Effect of Pressure Management on Performance Indicators of Water Distribution Network in Tehran

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Abstract

Limitation of water resources, population growth, increase of water consumption per capita, industrial and agricultural development, highlighted the non-revenue water (or unaccounted-for water) as an important issue especially in developing countries. Therefore managers and decision makers in water and wastewater sectors should consider this important issue in their plans. Pressure management is one of the most effective and economical methods for water loss reduction in distribution networks. In spite of many studies which describe the principles of pressure management theory, however, only few studies on pressure management at field are available, therefore more studies on pressure management at field are necessary. In this paper, effect of pressure management on improving of performance indicators of water distribution network was studied. To perform the study, a small water distribution network in Tehran city was isolated. A modulated pressure reducing valve (PRV) with an ultrasonic flowmeter used to control and monitor the flow parameters. Some different pressure patterns were generated by the modulated PRV applied on the network and for each case, minimum night flows were measured. By suitable adjustment of pressure patterns, no complaint reported by consumers during the study period. Results showed that a good pressure management could significantly decrease the minimum night flow and improve performance indicators.

Keywords: Leakage, Minimum night flow, Performance indicator, Pressure management, Water network

Introduction

Considering water scarcity, population growth, increase of water consumption per capita and high cost of drinking water production, optimum usage of existing water resources is a vital issue. In developing countries, this important issue has a greater significance because of limited water resources on one hand and population and industrial consumption growth on the other hand. To deal with the problem of drinking water shortage, conventional water resource management methods are not solely sufficient and modern water supply management methods must be used as a new way which enhances efficiency of water distribution system. Pressure management is one of the most effective solutions among the water demand management methods.

The main objective of reducing leakage in arid or semiarid regions is responding to water shortage. Another important objective relate to economical aspects, such that by reducing unaccounted-for water costs, consumption of electricity, storage, treatment and pumping are also reduces and because of water cost payment there is revenue for water and wastewater companies. Also if new demands of customers could be satisfied by decreasing the unaccounted-for water, there would be a great saving in cost of developing new resources (e.g. making new dams and reservoirs and construction and equipment of treatment plants).

Many studies have been recently carried out to reduce the unaccounted-for water, however only a few of them have considered the developing countries conditions. On the other hand efforts to decrease unaccounted-for water in developing countries turn into impasse by factors like improper leakage control, lack of effective management performance and general regulations and etc (Chowdhury et al. 1997).

Although pressure management is one of the best methods for water demand management, some operation managers ignore using this method in their water distribution networks and would prefer to use other methods such as water rationing when they face water scarcity. It may be because of lack of experience on pressure management. The main objective of this paper is to show the good results and practicability of pressure management especially in existing and old water distribution networks.

Background

Excess pressure in network causes an increase in leakage, consumer's consumption, network bursts and a decrease in effective lifetime of equipment.

For existing networks, pressure management is the most practical method for reduction of leakage. Therefore pressure management is a practical, effective and low cost solution to control amount of leakage solely or in combination with other methods such as using varied speed pumps and water surface elevation in reservoirs. Some advantages of pressure management are reduction in servicing costs, lower emergency services and lower dissatisfaction of consumers (Thornton and Lambert 2006). For each type of leakage, pressure reduction can reduce water loss. Many pieces of researches have been allocated to this interesting topic such as: (Lambert 2003, 2004) (Marunga et al. 2006) (Walski et al. 2006), (Tabesh and Humehr 2007), (Karamouz et al. 2006).

Thornton and Lambert have shown that reduction of pressure and its stabilization in the network not only reduces the amount of existing leakage but also decreases occurrence of future leakages (Thornton and Lambert 2006).

Water and wastewater companies can save huge amounts of money by controlling leakage. For example a city of 25000 population was reported to save a cost of 100000 $ annually only with 5 percent reduction of leakage (Zimmerman et al. 1987). In a study in Melbourne of 4000 consumers, pressure management could save 20 to 55 percents of consumed drinking water in different areas (Burn et al. 2002).

Pressure management by modulated PRV

Water distribution networks are usually designed based on peak hourly demand. The water consumption in the first years of operation is lower than these values. The same is true for some days in winter and also some hours during the night time. Therefore in non-peak hours, the amount of pressure in the network is larger than the necessary values. In such conditions excess network pressure in low elevation regions especially in the night hours can cause pipe bursts.

Ordinary PRVs is adjusted base on a certain output pressure so that it cannot exceed beyond this adjusted pressure. On the other hand, output flow of PRVs must provide a minimum pressure needed by consumers in peak hourly demand. These conditions lead to an excess network pressure in non-peak hours.

By installation of modulated PRV, the downstream pressure can be adjusted to the range of minimum required pressure during the both night and day time.

Case study & methodology

A water distribution network in Tehran city was chosen for this study. Region is supplied with only one reservoir. After isolation of the region, assembled a modulated PRV in the entrance of the isolated region (Figure 1.1), moreover, a digital pressure regulator and a pressure logger were installed to induce different pressure patterns. Also an ultrasonic flowmeter was installed downstream of the reservoir used in order to measure input flow to the isolated region.

Since at the begging of study the optimum pressure pattern was not exactly known, therefore after preparation of isolated region and setting up the equipment, different pressure patterns were applied to the modulated PRV as try and error process to find the best pattern. This process continued by applying more pressure reduction to the PRV until the first complaint was received from the customers. These patterns are shown in Figure 1.2. On the other hand, by having different pressure patterns and measurement of night flow for each one, it could be possible to follow changing of night flow at variance with pressure.
For each patterns inflow was recorded in 10 minute intervals and the measurements were continued for a week. Output pressure of PRV before installation of modulated PRV was 50 meters. It should be noticed that output pressure patterns of PRV were adjusted such that the costumers didn't face any pressure shortage and no complaint was reported during the study. In Tehran city, the water and wastewater company is responsible for providing pressure at most five floors buildings. Taller buildings have booster pump for providing additional required pressure.

Different conditions and information of measurements are shown in Table 1.1. For better comparison of mentioned patterns (Figure 1.2), average amount of applied pressure patterns during 24 hours is also mentioned in table.

Results & discussion

After completion of measurements, the data was analyzed and following results are obtained.

Reduced minimum night flow

Minimum night flow is composed of network leakage and consumer's night consumption. Since amount of consumer's night consumption is almost constant, the minimum night flow could be a convenient indicator for estimation of network's leakage. Minimum night flow occurs at midnight hours and especially between 12 to 4 AM. Table 1.2 shows the measurement results of minimum night flow in the different phases (weeks).

As the results of Table 1.2 indicate, by reduction of outlet pressure of the PRV, minimum night flow reduces. In Figure 1.3 reduced outgoing pressure of the PRV (%) versus percent of reduced minimum night flow is shown for different phases. In this figure, reference outlet pressure was outlet pressure of PRV in phase 1 e.g. 50 meters.

Results of Figure 1.3 are fitted by a linear curve. One of the causes for sparsity of points in Figure 1.3 was field conditions and variation of temperature during the measurement periods. However, the trend of results shows a reduction of minimum night flow with reduction of pressure and a potential for reduction of night flow more than 30 percents. It should be also mentioned that no complaint was received from consumers when pattern 3 was applied to themodulated PRV.

Performance indicators improvement

Performance indicators can use for evaluation and comparisons situation or determination of leakage level.

Technical Indicator Real Losses (TIRL), Unavoidable Background Real Losses (UBRL) and finally Infrastructure Leakage Index (ILI) of the network for different phases of 4, 5 and 6 were calculated. Results are shown in Table 1.3.

As results of Table 1.3 show the amount of ILI index reduces from 45 in phase 4 to 21 in phase 6.

In Figure 1.4, reduced outgoing pressure of PRV in percent is shown versus reduction of ILI index in percent. In Figure 1.4, the calculated data is fitted by a curve showing the trend of data.

To demonstrate calculation procedure of these indexes, computation steps for phase 4 as sample are given below.

The network has 280 service connections and distribution pipes length of 3591 meters.

In studied pilot, distance of connections from main line is 10 meters in average. Based on existing data, density of connections is:

$$DC = 280/3.591 = 78 conn./km$$

Amounts of Technical Indicator Real Losses (TIRL), Unavoidable Background Real Losses (UBRL) and Infrastructure Leakage Index (ILI) are calculated based on equations used in reference (Preston and Sturm, 2003) as follows:

$$TIRL = \frac{3111.47 m^3 \times 1000 lit}{7 day \times 280 conn.} = 1587 lit/conn./day$$

$$UBRL = (9.6/DC + 0.6 + 16 \times L_p / N_c) \times P$$

$= (9.6/78 + 0.6 + 16 \times 2.8/280) \times 40$

$= 35 lit/conn./day$

$ILI = TIRL/UBRL = 1587/35 = 45$

In Figure 1.5, ILI indexes for different countries and ILI indexes in phase 4, 5 and 6 are shown.

Conclusions

In present study, results of pressure management in an isolated network are analyzed. Results showed a potential for reduction of night flow more than 30 percents by adjusting the upstream network pressure.

It is experienced that pressure management is practical method for leakage reducing even for old water distribution networks.

This study also showed that in the selected area which was a regular and a general sample of Tehran water network, there was a considerable potential for leakage reduction.

Since pressure management in addition to leakage reduction has some more benefits, applying this method is recommended as practical and economical method especially for existing networks. However, due to different situations of networks, more studies are needed to evaluate the effect of pressure reduction on improving of the performance indicators.

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Figure 1.1 Satellite photo of studied region, yellow lines (thin lines) show distribution network, white lines (thick lines) show region border

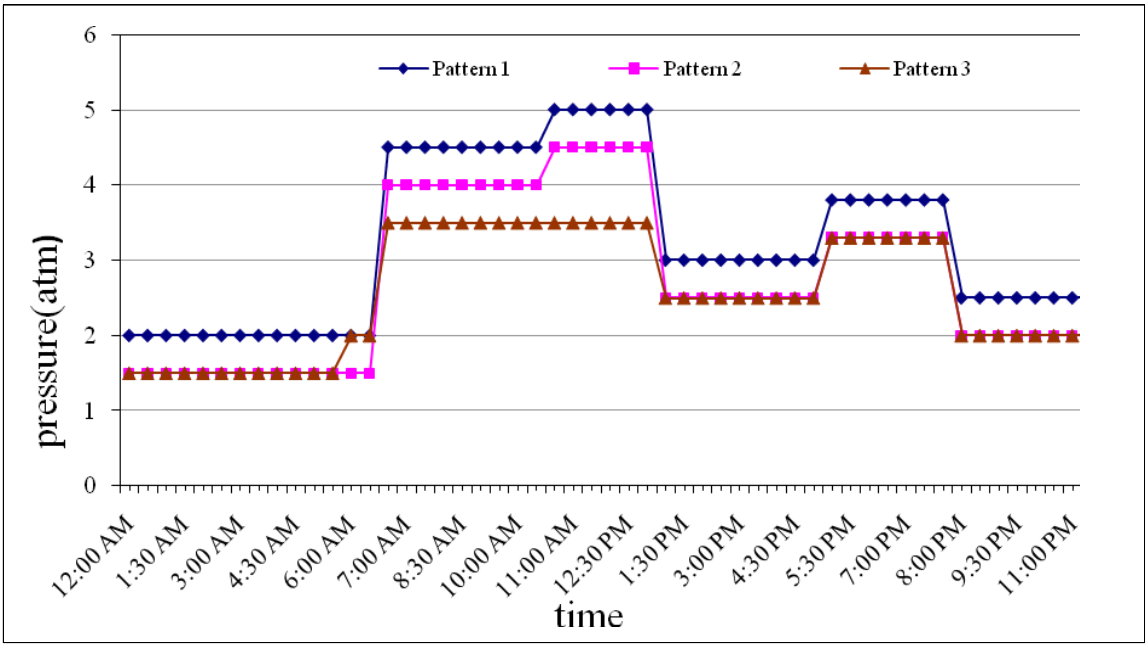

Figure 1.2 3 patterns applied on the modulated PRV

Table 1.1 Different conditions of measurements

Purpose	Phase	Measurement dates		Output pressure of PRV
		from	to	
Measurement of minimum night flow	1	07/10/13	07/10/20	Constant 50m
	2	07/10/20	07/10/27	Pattern 1(average 31.94m)
	3	07/10/27	07/11/3	Pattern 2(average 26.94m)
Measurement of minimum night flow and performance indicators	4	08/1/2	08/1/9	Constant 40m
	5	08/1/9	08/1/16	Constant 33m
	6	08/1/16	08/1/23	Pattern 3(average 25.27m)

Table 1.2 Minimum night flow and upstream pressure of the isolated region

phase	Output pressure of PRV in time of minimum night flow(m)	Minimum night flow (m^3/hr)
1	50	21.96
2	20	19.26
3	15	10.69
4	40	18.55
5	33	16.79
6	15	14.44

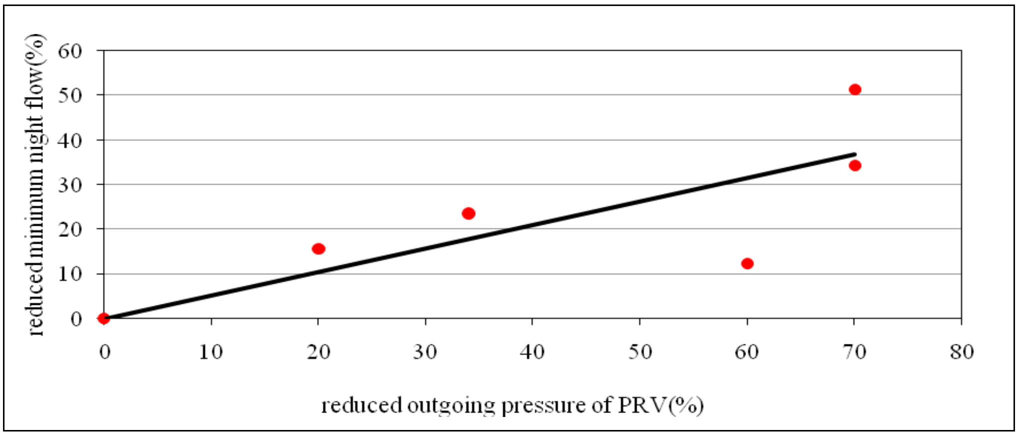

Figure 1.3 Reduced outgoing pressure of PRV (%) versus reduced minimum night flow (%)

Table 1.3 Calculated performance indicators

Phase	TIRL(lit/conn./day)	UBRL(lit/conn./day)	ILI
4	1587	35	45
5	853	29	29
6	498	23	21

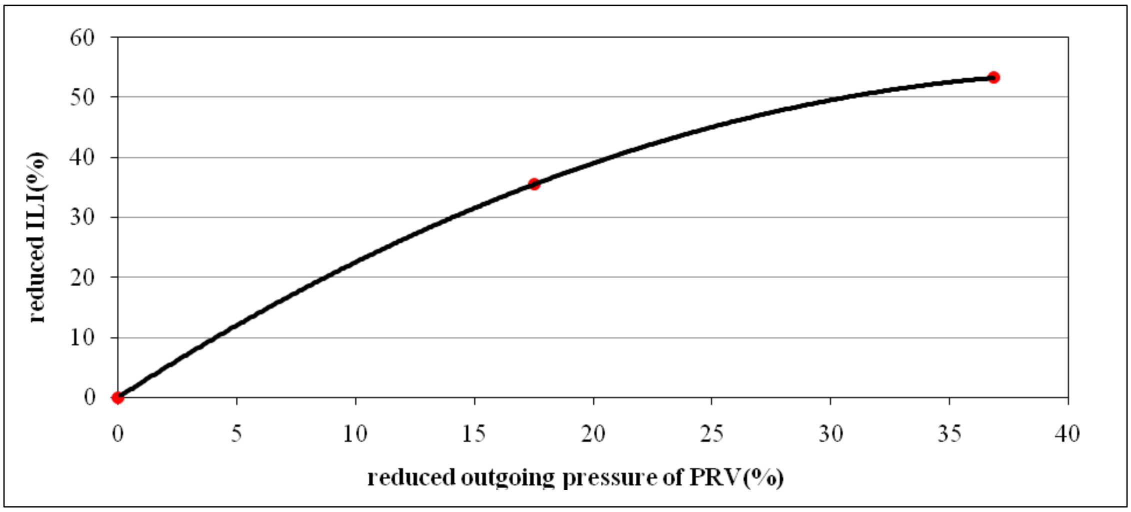

Figure 1.4 Reduced outgoing pressure of PRV (%) versus reduced infrastructure leakage index (%)

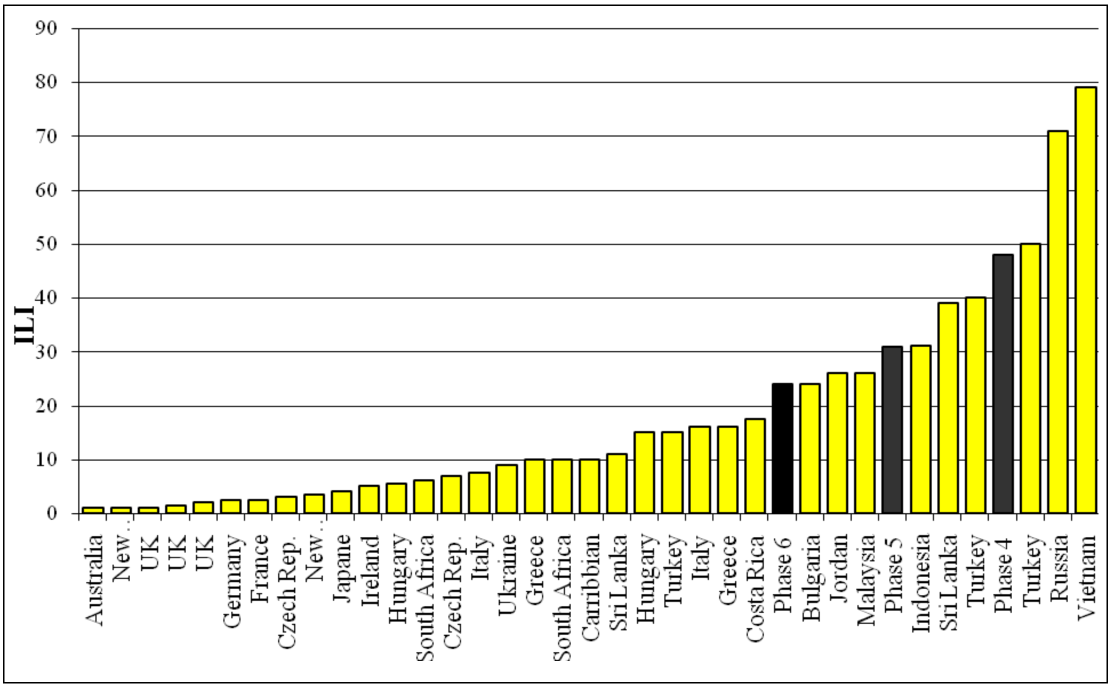

Figure 1.5 Comparison of ILI index for different countries (WB-Easy-Calc, 2006) and phase 4, 5 and 6 for the studied pilot