Segmentation vs Pressure Sensing: A decision support system to obtain the best alternative for water leakage detection in water distribution networks.

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Abstract

Due to direct, indirect and environmental costs, physical water losses are one of the key problems in water distribution networks. The management of such losses is being widely studied and the network segmentation is considered one of the most efficient techniques with higher cost-effectiveness ratio. Recently, and thanks to technological development, several methodologies have also been proposed based on the use of pressure sensors for leak location (Salguero et. al., 2018). Selecting the appropriate technique is not a trivial matter because of the high number of variables involved and because of the influence of manager's experience. In this study, a decision support system is developed to compare both techniques in a quantified way. It is applied to a synthetic case study.

Methods

In order to compare both techniques, an evaluation system is established to assess the pros and cons. To do this, an evaluation system is proposed based on common objectives to be achieved and on criteria and metrics which quantitatively show the level of achievement obtained.

Table 1 – Proposed evaluation objectives

Objectives
1 - Effectiveness and efficiency in the search for unreported leaks
2 - Hydraulic capacity of the final network
3 - Water quality of the resulting network
4 - Implementation costs

Table 2 – Evaluation criteria and metrics

Object.	Evaluation criteria	Metrics	Unit	Weight
1	1.1 – Detection time	Leak detection time	d	0,5
	1.2 - Location time	Leak location time	D	2
2	2.1 - Hydraulic pressure	Pressure variability	mwc	1
		Average pressure excess	mwc	2
		Average pressure deficit	mwc	2
		HP	%	1
	2.2 - Resilience	NFP	%	1,5
		Reliability index	-	0,5
		Deviation from the Reliability Index	%	2
		Robustness Index	-	0,5
		Deviation from the Robustness Index	%	2
	2.3 - Energy	Energy delivered to users	kw/h	1,5
		Energy dissipated in friction	kw/h	0,5
		Dynamic energy efficiency	-	2
3	3.1 - Water age	Maximum water age	h	2
		Average water age	h	1
	3.2 - Chlorine concentration	Chlorine average concentration	ppm	1
		Chlorine minimum concentration	ppm	1,5
4	4.1 - Direct implementation costs	Direct implementation costs	€/km	2
	4.2 - Other costs	Other costs	€/km	1

Application. Case study

As a case study, a synthetic network with a length of 50 km has been used. It is composed of 58 pipes that supply 38 consumption nodes (elevation of every node is 0 m). The volume consumed is 6,500 m^3/day. Both reservoirs have free water surface at ground level 50 m.

For the segmentation technique, 3 sectors are analyzed with lengths of 9.9, 26.3 and 8.2 km respectively and 4 water meters and 8 cut valves have been installed. In the case of sensorization, 15 pressure sensors are homogeneously distributed throughout the network. In both cases, an intervention policy based on the minimum night flow and two correlation teams with an average performance of 150 meters per hour will be assumed.

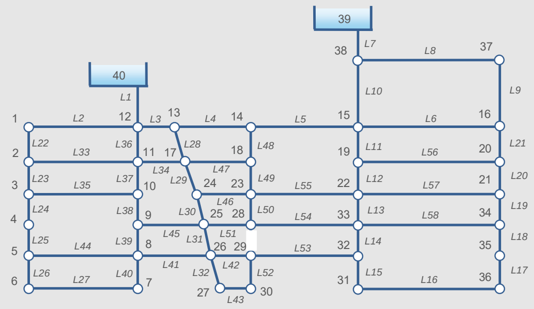

Figure 1 – Network layout

Discussion

Once the value of all the metrics is recovered, these absolute values must be transformed to relative values.

Table 3 – Evaluation of metrics

Evaluation criteria	Metrics	Segmentation Mean Value	Segmentation Rel. Value	Press. Sensing Mean Value	Press. Sensing Rel. Value
1.1	Leak detection time	7	9,22	7	9,22
1.2	Leak location time	6,05	7,98	3,76	8,75
2.1	Pressure variability	4,8	3,20	3,17	2,11
	Average pressure excess	0,04	9,97	0	10,00
	Average pressure deficit	-2,73	3,94	0	0,00
	HP	1,68	5,60	1,15	3,83
2.2	NFP	5	6,67	4	7,33
	Reliability index	0,63	3,64	0,49	5,05
	Deviation from the Reliability Index	-21,8	4,84	0	0,00
	Robustness Index	0,35	3,54	0,42	4,24
	Deviation from the Robustness Index	17,69	6,07	0	10,00
2.3	Energy delivered to users	26,04	5,08	28,05	4,19
	Energy dissipated in friction	10	6,31	8,55	5,88
	Dynamic energy efficiency	57,27	7,15	53,16	6,88
3.1	Maximum water age	24	0,00	6,43	7,32
	Average age of the water	4,83	7,99	2,43	8,99
3.3	Chlorine average concentration	0,79	7,67	0,78	7,56
	Chlorine minimum concentration	0,54	4,89	0,48	4,22
4.1	Direct implementation costs	163,93	7,27	220,00	6,33
4.2	Other costs	0	10,00	0	10,00

With the use of each metric and its weight, the evaluation of each criterion and objective can be calculated.

Table 5 – Evaluation of criteria and objectives

Objectives	Evaluation criteria	Assessment: Segmentation		Assessment: Press. Sensing	
Objective 1	Criterion 1.1	9,22	8,23	9,22	8,84
	Criterion 1.2	7,98		8,75	
Objective 2	Criterion 2.1	6,11	5,89	4,32	5,13
	Criterion 2.2	5,45		5,48	
	Criterion 2.3	6,27		5,75	
Objective 3	Criterion 3.1	2,66	4,18	7,88	6,82
	Criterion 3.3	6,00		5,56	
Objective 4	Criterion 4.1	7,27	8,18	6,33	7,56
	Criterion 4.2	10,00		10,00	

Finally the evaluation of each of the techniques:

Table 5 – Final evaluation of the alternatives

Technique	Final assessment
Segmentation	6,62
Pressure Sensing	7,09

Conclusions

- Although a leak-free network is impossible, detection and quick repair becomes on of the manager's key goals. Several actions may be taken and their comparison is complicated due to the high number of criteria involved.
- This document proposes a decision support system to compare the performance of two techniques such as network segmentation and use of pressure sensors with regard to several criteria.
- This decision system also considers the manger's experience.
- The final result will depend on network layout and the management policies followed.

References

Salguero, F. J., Cobacho, R. and Pardo, M. A. (2018)."Unreported leaks location using pressure and flow sensitivity in water distribution networks". Water Science and Technology: Water Supply ws2018048.