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Research Article

PRESSURE MANAGEMENT TO REDUCE LEAKS IN WATER SUPPLY NETWORKS

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ABSTRACT
Water networks and water distribution as a hydraulic transmission and distribution system, has been the focus of researchers. Water transmission factor in networks is energy difference (pressure head). But because of extra network pressure, leak as an adverse event which is directly related to the pressure will become visible. Leak causes the shortage of water resources and imposes the cost of pumping, water purification and its transmission on the producer and takes consumer out of the cycle respectively. In this research, with the aim of pressure and leak control, one of the Integrated Water Supply and Sewage Company of South Khorasan was selected and this rural water supply based on demand approach (DDSM), a common technique in which the demand is constant in the nodes was analyzed hydraulically. By installing reducing valve (PRV) at critical points and timing to provide standard pressure on all nodes in the network, the effect of pressure intelligent management on the network was evaluated. Then its effect on controlling the leak was investigated. The results showed that the pressure smart control by valves is a suitable method for managing the suitable consumption of water and considerably reducing the network leakage. With 26.45% reduction of the average pressure, the amount of 589 cubic meters of water will be saved per year and 19.38% of the leakage be reduced.

Keywords: *Hydraulic Analysis Based On Demand (DDSM), Pressure Breaker Valve (PRV), Pressure Management, Water Leakage*

INTRODUCTION
Supply history began when a group of human selected a group life and for the provision of water, constructed the first cities along the river. Chinese, Indians, Babylonians and Egyptians were the first nations that left some footprints in the field of water works. In Iran Urban Water Supply was studied for the first time in 1922 and part of Abadan, Mashhad and Birjand were piped.
In general, the main cause of water in Network is pressure head difference between two points respectively. More pressure than standard in network nodes cause adverse events of leak. Water leaks in water supply networks are causing a shortage of water resources and take the amount of water that actually imposes pumping and treatment costs on the producer out of consumption cycle. Control of the leak is one of the ways to optimize the use of available water resources. This will result in saving resources and reducing costs. According to Figure 1, leakage reduction methods include passive control (daily dealing with accidents and reported fractures and the speed and quality of repair), active leakage control (direct finding of the leak and repair it), management of pipelines and pressure management.
Network pressure management is the most efficient and simplest method of reducing leakage methods. For this method, there are tools that can point to the correct selection of the site of the reservoir, the project of pressure zoning (pressure zone), pump control, control of water levels in storage tanks, pressure adjustment pools establishment and use of pressure and flow control valves (MOE, 2007).
In a case study of Seattle with the performance of peak consumption reduction methods, despite of a 20 percent increase in population, daily peak reduced about 30 percent (Jalili *et al.*, 2008). After applying pressure management using PRV valve with a case study on the city Chykanga, loss reduction of 32% have been reported (Maronga *et al.*, 2006), in some studies, integrated use of GIS and Water GEMS to hydraulic management of urban water distribution networks was evaluated and good results have been achieved (Ajori, 2009). Research has shown that by using EPANET and also genetic algorithm

optimization tool software can present a model for locating and regulating pressure breaker valves to control the pressure and leakage reduction (Araujo, 2006; Cheung 2005). In the pressure management to reduce water demand and leakage, stated pressure management tools that one of them is network pressure management using the water tap PVR (Mistry, 2003). Pressure control is introduced in three variants: (a) pressure control by using constant outlet pressure breaking valves, (b) intelligent control pressure with flow regulator which by using of a temporal pattern change the pressure in the hours defined with switching on the pressure breaking. (c) Intelligent control pressure with flow regulator (Yoneslo, 2006) by noting of a relationship between pressure and leakage in water distribution networks reported that one of the not accounted components of water in the distribution network is leakage that allocates the most of it to itself and one of the leakage, is network pressure (Ardakanian and Ghazali, 2003). Also by using of genetic algorithms and pressure and flow regulator valves can offer a model for the reduction of excess pressure in distribution networks by applications programs (Tabesh *et al.*, 2007).
In this research to manage the pressure and the amount of water leakage, using of pressure breaker valves in a water network under the cover of rural water and waste water company of South Khorasan is studied. The network was modeled in the soft ware environment so network is simulated in stable condition. According to preliminary data and network design in the software, modeled network is equipped with valves, pressure regulator with fixed output and an intelligent pressure control valves. Finally, the network condition pressure has been studied in the before and after the pressure intelligent management and by using the theory of FAVAD leakage is calculated.

MATERIALS AND METHODS

Pressure Reducing Valves are used in order to eliminate excess pressure in the network by adjustment of output pressure in installation position. These valves have the effect of pressure breaking when the pressure amount in their location become higher than in the downstream and less than upstream pressure. According to Figure 1, the energy equation between pressure relief valves installation location and an arbitrary node in the network is as follows (Monzavi, 1999).

$$\frac{P_j}{\gamma} + Z_j = \frac{P_v(u)}{\gamma} - \Delta h_v + Z_v - h_f \quad (1)$$

$$\frac{P_j}{\gamma} = \frac{P_v(d)}{\gamma} + Z_v - Z_j - h_f \quad (2)$$

In which, $P_v(u)$ and $P_v(d)$ are as inlet and outlet pressure of relief valves, P_j and Z_v is pressure and height of node J respectively. Also h_f is the dynamic loss of the two points and Δh_v is loss amount of static head of pressure in valve respectively. The pressure of arbitrary node j in the water supply networks is a function of time and place and equation 2 can be used for its calculation.

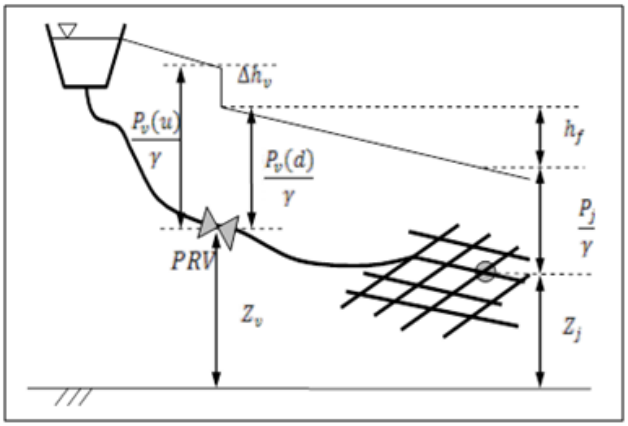

Figure 1: The effect of pressure reducing valve to reduction of pressure (Monzavi, 1999)

Kinds of Pressure Regulator Valves

Pressure breaker valve with constant output: the output pressure setting in this type of valve on the required pressure in the critical points is done in a way that the peak usage during the day to keep the minimum pressure in the point at standard level. This setting where the demand is less than maximum increases the pressure of network and in non-peak times of consumption and especially in mid-night, forces unnecessary pressure to the network.

Intelligent pressure valve with timing of pressure: in this system the pressure oscillation is created in the exhaust of pressure relief valve and input to the location. Amendment of the voltage by pressure breaker valve permits a larger amount of medium pressure than equivalent pressure of valve decrease with constant output. This resulted in a further reduction of water leakage in the network. Amendment of the pressure flow is done by means of the pressure controller tool (Figures 2).

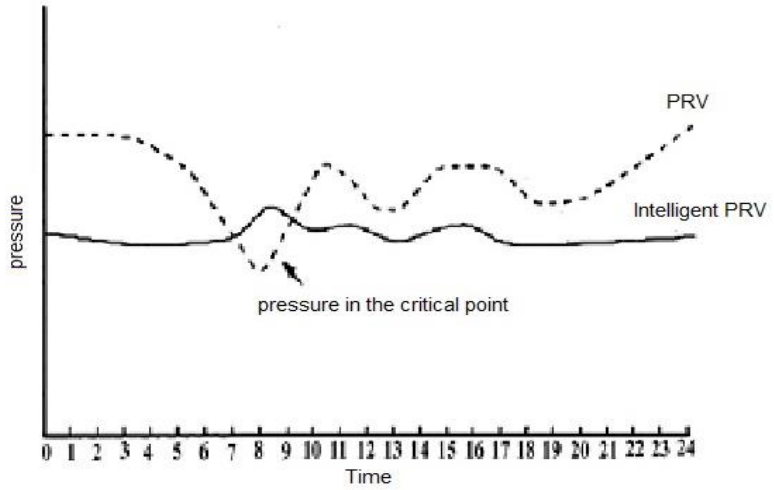

Figure 2: Pressure oscillations for two types of pressure relief valvesUsed software

Hydraulic analysis, involves finding all the unknown parameters of the pipeline and network nodes using basic information of pipeline and nodes. If the research method has high degree of accuracy, the results will be closer to the field studies of the network and will respond to lots of different mechanical and hydraulic factors well. Network analysis method based on stable demand (DDSM) is the first and most common method of network analysis. This method based on an approach of constancy of demands and regardless of pressure mount is constant in nodes.

Among software based on the production method and are available on the market could refer to WaterGEMS software. In this research in order to analyze the various modes of network hydraulically before and after the installation of pressure breaker valves the software was used. The advantage of the software is that unlike all previous softwares which needed manual calculations and preliminary maps to enter basic information, has the combination ability with ArcGIS, AutoCAD and Excel as well as ability of removing of additional computing.

In addition, has the stress management computing technology by imaginary installation of valves and drawing of different kinds of contour lines, longitudinal profile as well as software support HAMMER (analysis program of water strike).

Studied Water Supply Network

Water supply complex of Aliabad in the city of Birjand, South Khorasan province, has 7 villages and a population of over 308 households and 1009 people, water is exploited from a deep well with a depth of 175 m and a flow rate of 19 liters per second of water and supplied by the concrete storage tank of 500 cubic meters located in well equipment.

The complex has a 22-kilometer water pipeline and 18 kilometer distribution network and 353 branches respectively. Geographical area and plan of the network layout is seen in Figure 3.

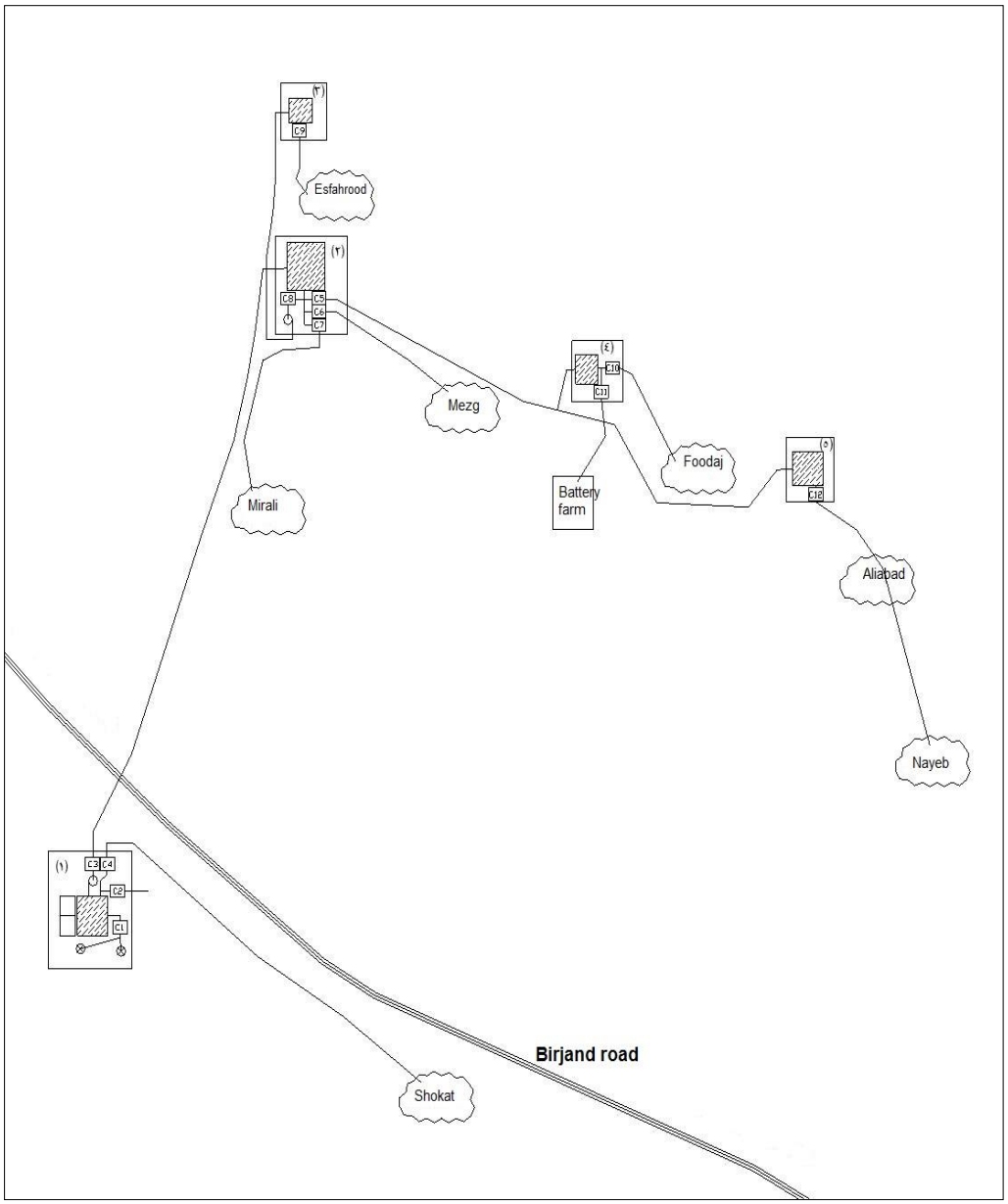

Figure 3: Geographical location and flat plan of studied complex

Water Consumption Pattern in the Network

According to the recorded data the studied water supply complex in customer affairs of south Khorasan Abfa company in 6 periods of 2014 and according to the covered population in each village, network consumption per capita was calculated and estimated. Due to figure 4, the average of this amount per person is 133.9 in liters per day.

This amount in the calculation of customer's demand and hydraulic analysis of network with the households is considered as 3.82.

Hourly Fluctuations of Water Use in the Network

To estimate the amount of demand during different hours of the day in this research the collected data of inlet water to the network in the outlet of storage tank at the specified time was used. Based on this analysis, it was found that the highest rate of demand is 1.71 at 11 am and the lowest is 0.4 in the midnight hours respectively. Hourly fluctuations graph of consumption is seen in Figure 5.

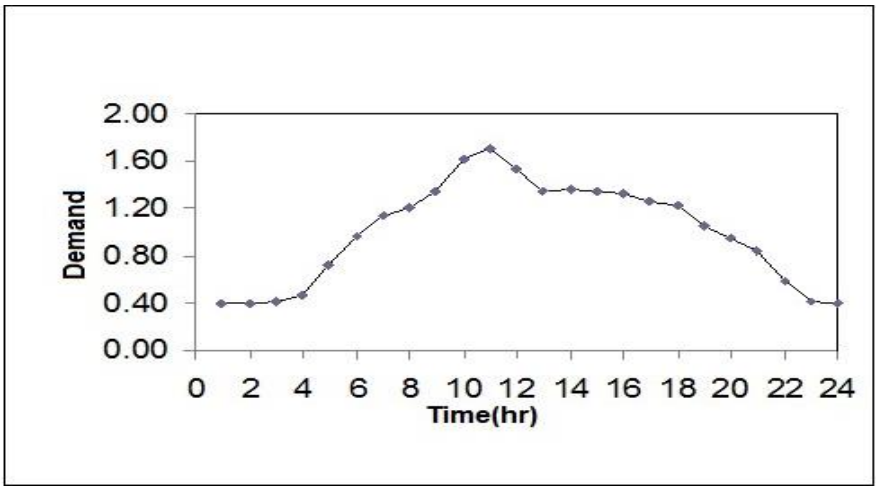

Figure 4: graph of per capita water consumption in each period of the study in 2014

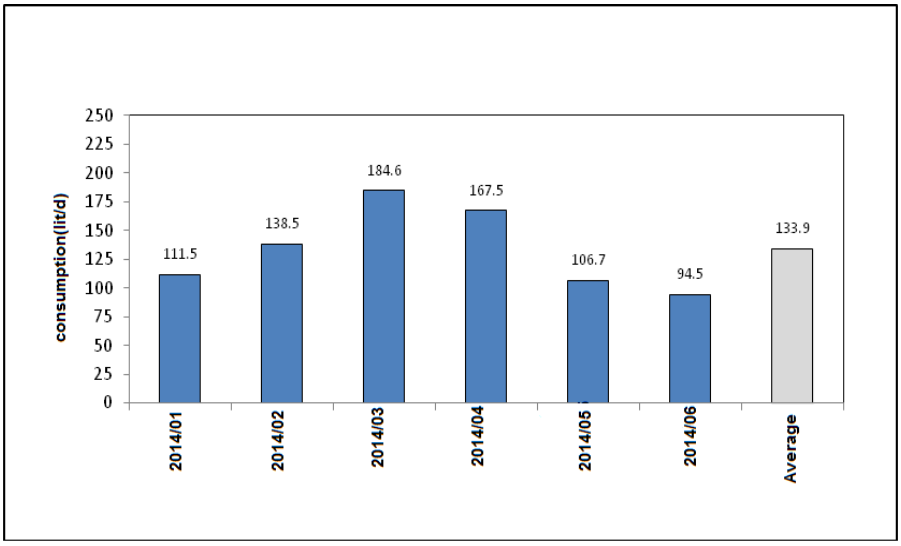

Figure 5: hourly fluctuations of consumption of studied area in the hours of the day

Hydraulic Analysis of the Network

To analyze the network hydraulically, at first the data related to network components using AutoCAD and Excel softwares were called to WaterGEMS software environment and received. Generally, the network has 78 tubes, 77 consumption nodes, one storage node and a node of pressure breaker valve. Due to the hourly fluctuation pattern (Figure6), the network was studied in two different modes and analyzed hydraulically.

1. Checking of the network containing pressure relief valves with fixed output: In this mode a pressure breaker valve as shown in Table 1 with an inlet and outlet pressure and head of location height in the network were applied. After analyzing the network hydraulically, maximum pressure of 18 knots and equal to 41.30 meters at 2 am and the most critical pressure of node 53 equal to 16.70 meters was observed at 11 am. Based on the hourly fluctuations and variations in the pattern of consumption at different times of day, pressure obtained with this method for each node when the output Pressure Reducing is constant follows the consumption of node. In this mode the pressure on peak hours of consumption reaches to the minimum and vice versa in the mid-night to maximum. This leads lack of network acceptance in consumption peak and the imposition of additional pressure in mid-night that is accounted as the major drawbacks of the state.

Table 1: Specifications and studied network pressure breaker valve position

Outlet pressure (m)	Inlet pressure (m)	Height head (m)	Diameter (millimeter)	Installation position of Valve	Pressure breaking valve
25	54.70	1523	150	Transferring route	Num.1

2. Examination of the network with pressure breaker valve by timing of pressure: by having the pressure of nodes in the network using of network analysis method with constant outlet pressure breaker valves and discharge pressure valve timing according to specific temporal pattern, in addition to adjust the maximum pressure in mid-night can adjust the critical pressure of peak consumption hours to the standard pressure. Outlet pressure adjustment of pressure breaker valve during day times can be done by opening the valve. In this study, after repeated calculation, the pattern shown in Figure 6 for the valves in the network was studied.

After applying the pattern and hydraulic analysis of the network by software it was detected that the maximum pressure was related to knot 25 in transmission line and is equal to 41.27 at 11 am that shows the appropriate pressure supply during peak hours. Also the most critical pressure is in node 56 to the 25.10 meters at 11 am.

RESULTS AND DISCUSSION

By the implementation of intelligent management of pressure in the water supply complex was found that the existence of pressure breaker valve in the network leads to considerable reduction of pressure amount.

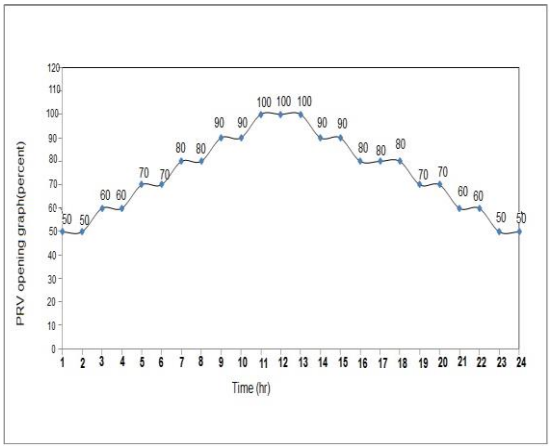

Figure 6: pressure reducing valve opening graph during hours of the day

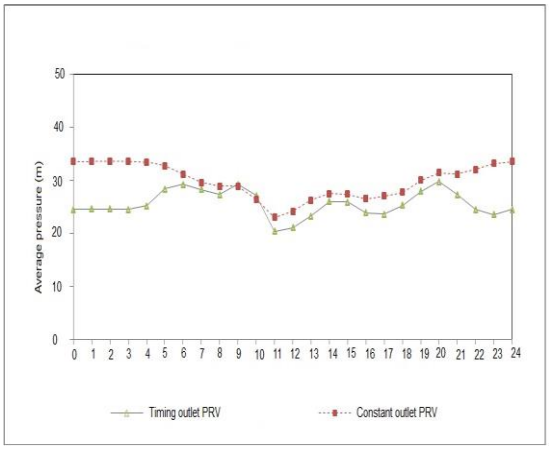

Figure 7: The graph of total average pressure of studied network in two states

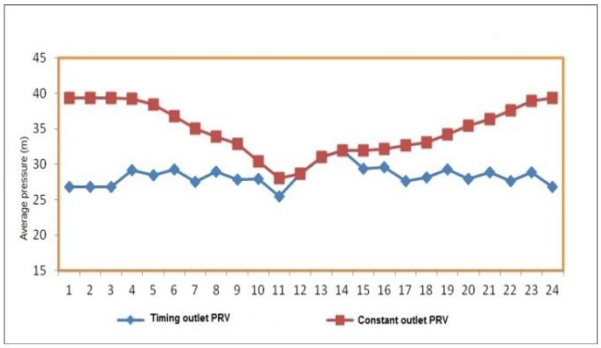

Figure 8: pressure graph of node 24 in transmission line in two cases

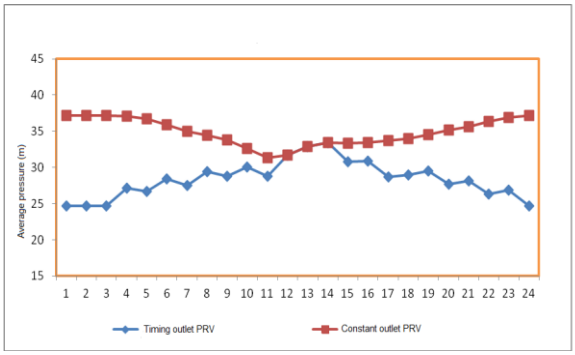

Figure 9: Pressure graph of node 35 in transmission lines in two cases

As the average pressure of places 1 and 2 are 32.74 and 26.50 meters respectively. Also according to the diagram average pressure of the network for above two states during day times (Figure7), it is seen that with timing of pressure by pressure breaker valve, the network pressure at different times has less volatility and becomes more uniform. Figures 8 and 9 show the examined pressure condition of critical nodes of network pressure and hourly comparison of both administered states.

Water leakage which is the main non-controlled consumption is happened through holes, cracks and breakage of pipes, branch, valves and conjunctions of the network and due to improper design and excess pressure, corrosion, strike, improper quality of performance, long life of network, hydraulic phenomenon of water strike and……. To estimate the amount of water leaking in the network pores formula was used.

$$Q = KP^n \quad (3)$$

in which Q: seepage, P: water pressure inside the pipe and K is coefficient of leakage respectively. The exponent n is 0.5 in free space, while in the water supply networks due to being buried tubes changed to 1.5. Given that in the studied network worked pipes made of polyethylene, number of events in 1393 is to 126 cases, and mostly is of the crack and gimlet of the joints. Therefore, using graph theory FAVARD that is the most popular method of calculating the value of the exponent n, the number 1.17 is recommended (DOE, 2007).

To determine leakage amount annual balance method was used. In this method existed parameters in the balance table of production amount 9772, consumption 6735 and the total network leakage was calculated 3037 cubic meters in 1393, respectively. Due to the hourly fluctuations in the pattern of consumption and network pressure in both studied systems, it was found out that intelligent management plan of pressure in the network leads to reduce water leakage to 19.38 per cent and annual saving to 589 cubic meters that is observed in Figure 10.

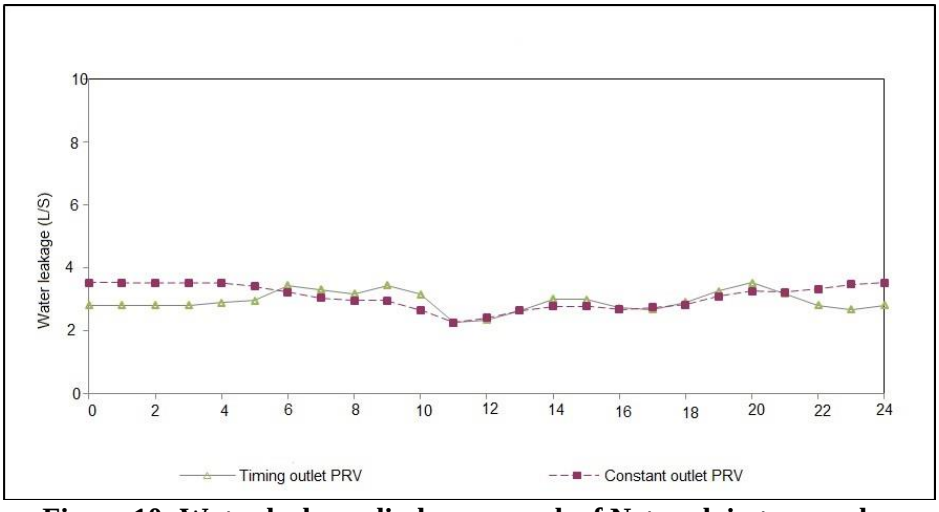

Figure 10: Water leakage discharge graph of Network in two modes

As shown above (Figure 10) using a pressure breaking valve fixed output when the demand is less than the maximum leads to increase pressure of network and during non-peak times of consumption, and especially in mid-night, imposes unnecessary pressure to network that increases water leakage in the network. But by using the pressure breaking valve and timing of the pressure, flow adjustment by pressure breaker valve permits medium pressure of the network to a larger amount of valve equivalent pressure with constant output decreases. This resulted in a further reduction of water leakage in the network.

Conclusion

Additional pressure in water supply networks will increase the consumption, leaks and accidents number. Pressure control using the pressure regulator valves has effective impact on controlling the amount of

additional pressure and water leakage in the network. Implementation of intelligent management of pressure causes that the pressure distribution occurs at different times the day with relatively good uniformity.

Given the direct relationship between the numbers of incidents with pressure in the network, the implementation of the pressure reduction strategy in the network leads the considerable reduction of fractures number in pipes and branches.

Functionality Software Water GEMS is very good in the modeling and hydraulic analysis of water supply networks, as well as combination with the software ArcGIS, AutoCAD and Excel. According to the study, the use of pressure valve timing and implementation of intelligent management of pressure averagely decreases network pressure to 26.45 percent and 19.38 percent of the leak.

It is recommended in future studies to use powerful and new optimization tools for minimizing of additional pressure on network nodes and the pressure regulating valve opening and optimum installation site of Pressure Reducing Valves.

Also use other tools in the software Water GEMS as well as flow control valve (FCV), pressure sustaining valve (PSV), pressure tank and storage tank for pressure management and compare the results.

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REFERENCES

Ajori H (2009). The use of integrated GIS and WaterGEMS for hydraulic management of water distribution networks. *The Second National Conference on Water and Sanitation with a View to Exploitation* 155-165

Araujo LS, Ramos HM and Coelho ST (2006). Pressure Control for Leakage Minimisation in Water Distribution Systems Management. *Water Resources Management* **20** 133–149.

Cheung PB, Van Zyl JE and Reis LFR (2005). Extension of EPANET for Pressure Driven Demand Modeling in Water Distribution System. *Water Resources Management*.

Jamasb and Tabesh (2010). Calibration of EPANET hydraulic analyzing model using genetic algorithms. *Water Distribution Systems Analysis 2008.*

James Richard Newbold (2009). Comparison and Simulation of a Water Distribution Network in EPANET and a New Generic Graph Trace Analysis Based Model. Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Environmental Engineering.

Ministry of Energy (1386). Instructions on how to identify and study of non-determined factors in water and its reduction strategies. Publication No. 308 (a). Ministry of Energy. 13-20 and 168-227

Monzavi MT (1999). *Urban Water Supply*, tenth edition (Tehran University Press) Tehran 136-175.

Tabesh M and Hoomehr S (2007). Consumption management in water distribution systems by optimizing pressure reducing valves' settings using genetic algorithm. *Desalination and Water Treatment* **2** 95-100.

Yoneslo P (2006). Optimization of hydraulic behavior of water distribution networks using intelligent management of pressure. *The Second National Conference on Water and Sanitation with a View to Exploitation.*