. In Figure 1 and Figure 2, the green line shows the actual pressure at the distribution pumps, the blue line shows the pressure setpoint, the orange line shows the pump speed, the black line shows the pressure at a critical point (CP) in the area and the purple line shows the flow of the distribution pumps.

The standard deviation of the pressure at the distribution pumps and the critical point for the control with only feedback (Reactive approach) and the predictive control (Predictive approach) are shown in Table 1. This data shows that predictive approach has minimal impact on the critical point pressure, while reducing the deviation in the distribution pump pressure. As a result, the pump speed also appears calmer with predictive control.

It’s also worthwhile to note that, both with the feedback and predictive control, the actual pressure at the distribution pumps deviates more than the pressure setpoint.

Figure 1 - Pressure control using feedback only

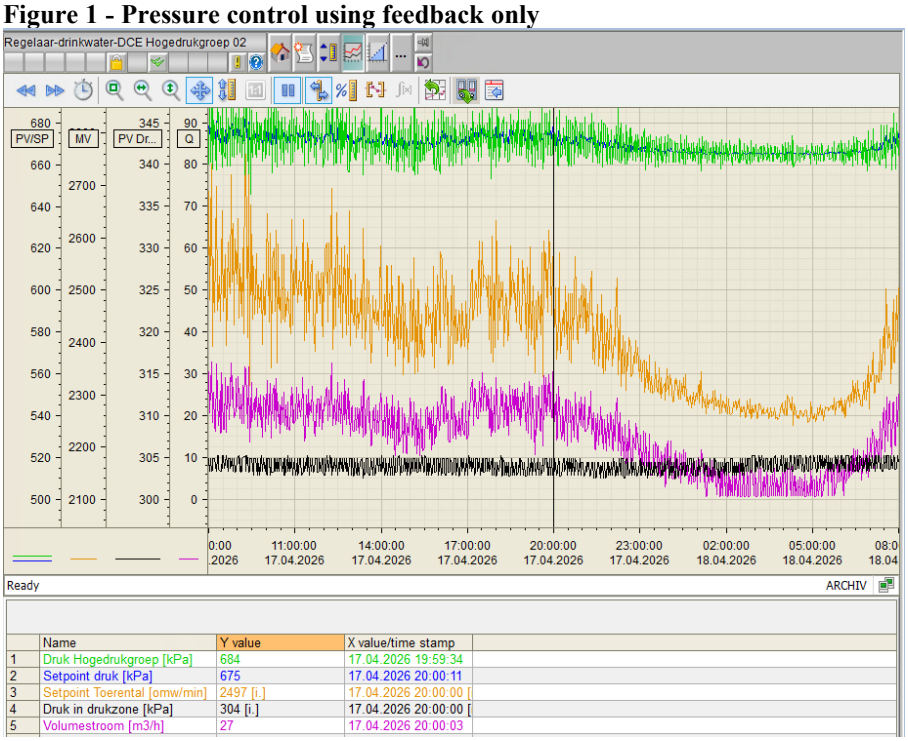


Figure 2 - Pressure control using predictive control

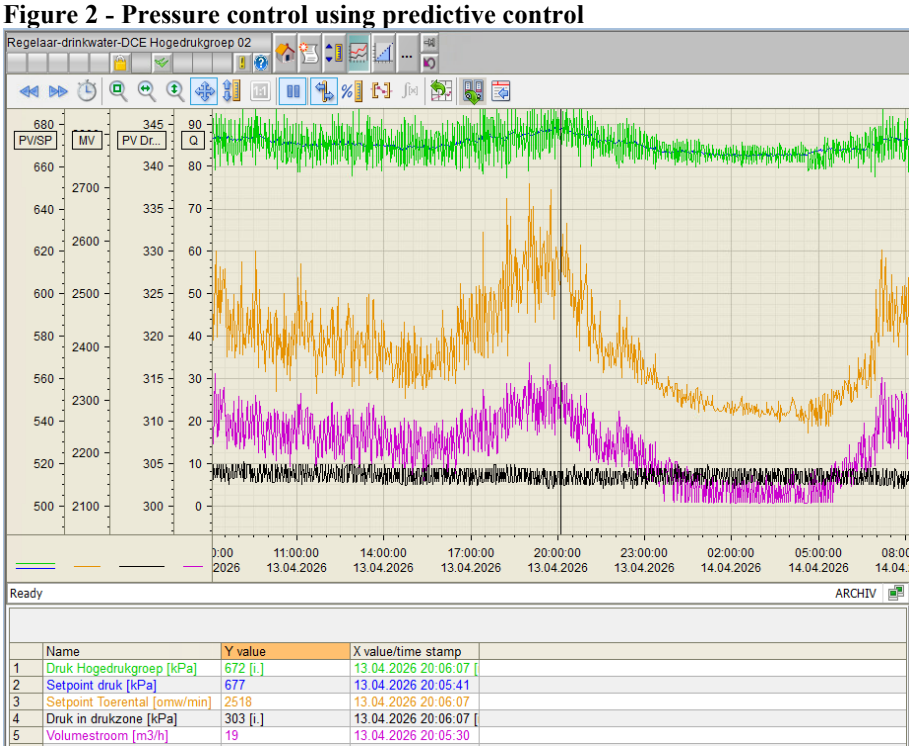


Table 1 – Pressure range and standard deviation for pressure zone Echt – Netherlands 2026

Pressure KPI (kPa)	Reactive	Predictive
Pump range	58.2	40.5
Pump standard deviation	6.5	5.8
CP range	2.8	3.2
CP standard deviation	0.4	0.4

Source: author's own elaboration based on data provided by Dutch utility WML (Netherlands, 2026).

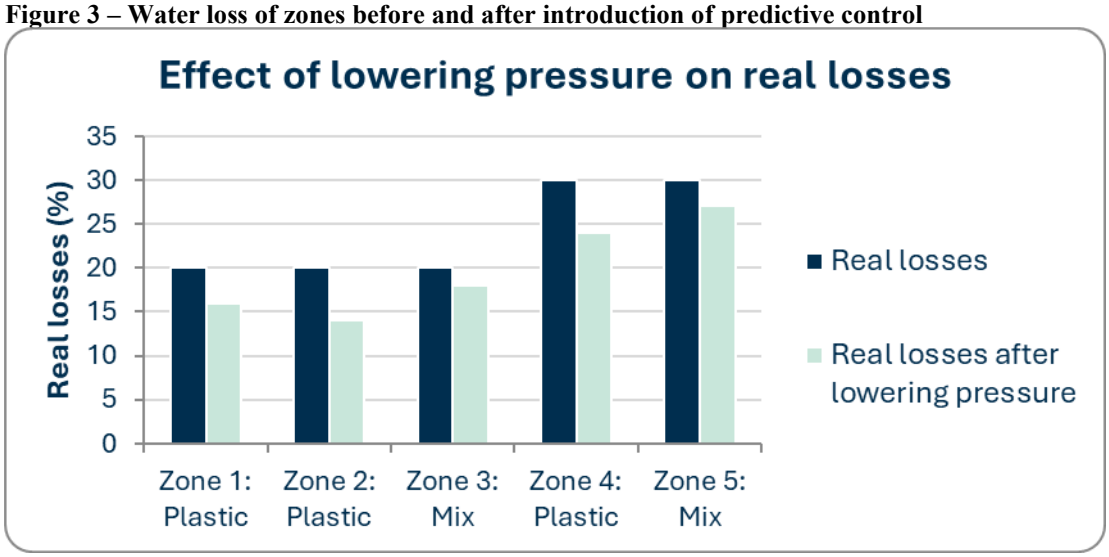
Figure 3 and 4 show the results for the water loss before and after the implementation predictive control.

The results for 5 different zones within Argentina are shown in Figure 3. The dark blue bar shows the real historical losses reported in these zones and the light cyan bar shows the expected losses with the pressure reduction after implentation of the predictive control.

The results for 4 months for a single zone in Parma are shown in Figure 4. The dark blue bar represent the real losses of these months in a year prior to the implementation of predictive control and the light cyan lines shows the real losses after implementation of predictive control.

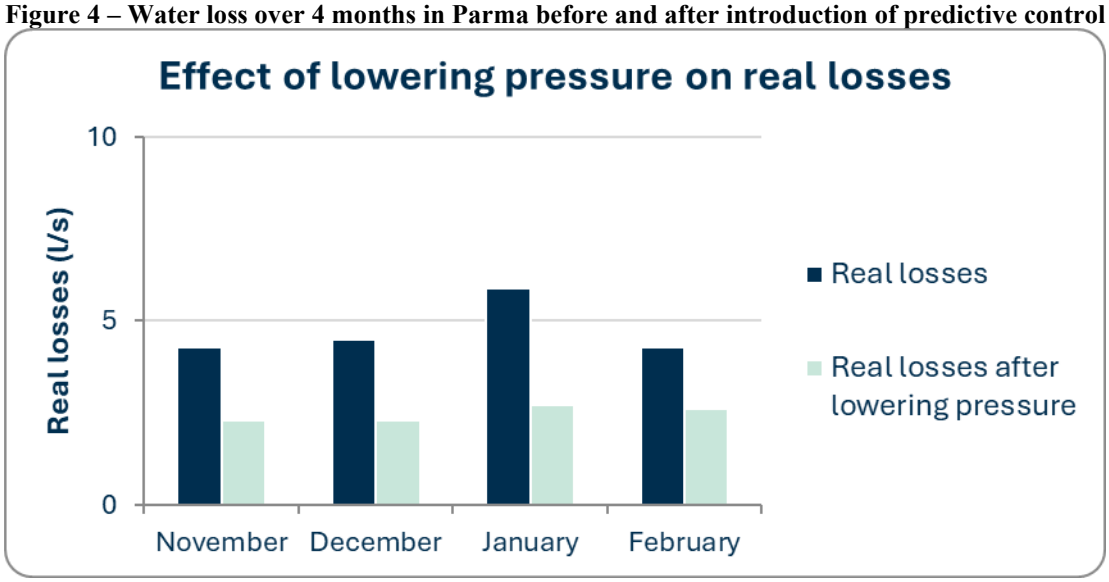
Both figures show a reduction in losses after implementation of predictive control.

Figure 3 – Water loss of zones before and after introduction of predictive control



Source: author's own elaboration based on data in collaboration with an Argentinian utility (Netherlands, 2021).

Figure 4 – Water loss over 4 months in Parma before and after introduction of predictive control



Source: author's own elaboration based on data in collaboration with an Italian utility (Netherlands, 2025).

ANALYSIS AND DISCUSSION OF RESULTS

Results demonstrate that predictive control is able to achieve pressure levels comparable to or better than advanced measurement-based control strategies.
More importantly, the method significantly reduces pressure variability, resulting in calmer network operation. Compared to timetable-based or reactive control, pressure transitions are smoother and daily pressure ranges are reduced, particularly at pumps and pressure control assets.
In several documented applications, pressure optimisation using predictive control has led to substantial leakage reductions and energy savings. While the primary focus of this paper is on pressure behaviour, these operational improvements are consistent with reported reductions in real losses and improved asset performance.

By actively minimising pressure variation, predictive pressure control directly addresses pipe fatigue and bursts. A calmer pressure regime reduces cyclic stress on pipes, which is expected to lower the rate of new bursts and slow down material fatigue. At the same time, reduced average pressure contributes to lower background leakage through existing defects.
Compared to conventional pressure management strategies, predictive control offers several advantages:

- Reduced sensitivity to demand disturbances.
- Lower pressure variability without compromising minimum service levels.
- Improved suitability for multi-feed zones.
- Reduced dependency on continuous, high-quality real-time measurements.

These characteristics are particularly relevant for large and complex distribution systems, including those in emerging economies, where sensor coverage and communication reliability may be limited.

CONCLUSIONS AND RECOMMENDATIONS

Predictive pressure control represents a promising evolution of conventional pressure management strategies. By combining demand forecasting with learned hydraulic behaviour, it is possible to achieve both low average pressure and reduced pressure variation, resulting in calmer distribution networks.
Based on operational results and established pressure–leakage and pressure–burst relationships, the approach is expected to reduce background leakage, lower burst frequency, and contribute to extended asset lifetime. In addition, smoother operation reduces mechanical stress on pumps and valves and can lead to energy savings.

It is recommended that utilities consider predictive pressure control as part of an integrated leakage management strategy, particularly in systems where pressure variability is a known issue. Future work should focus on long-term

empirical evaluation of burst statistics and leakage indicators under predictive control. Next to this, improvement of PID control may lead to even smaller pressure variability.

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