OPTIMAL PRESSURE REGULATION IN WATER DISTRIBUTION NETWORKS USING SELF-ORGANIZING MAPS

HAYTHAM AWAD [1], AKIRA KAWAMURA [2] and KENJI JINNO [3]

[1] Lecturer, Department of Civil Engineering, Alexandria University, Egypt,
Post No. 21544, Alexandria, Egypt
(Fax: +20-3-5971853, e-mail: awadhay@yahoo.com)
[2] Professor, Department of Civil Engineering, Tokyo Metropolitan University, Japan,
Minami-Ohsawa, Hachioji, Tokyo, 129-0397, Japan
(e-mail: kawamura@c.metro-u.ac.jp)
[3] Professor, Institute of Environmental Systems, Kyushu University, Japan,
6-10-1, Hakozaki, Kigashi-ku, Fukuoka, 812-8581, Japan
(e-mail: jinno@civil.kyushu-u.ac.jp)

This paper presents a simple and efficient technique for improving the existing optimal pressure regulation and leakage minimization algorithms for supervisory water distribution networks. With the assistance of Supervisory Control and Data Acquisition (SCADA) we have trained a Self-Organized Map (SOM), an unsupervised Artificial Neural Network (ANN), to classify well regulated pressure cases for the water distribution network based on its actual values of flow meter readings which reflect the real network water demands or consumption. After training the SOM, a simulation step is used to classify the unregulated pressure cases into the different model classes. Based on these classifications the appropriate electrical motor valves setting of the well pressure regulation events are used for the unregulated ones. Regarding that available algorithms deal directly with the pressure regulation problem from an optimization point of view (Jowitt and Xu 1990; Miyaoka and Funabashi 1984; and Savić and Walters 1995) which required a computational time depending on the water network size and the used optimization method and in most cases requires also a network simplification method which is considered as another optimization problem. Using SOM as a pre-optimization method could prevent all errors resulting from applying optimization models, save its computational time and provides us with an on-line pressure regulation method.

In order to illustrate the capability of the proposed pressure regulation model, Block 12 of the supervisory Fukuoka City water supply network is selected as a case study. In this Block, there are 7 flow meters, 20 electric motor valves and 11 pressure gauges. One of the main objectives of the supervisory control of the water network of Block 12 is to regulate the pressure in all the network nodes between an upper target value (32 m) and a lower value (24 m). The values of flow rate passing each flow meter, the opening percentage of each motor valve and the pressure intensity at each pressure gauge are recorded every minute. The analyzed data of this study are based on one minute data for all telemeters for a randomly selected two days (Total number of vectors = 2880).

Different map size has been evaluated by calculating both topographic and quantization errors (Kiviluoto 1996; and Kohenen 2001). All possible two-dimensional map sizes which vary from 2 to 30 neurons have been tested. The map size selected to present the different classification of flow meters is hexagonal lattice with middle size of 11×16. At that size, the topographic and quantization errors equal 2.0021 and 1.4561, respectively.

Computational results for Block 12 using the short-term data set show that SOM has successfully regulated 1437 cases out of the 1931 unregulated cases. For the remaining 494 cases, an improvement in pressure status using the proposed model are recorded in 298 cases comparing to the situation before applying the SOM model. The proposed method shows high efficiency in case of regulating pressure during daily operation with high performance for night time when there is an increase of hydraulic pressure in the network. This paper presents analysis and comparison for the situation of pressure before and after applying the proposed method. This comparison is done for all the location of the 11 pressure gauges. Significant improvement was recorded at the location of pressure gauges (P1) and (P3). Those two pressure gauges are the most critical points as there pressures for the majority of cases exceed the required target range before applying the proposed method.

For demonstrating the efficiency of the proposed method, we have used a short-term data set. The same procedure could be repeated for a long-term data set taking into consideration that the size of SOM should be big enough to represent the majority of operational cases.

REFERENCES

Jowitt, P. W. and Xu, C. (1990). "Optimal valve control in water distribution networks," *Journal of Water Resources Planning and Management, ASCE*, Vol. 116, pp. 455-472.

Kiviluoto, K. (1996). "Topology Preservation in Self-Organizing Maps," *Proc. of the International Conference on Neural Networks (ICNN'96)*, pp. 294-299.

Kohonen, T. (2001). *Self-Organizing Maps*, 3rd edition, Springer-Verlag, Berlin.

Miyaoka, S. and Funabashi, M. (1984). "Optimal control of water distribution system by network flow theory," *IEEE Transactions on Automatic Control*, Vol. 29, pp. 303-311.

Savić, D. A. and Walters, G. A. (1995). "An evolution program for optimal pressure regulation in water distribution networks," *Engineering Optimization*, Vol. 24, pp. 197-219.