reliability are obtained via averaging over time and network nodes.

3. Discussion of Results

The any town network has three parallel pumps in which pump rotation speed values during 24 hours of a day for these pumps are considered as decision variables. By performing the optimization process, the following Figures are obtained for each kind of reliability. As shown in Figure 2, pump reliability is reduced or on the other hand pump repair and maintenance costs are increased by decreasing pump rotation speed values.

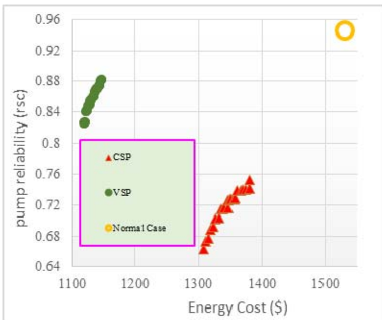

Fig. 2. Optimization of energy cost and pump reliability

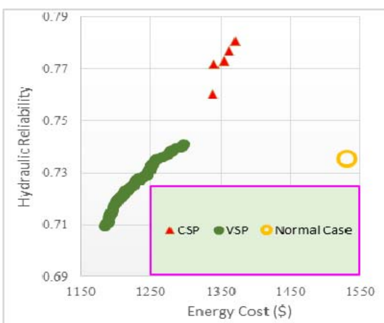

Fig. 3. Optimization of energy cost and hydraulic reliability

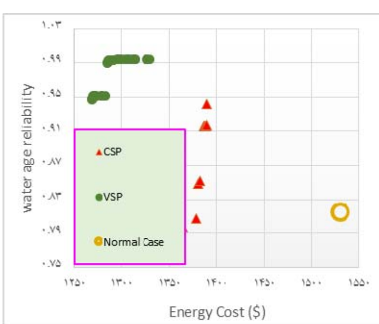

Fig. 4. Optimization of energy cost and water age reliability

4. Conclusion

The most important conclusion of this research is that there is no unique combination of pump rotation speed values such that all three kinds of reliability are increased simultaneously similar to when they are entered into the optimization process alone.

Optimization of Energy Costs Considering Hydraulic and Quality Reliability Using Ant Colony Algorithm

Mahmood Fotuhi[1*] Masoud Tabesh[2]

1. Introduction

Pumping energy costs form an important part of the operational cost of water distribution systems worldwide. Savic et al. (1997) formulated a pump scheduling problem as a multiobjective optimization problem based on the concept of Pareto optimal ranking of Goldberg (1989). Rouhiainen et al. (2003) presented two new Pareto-based multiobjective genetic algorithm techniques for determining the optimal schedule of chlorine dosing with multiple conflicting objectives: primarily disinfection control and aesthetic control. Doby et al. (2001) investigated a genetic algorithm-based method for determining the minimum cost design of looped networks while considering the residence time of water in the network as a quality surrogate. Farmani et al. (2006) performed multi-objective optimization of the design and operation of water distribution network in which they considered three objectives including cost, reliability and water quality in their study. They presented results for the pay-off characteristics between total cost, reliability and water quality, for 24 h design and five loading conditions.

2. Methodology

In this research, multiobjective optimization of energy costs is performed for any town network using ant colony algorithm by considering variable speed pump (VSP) and comparing it with constant speed pump (CSP). Energy cost is obtained through the following equations.

$$\text{MinZ} = \sum_{P=1}^{NP}\sum_{t=1}^{NT} \text{EnergyCost}_{pt} \quad (1)$$

$$(\text{Energy})_{pt} = \frac{Y_w \times Q_{pt} \times H_{pt}}{\eta_{pt}} \times D_{pt} \quad (2)$$

$$(\text{EnergyCost})_{pt} = (\text{Energy})_{pt} \times ET_t \quad (3)$$

where $(\text{EnergyCost})_{pt}$ is energy consumption cost of pump p at time t ($), $(\text{Energy})_{pt}$ is the energy consumption of pump p at time t (Kw), Y_w is the specific weight of water (KN/m3), Q_{pt} is the discharge of pump p at time t (m^3/sec), NP is the number of pumps, NT is the number of time steps, H_{pt} is the pressure of pump p at time t (m-H2o), η_{pt} is the efficiency of pump p at time t (%), ET_t is the electricity tariff at time t ($/Kwh) and D_{pt} is the time step length (hr).

In this research, three reliability equations are considered including pump, hydraulic and water age reliability. Pump reliability is computed based upon pump efficiency variation shown in figure 1. Also, hydraulic and water age reliability are defined in equations 4 and 5.

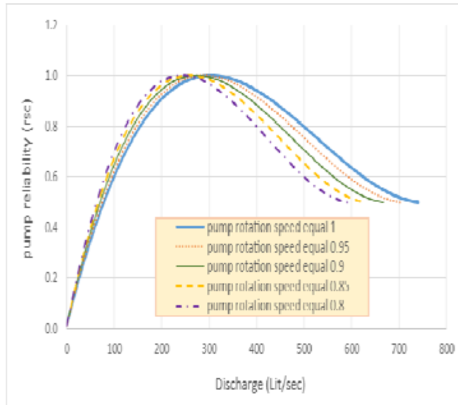

Figure 1. pump reliability definition for different pump rotation speed values

$$r_H(i,t) = \begin{cases} 0 & P(i,t) < P_{min} \\ \dfrac{P(i,t) - P_{min}}{P_{des} - P_{min}} & P_{min} < P(i,t) < P_{des} \\ \dfrac{P(i,t) - P_{max}}{P_{des} - P_{max}} & P_{des} < P(i,t) < P_{max} \\ 0.25 & P(i,t) > P_{max} \end{cases} \quad (4)$$

$$r_{WA}(i,t) = \begin{cases} 1 & WA(i,t) < 6 \\ 2.5 - 0.25WA(i,t) & 6 < WA(i,t) < 10 \\ 0 & WA(i,t) > 10 \end{cases} \quad (5)$$

In these equations $r_H(i,t)$ is the node hydraulic reliability at node i and time t, $P(i,t)$ is the pressure at node i at time t, P_{min} is the minimum pressure equal to zero, P_{des} is the required pressure to satisfy demands equal to 30 meters. $r_{WA}(i,t)$ is the node water age reliability at node i and time t, $r_{WA}(i,t)$ is the water age at node i at time t, WA_{min} is the minimum water age value (6 hr) and WA_{max} is the maximum water age value (10 hr). Then the values of each kind of

[1*] Corresponding Author, Ph.D Student, Ferdowsi University of Mashhad
Email: mahmood_fotuhi@yahoo.com
[2] Professor, University of Tehran.