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UNSTEADY SIMULATION OF VALVE OPERATION IN SUPERVISORY WATER SUPPLY NETWORKS

Haytham Awad Student Member, Institute of Environmental Systems, Kyushu University.
Akira Kawamura Member, Institute of Environmental Systems, Kyushu University.
Kenji Jinno Member, Institute of Environmental Systems, Kyushu University.
Yusuke Kuno Student Member, Institute of Environmental Systems, Kyushu University.

1. Introduction

This paper presents the effect of valve operation on different nodal pressure values of a supervisory water supply network using an unsteady simulation which is based on statistical correlation analysis. Application of this method is presented to Block 12 of Fukuoka City water distribution network using a short term Supervisory Control and Data Acquisition (SCADA).

2. Block 12 Description and Data Used

The water supply network of Fukuoka city is divided into 21 blocks and the area served by each block takes into consideration separate water distribution areas, differences in land elevation, location of rivers and railroads, as well as local differences in water usage[1]. Block 12 as one of the main blocks of the city network is selected as a case study due to its location in the center of the city.

Our case study (Block 12) is surrounded from the north by Hakata bay, from the east by Hii River, from the west by Naka River and Block 9 and from the south by an elevated area (Block 50) and also by Block 13. A skeletonized figure of Block 12 containing 45 nodes and 49 pipes is shown in **Fig. 1**. In this block, there are 20 motor valves, 7 flow meters, and 11 pressure gauges. It is noticed from the figure that flow meters are connected to the main inlets and outlets and a valve is connected adjacent to each flow meter in order to control the flow entering or leaving the block (e.g., M1, V1; M4, V18; ...). The remaining motor valves are connected to the main junctions of this network (e.g., V2; V3; V5; ...) to make water distribution more efficient.

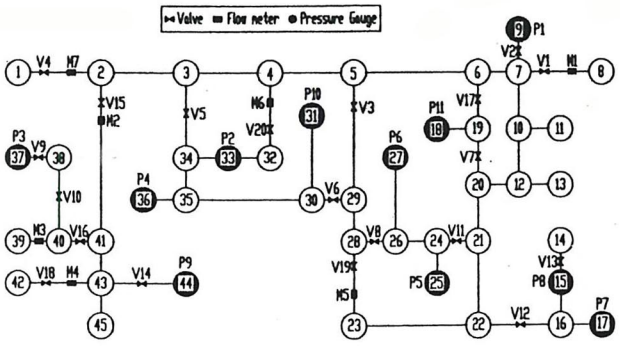

Fig. 1. Block 12 of the Fukuoka City water supply

Motor valves are operated by remote control while pressure gauges and flow meters fitted to distribution pipes are monitored. 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 flow meters, pressure gauges, and motor valves for a randomly selected two days (Saturday and Sunday, 9th and 10th of November 2002). The total number of data for each telemeter equal to 2880 (total number of minutes during those two days).

One of the main objectives of the supervisory control of water supply network in Fukuoka City is to regulate pressure in all the network nodes between lower and upper values (approximately 2.4 kg/cm^2 and 3.2 kg/cm^2, respectively) and as near as a target value[2].

With the ever-increasing complexity of the city-wide distribution pipe network, motor valve operation to regulate pressure and flow came to depend more and more on the experience and skills operators. For this reason, an improvement of valve operations support functions should be done based on valve operation planning for flow and pressure regulation, and the operation knowledge database which is constructed on the basis of past experience in order to prevent the events of pressure regulation falls outside the target pressure range and also to reduce the effort of investigator operators.

3. Cross-Correlation Analysis

In order to improve the existing valve operation used for pressure regulation, this paper present a correlation analysis based on real data obtained from different pressure gauges and electrically motor valves for the above mentioned Block for a randomly selected time interval. The basis of this analysis could be generalized for the entire city and could be expanded to include longer time intervals.

To ensure that the values obtained of correlation coefficient will accurately describe the relationship between the recent valve opening and the alternate pressure value, the Cross-Correlation analysis used in this study are based on the differences of times series (incremental values) for the different 11 pressure gauges and 20 electrically motor valves. To neglect the effect of many zero incremental records of valve openings, all these points are substituted by one point taken as mean value of the corresponding pressure gauge values.

The overall procedures mentioned above in the computation of correlation coefficients between the different 11 pressure gauges and 20 electrically motor valves are repeated up to a lag time equal 10 minutes with one minute step.

Figs. 2A and **2B**. show an example time series of pressure gauge (P11) and motor valve (V7), while **Figs. 2C** and **2D** show the time series differences of (P11) and (V7) which are used in the computation of correlation coefficients used in this study.

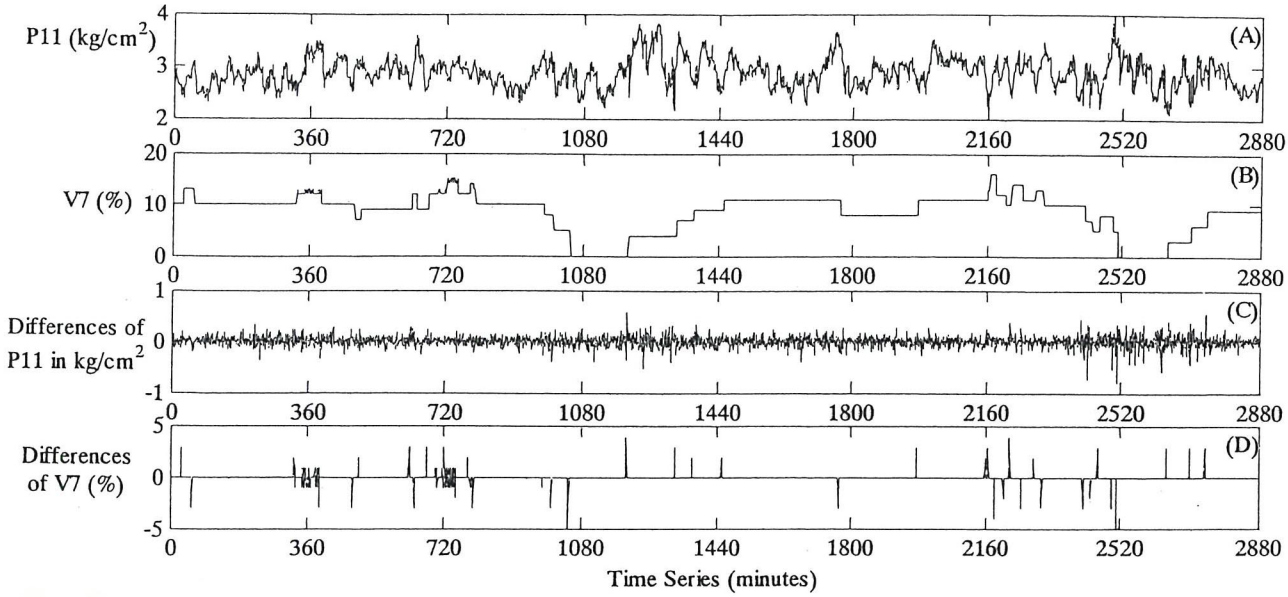

Fig. 2. Time series of pressure gauge (P11) and electrically motor valve (V7).

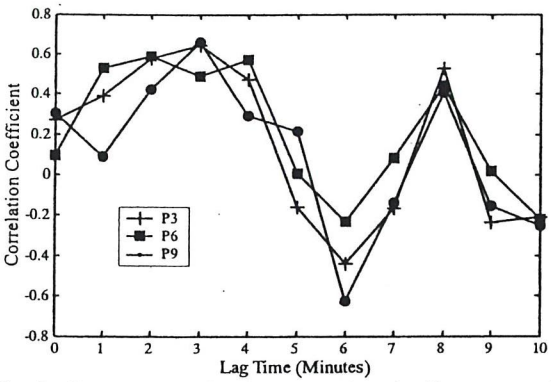

Fig. 3. Cross-correlation between electrically motor valve (V9) and selective pressure gauges.

Table 1. Block 12 highest recorded values of correlation coefficients between pressure gauges and motor valves.

Cross Correlation	Motor Valve	Pressure Gauge	Lag time (min.)
-0.627	V9	P9	6
-0.574	V15	P9	5
-0.521	V19	P8	4
0.782	V7	P11	0
0.802	V5	P4	0
0.840	V2	P7	2

4. Results and Discussions

The number of correlation coefficient values computed in order to describe the relationship between the different telemeters of Block 12 is 2420 value. 5% of these values are ranked as highly correlated (absolute value of correlation coefficient > 0.5), 16% of values are medium correlated (absolute value between 0.25 and 0.5) and the remaining 79% of values are poorly correlated (absolute value less than 0.25). **Fig. 3** shows an example of the distribution of correlation coefficients between valve 9 and some of the pressure gauges (P3, P6 and P9). From this figure the highest recorded value of correlation is between V9 and P9 (equal to -0.627) with lag time of 6 minutes. Similar curves are obtained for all the 20 electrically motor valves to investigate their operations on the different nodal pressure values. **Table 1.** shows the highest values of correlation coefficients between all the pressure gauges and motor valves of Block 12. This table shows also the lag time in which the correlation coefficients are recorded. Findings of this study could be useful for the operators during the daily operation, for example, when an increase of pressure are recorded at the location of (P11), then the most effective solution to decrease the pressure is to slightly close (V7) (see 4th row in **Table 1**). The results of other calculations confirm that the majority of the highest correlation values are recorded between motor valves and pressure gauges located in the same local areas of the Block.

5. Conclusions

This paper presents a set of correlation coefficients values connected several pressure gauges and motor valves of Block 12 of Fukuoka City water supply network. Highly correlated values could be useful to help the investigator operators to improve the operation of this Block in order to regulate pressure and flow. Existing of several best choices could be useful for achieving a better decision during daily operation. The results obtained in this paper could be generalized for the entire city water supply network.

References

1. Awad, H., Kawamura, A., Jinno, K., Annoura, T. and Shimomura, Y. (2002). "Characteristics of water distribution control in Fukuoka City for efficient water resources management." *Proceedings of the International Symposium on Lowland Technology, Saga, pp. 305-310.*

2. Fukuoka City Waterworks Bureau (2001). "Water distribution control center." *Publication of the Fukuoka City Waterworks Bureau.*