AUTOMATIC DISTRIBUTION OF PRV FOR LEAKAGE RE-DUCTION

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Abstract: In this work an automatic distribution of the pressure reduction valves (PRV) is proposed. First, a well calibrated hydraulic model is required. The model of Manresa, a city of Catalunya in the mediterranean area, was calibrated using pressure sensors and the background leakage was es-timated using weighted emitter coefficients. Simulating the model in real boundary conditions highlight the areas of maximum background leakage. The manually introduction of PRV shows its effectiveness in the leakage reduction. An algorithm for finding the high-pressure areas and their boundary pipes is presented. The introduction of the PRV, taking into account the flow constraints, produce a new sce-nario. Finally, the leakage reduction thanks to the pressure control by means of new actuators is evalu-ated. The leakage is reduced around 6%.

Keywords: Pressure Reduction, Leakage, WDN

1. Introduction

Leakage in a Water Distribution Network (WDN) is always a main issue. The commnity devotes con-tinuous efforts in its reduction. Furthermore, during drought episodes leakage reduction becomes im-perative in some regions like mediterranean region. In such situations pressure management that leads leakage reduction appears to be suitable both for its effectiveness and the general agreement in reduc-ing pressure service.

There is plenty of research about how to manage pressure within the WDN to reduce leakage. In [6] the authors present a case study for improving the performance of a mul-ty-PRV supply system in 2001. Lately more and more sophisticated control strategies from predictive control [2], distributed control [1] in case studies over the world [3] have been developed. Nevertheless, when a practitioner decides to reduce pressure in a WDN the introduction of new actuators (PRV) must be well evaluated given the investment involved. Moreover, the study is highly site dependent as the geography of the region and the topology of the network condition the decisions. Thus, the use of the hydraulic model and simulations helps the decision making.

In this work an automatic distribution of the PRV is proposed. First, a well calibrated hydraulic model is required. In [4] the model of Manresa, a city of Catalunya in the mediterranean area, was calibrated using pressure sensors and the background leakage was estimated using weighted emitter coefficients. Simulating the model in real boundary conditions highlight the areas of maximum background leak-age. The manually introduction of PRV shows its effectiveness in the leakage reduction. An algorithm for finding the high-pressure areas and their boundary pipes is presented. The introduction of the PRV talking into account the flow constraints produce a new scenario. Finally, the leakage re-duction thanks to the pressure control by means of new actuators is evaluated.

2. Materials and Methods

The starting point of the work is a real network. This network is presented as the case study in the first subsection. Within this network there are different pressure levels that are no optimized in terms of leakage. First, the effect on leakages of a manual distribution of PRV is evaluated. This evaluation suggests an automatic procedure for PRV distribution that can be applied to any network when a hy-draulic model is available. This method is presented in the third subsection.

2.1. Case study

The WDN object of this work includes 39.000 consumers, its mean flow is 373 m3/h. Its model (Fig-ure 1) includes 5123 nodes and 5285 pipes. It is fed by gravity from a tank where an electromagnetic flowmeter provides the global consumption on-line.

The model includes background leakage model given a performance of 85% [5]. Within the WDN there are nodes with pressure from 25 mWC and above 60mWC.

2.2. Manual PRV distribution

The initial simulation of the model produces the pressure values for all the nodes. The valves will be introduced following two criteria. First, the pressure must be over the 40mWC that is considered enough for satisfying the service. Furthermore, they are introduced where the flow cannot be easily diverted increasing the pressure in other regions.

The manual procedure is applied iteratively discarding those valves whose improvement in terms of pressure reduction is negligible and repeating it till there are no more clear possible locations.

This procedure improves the performance as it will be seen in results section but it is time consuming and requires the contribution of an expert.

2.3. Automatic PRV distribution

In order to utilize the information generated by the simulation model a traversal algorithm is used for finding the areas of high pressure and their boundaries. The Algorithm *High pressure zones definition* assigns to those nodes with a pressure over a threshold a label of the high pressure zone where they belong. The boundary nodes between high and normal pressure zones are chosen for valve installation.

Algorith: High pressure zones definition
Input: Node Id; Nodes' Pressure; Links' nodes; Pthreshold
1 Choose a non-visited node i
  If Pi > Pthreshold
    Assign high-pressure zone Visited
    2 Obtain consecutive nodes j
      If Pj > Pthreshold
        Assign high-pressure zone Visited
        Go to 2
      else
        Assign high-pressure zone and boundary
        Go to 1
Return: High-pressure zones and boundaries

3. Results

3.1. Manual PRV distribution

In the first manual iteration 10 PRV are introduced. It reduces the in-flow in 0.59%, after two iterations this reduction goes up to 0.8%. The automatic algorithm improves this result without the expert information. The in-flow reduction is 0.9%. The number of valves in the automatic procedure arrives to 33. The manual study of so many valves appears unrealistic. Table 1 presents the results of three manual iterations and the automatic approach in terms of leakage an pressure reduction. In figure 1 the location of the third manual iteration and the automatic location are presented.

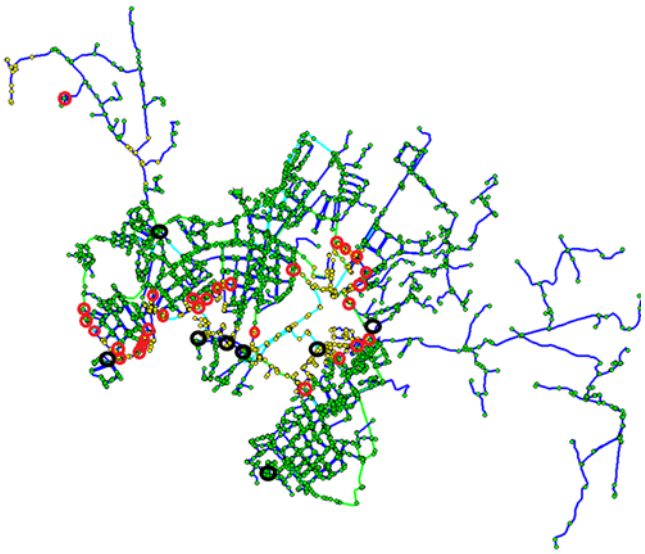

Figure 1. PRV introduced manually after three iterations (black) and those introduced automatically (black and red).

Table 1. Results of three manual iterations and the automatic approach in terms of leakage an pressure reduction

Property	Without PRV	Manual 1st iteration	Manual 2nd iteration	Manual 3rd iteration	Automatic
Number valves	0	10	4	8	33
Inflow [l/s]	58.04	57.7	57.7	57.57	57.514
Inflow decrease [l/s]		0.34	0.34	0.47	0.522
Inflow decrease [%]		0.59	0.58	0.8	0.9
Mean Pressure [mWC]	49.78	48.72	48.74	48.05	47.21
Mean Pressure decrease [mWC]		1.06	1.04	1.73	2.57
Mean Pressure decrease [%]		2.13	2.09	3.5	5.16

4. Conclusions

This paper presents an algorithm that automatically distributes the PRV that allow reducing the pressure in a DMA. This pressure reduction produces a decrease of in-flow due to the dependence of background leakage on pressure.

Results obtained by the automatic algorithm include the valves suggested by a manual iterative process lead by an expert. The algorithm requires many PRV that can be an excessive investment thus a valve selection procedure could be developed as future work. Nevertheless, this work demonstrates that the time-consuming process of finding all the relevant locations for the valves can be automatized.

The in-flow decrease obtained is due to the leakages as demands have been assumed to be all volumetric. The decrease of a 0.9% of the inflow would be higher in a less efficient system (performance of 85%). In this scenario this corresponds to a reduction of 6% of the leakage. Furthermore, there is a component of demand that is pressure-dependent [4] and this increases the actual water saving due to pressure reduction. Such demand reduction should be studied.

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