BTO Executive Summary

Proof of concept for DMA fingerprinting: valve anomalies and leaks can be detected based on changes in pressure waves

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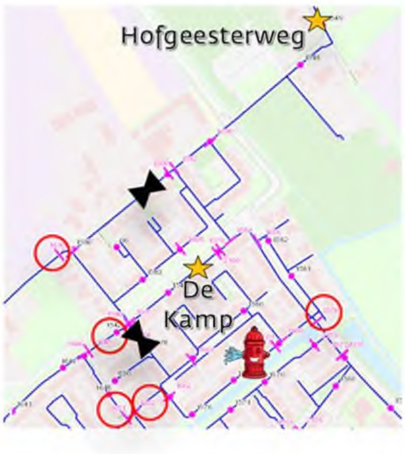
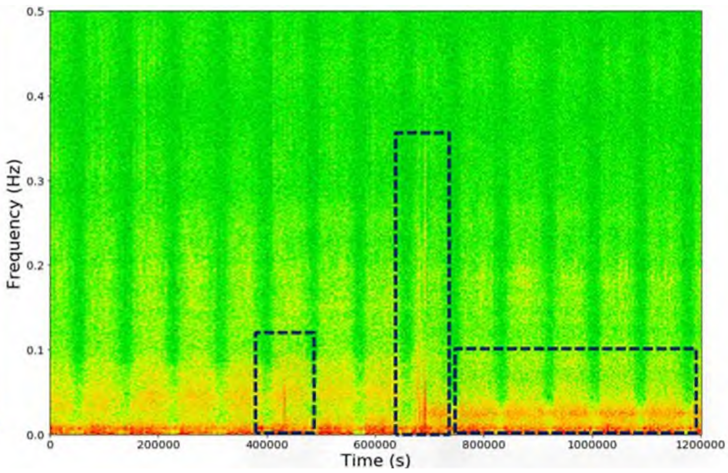
Exploratory research has produced a proof of concept for the detection of closed valves in real water distribution networks using DMA fingerprinting: spectral analysis of pressure waves (transients) in District Metered Areas, as demonstrated theoretically by Richard Collins (University of Sheffield, UK). This research used a pilot DMA of the PWM water utility (at Velserbroek) with a single entrance (Figure 1.A). High-frequency measurements were registered over 22 days using pressure loggers at two strategic locations. Several disturbances, such as valve closures or the opening of a fire hydrant, were generated in the DMA. The spectrograms presented a stable picture during normal operational conditions and a visible change in the frequency response during the disturbances. Thus, a DMA does in fact have a fingerprint, and disturbances in a DMA can be detected. Important applications for drinking water utilities include the testing of (partial) closure of a valve and leak detection/localisation.



(A)



(B)

Pilot area (A) and the results of the first 14 days from the logger at Hofgeesterweg (B).

Interest: detection of anomalies in the distribution network

Previous research has shown that, on average, the position of 0.7 – 1.0% of the valves in drinking water distribution networks are other than expected. Typically, these anomalies come to light during flushing or repair work activities, resulting in additional CMLs (customer minutes lost). Greater understanding of anomalies in valve positions can help keep CMLs as low as possible. Theoretical research by Richard Collins (University of Sheffield, UK) demonstrates that pressure waves (transients) that flow through a DMA as a result of the opening or closure of taps in households, can provide information about valve position. Also, whenever someone turns on a tap (or takes a shower, uses the washing machine, etc.), a (small) pressure wave is transmitted through the DMA, which can be detected at the DMA’s entrance. The geometry of the DMA determines the path of these pressure waves and, combined with limited daily variations in drinking water demand, a frequency analysis of the transients produces a 'fingerprint' of the DMA in the spectral domain. Changes in geometry (associated, for example, with the closure of a valve or a leak) result in different paths and therefore a different fingerprint. Although daily use varies a little every day, the frequency spectrum provides a reasonably stable picture as long as the path taken by the transient does not change significantly. When a valve is closed for example, the total volume that flows into the DMA and the pressure do not change. However, because the path of the pressure waves changes there is a visible change in the fingerprint of the DMA. The objective of this exploratory study is to verify whether transients can in practice actually produce a fingerprint of a DMA, and whether this makes it possible for instance to detect a change in the valve position.

Approach: small pilot with closed valves

Under normal circumstances, in which customers continue receiving water, it is not easy to detect anomalous valves by simply measuring the flow volume or pressure at the DMA's entrance. In order to provide a proof of concept, a small DMA (Figure 1.A) was created in Velserbroek (PWN) with a single feed, by closing a number of boundary valves (red circles, Figure 1.A). Two pressure loggers (yellow stars, Figure 1.A) were installed: one at the entrance of the DMA (Hofgeesterweg) and the other at a central point (De Kamp). For 22 days, high-frequency measurements (100Hz) were registered using pressure loggers at two strategic locations. Measurements were made under undisturbed conditions over a few days, after which several disturbances were generated in the DMA, such as the closure of valves and the use of a fire hydrant. During the measurements, the importance of a method to detect incorrect valve positions again became apparent: the valve in the feeder main was not open but closed, and two boundary valves leaked. Because of these anomalies the measurements required a little more time.

Results: concept is promising, a fingerprint of a DMA can in fact be taken

The spectrogram in Figure 1.B was produced by resampling the data from 100Hz to 1Hz. The figure clearly shows the anomalies during the pressure complaints (closed valve on the feeding main), the flushing and opening of the valve on the targeted feeding main, and the control of the boundary valves. The exploratory research shows that transients indeed lead to a fingerprint of a DMA, and that closed valves can be detected. It also shows that loggers with a lower resolution (e.g., 8Hz or 16Hz) perform sufficiently well for the objectives of the DMA fingerprinting. Further research is needed to determine how spectral analysis can be quickly translated or interpreted as an anomaly; whether it also works when DMAs are fed from several sides; what the maximum DMA dimensions are for this application; and whether models can assist in the identification of leak locations or anomalous valve positions.

Application: increasing system knowledge

This new approach gives water utilities the option of acquiring extra information about DMAs, in support of their operational interventions. It offers the prospect of new applications, such as testing whether a valve closes adequately, or of improving the means of identifying the location of leaks – particularly small ones – in the network.

Report

This Exploratory Research project is being followed up in DPWE2020, after which the outcomes will be described in the report KWR 2021.007 - "DMA Fingerprinting Fase II.

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