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Implementation of Water Management System Based on Middle-Block-Centered Monitoring

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Abstract

The evaluation standards of management efficiency for managing the water supply can be called the Revenue Water Ratio. The revenue water ratio is an important index that shows the standards on the cost of production as well as the ratio of quantities received through the rate income from the total amount of water supply produced from the water treatment plant. In general, the calculation of revenue water ratio is made on the basis of small blocks after the progression of blocking business, thus the management of water pipe network is also made on the basis of small block unit. However, the boundaries of adjacent blocks have many obscure points with many number of blocks, there are many difficulties of performing the work by the limited management personnel. Therefore in this paper, in order to improve the problems and limits of the previous block monitoring system based on inefficient small blocks, a block monitoring system based on real-time flow analysis centering on the middle block is proposed. In addition, by performing the dynamic pattern-based abnormal flow analysis considering the characteristics of each block and also by performing the real-time analysis on the rate of water supply between the classes, it will prove that the efficiency of management can be improved.

Keywords: *Real-time flow information, Block monitor system, Water Supply Analysis, SCADA, HMI*

1. Introduction

The water pipe network block system began with the proposal of Professor Goitae of Nagano University as a measure to recover after the severe earthquake of Nikata-city of Japan in 1964. However, it had been widely distributed across Japan since it was proved to efficiently respond to the maintenance and management of drainage system. As a result, Japan's national water flow rate currently reaches about 93 percent [1, 2]. A large number of water facilities in South Korea had been intensely distributed or installed along with the rapid economic development from 1970s to 1980s; thus, many water facilities are currently facing the need for realignment due to aging. As a result, how appropriately an improvement would be implemented through such measure as upgrade has become an important issue. Yet, the

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supply network management has not been conducted efficiently due to the lack of diagnostic technology, preliminary data and system that would be utilized for rational diagnosis [3].

The block management has been implemented based on the real-time monitoring of block flow information by using the SCADA, HMI (Human Machine Interface) system that are primarily used for the plant automation system; therefore, the abnormality assessment is being conducted through the real-time flow information that would rely on the experiences of administrators without taking the attributes for each block into account. Also, an efficient management could not be achieved due to the monitoring method based on a large number of small blocks.[9]

Thus, this thesis proposes a newly conceptualized water supply block monitor system based on real-time water supply analysis in order to enhance the problems and limitations of the existing inefficient block monitor system as for water supply monitor system. The proposed system would improve the managerial efficiency through the real-time water supply analysis that is applied by the abnormal flow detection method through flow pattern analysis in addition to supporting the block monitor operating method based on the inter-layer water supply rate. Also, it would improve the accuracy of abnormal flow detection.

2. Overview of Block Monitor System

2.1. Existing Block Monitor System

Currently, most of the waterworks business sites have installed the SCADA and HMI (Human Machine Interface) system that would be primarily utilized for plant automation monitoring rather than the water supply analysis dedicated system. As a result, the purposes of the thesis are to monitor the operational status of remote flow layers by gathering real-time flow information and assess the soundness of block operation by calculating the daily and monthly flow rate with the gathered flow information and analyzing the water flow rate with automatic and manual methods [9].

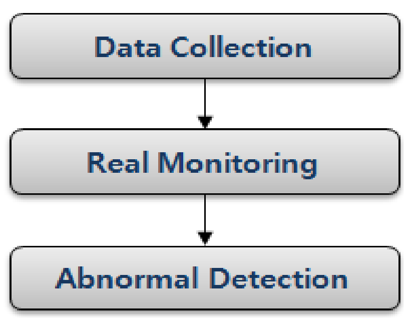

Figure 1. Management of Existing Block Monitor System

2.2. Problems Associated with the Existing System

The existing operating methods have the following problems.

1) Reduction of efficiency due to the block monitoring based on a large number of small blocks

As for the existing operating systems to monitor the flow information for each block, each individual block would become a target of management; thus, there would be a large number of targets that should be monitored at once. This phenomenon would subsequently lead to reduction of managerial efficiency. This would make it hard for prepare a aggressive proactive measure and also reduce the possibility of capturing abnormalities that could be detected in advance since it would be difficult to identify the exact situation unless it was a sudden occurrence of abnormality. Moreover, the system has been operated based on the provision of basic data for post-analysis of causes with the judgment for abnormality on the basis of long-term daily and monthly flow information or analysis (water flow rate) of usage compared to supply.

2) Difficulty of Identifying the Operational Status between the Layers of Large/Middle/Small Blocks

The existing water supply analysis has been managed with the emphasis placed on the presence of leakage of water supply piping at the tip of the water system by analyzing the outflow volume for each block and the water flow rate between "small blocks to consumers". Thus, it is vulnerable to the management on the water transmission pipeline between the block layers of large blocks to middle blocks and middle blocks to small blocks. In fact, it would be important to manage the outflow volume of small blocks to be supplied to consumers; however, it would also be necessary to have an efficient management for the soundness of water transmission pipeline ranging from producers (water treatment plant / reservoir) to large blocks and middle blocks to small blocks.

3) Difficulty of Judging in Consideration of Operational Attributes for Each Block [5]

Water is being consumed all the time; however, it is also resource that is largely influenced by temporal factors (morning/afternoon, beginning and end of month, beginning and end of year) and environmental factors (heat and weather). Therefore, the gap between the maximal value and the minimal value is large and consequently, the detection and judgment of abnormal flow through fixed threshold value would cause a lot of problems. In addition, the flow pattern would vary significantly for each region including residential district, villa and apartment complex, commercial district, etc.; thus, it would be hard to assess the soundness of block monitor only based on real-time flow information (hour flow rate and pipe pressure).

Accordingly, it would be required to have a measure to increase the efficiency of management by reducing the number of targets for block monitor and a detection technology of abnormal flow through self-learning with flow pattern analysis for each hour and day in order to resolve the aforementioned problems.

3. Water Supply Block Monitor System based on Real-Time Water Supply Analysis

3. 1. Overview of the Proposed System

Most of the waterworks business sites have installed a large number of flowmeters for management corresponding to large/middle/small blocks; however, only a few staffs are responsible for the management as there are about 2 regular staffs assigned to the block monitor. As a result, they are conducting a very inefficient operating method of monitoring all of the monitoring targets in real-time just like the existing system. Thus, this thesis aims to improve the problems arisen from the existing system with a more efficient and scientific operating method based on the secondary input-output analysis by avoiding the existing simple block monitoring based operation through applying the water supply block monitor system based on real-time water supply analysis.

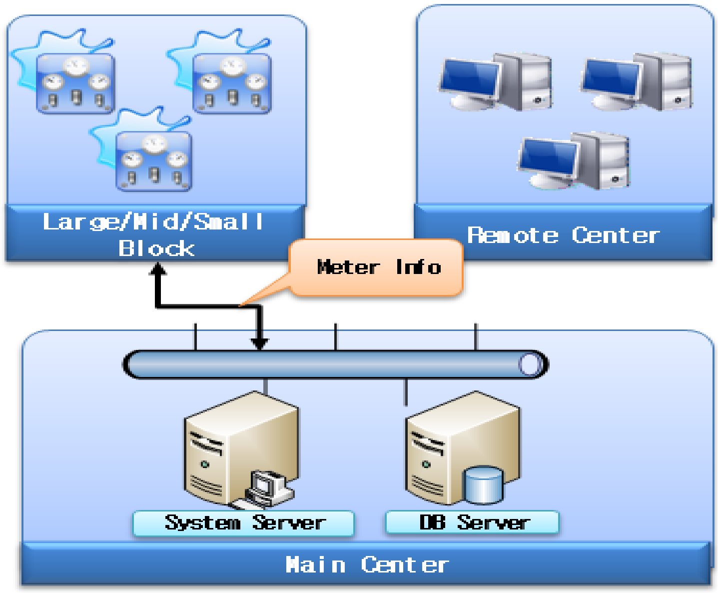

Figure 2. Module Structure of Proposed System

The proposed system was developed as a system dedicated for water supply block monitor and improvement of water flow rate, whereas the existing system has installed the block monitor system by using SCADA, HMI (Human Machine Interface), *etc.*, that would be primarily used for plant automation control, *etc*. Hence, it would allow for an application of various analysis techniques and it has the advantage of having a high degree of managerial efficiency since it would allow for an operation for each level with an integrated system through the client/server structure, per-user authorization and user-specific designation of block/level. The existing system aims to conduct collection and monitoring of flow data and cyclic data output; however, the proposed system would allow for intuitive status monitoring through input-output analysis information in accordance with block configuration in addition to real-time flow information by operating the dedicated water supply analysis module and the real-time flow information binder module separately.[9]

Next, the analysis module was separated and developed into the data analyzer for analysis viewing of water supply rate, water flow rate, leakage ratio and other data and the service analyzer for real-time water supply rate and detection and pattern analysis of flow abnormalities as shown below in order to promote the stability of system operation. And WCF (Window Communication Foundation) / WPF (Window Presentation Foundation) technology based on (MS).Netframework 4.0 was selected for the development to secure the smooth binding of real-time water supply analysis information, the encryption for communication security between client and server and the expandability.[7]

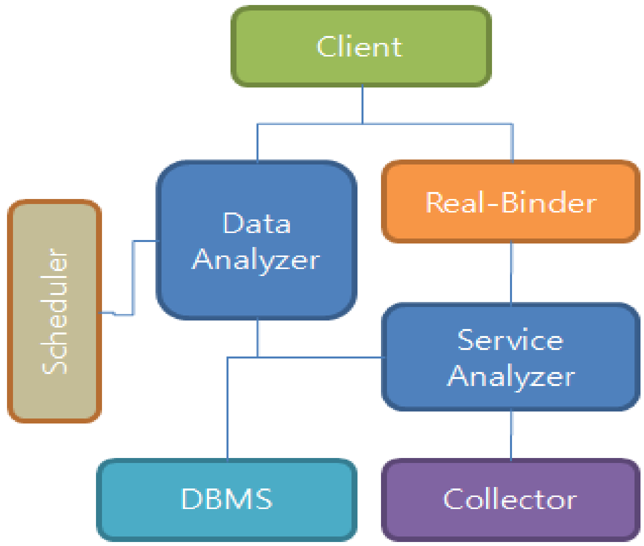

Figure 3. Module Structure of Proposed System

* DBMS: Database Management Module

* Collector: Data Collection Module

* Service Analyzer: Real-Time Collected Data Analysis Module

* Data Analyzer: Inquiry Request Data Analysis Module

* Scheduler: Cyclic Data Analysis and Processing Module

* Real-Binder: Module allowing for real-time monitoring by rapidly binding real-time water supply analysis data with client user interface (Client UI)

3.2. Block Monitor based on Water Supply Rate between Block Layers

The water supply rate from the sum analysis of upper blocks' outflow volume and lower blocks' inflow volume would have a drastic change in flow when abnormal flow occurs at upper/lower blocks. Based on such mechanism, the number of management targets would decrease significantly if analyzing and monitoring the water supply rate of relevant upper blocks rather than monitoring the flow information of all the block flowmeters like the existing system. Therefore, the managerial efficiency could be improved. In general, small blocks would be composed on the basis of 500 to 1,500 hydrant and 5 to 10 of such small blocks would be formed to create a middle block.[6] Thus, the managerial efficiency would be lower when conducting block monitoring for all the middle/small blocks by the existing system; however, it would be possible to manage water supply blocks rationally and efficiently by conducting an in-depth water supply analysis (pattern and history analysis) after an occurrence of abnormal incidence (radical change in water supply rate) after monitoring only one of the upper middle blocks intensely when conducting block monitoring by using the proposed system. Comparing "the existing system: the total of 7 sites" VS "the proposed system: 1 site" with the assumption that one site of middle block was formed by 5 to 10 sites of small block as stated in the above example would allow us to have an effect of reducing the managerial load to less than 20 percent.

☞ Middle block : Small blocks 5 ~ 10

☞ Small block : Hydrants 500~ 1,500

(Upper blocks count :Lower blocks count = 1 : 7, Average)

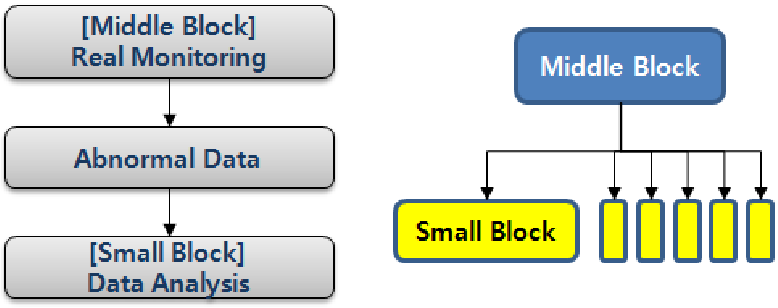

Figure 4. Water Supply Rate Analysis between Upper Blocks to Lower Blocks

In addition, the water flow rate analysis based on usage compared to supply would provide a managerial measure based on the water supply system through water supply analysis between "small blocks to users"; however, the water supply rate analysis between large to middle blocks and middle to small blocks would improve the efficiency of water transmission pipeline operation by providing preliminary data for the analysis of soundness as to the main water transmission pipeline.

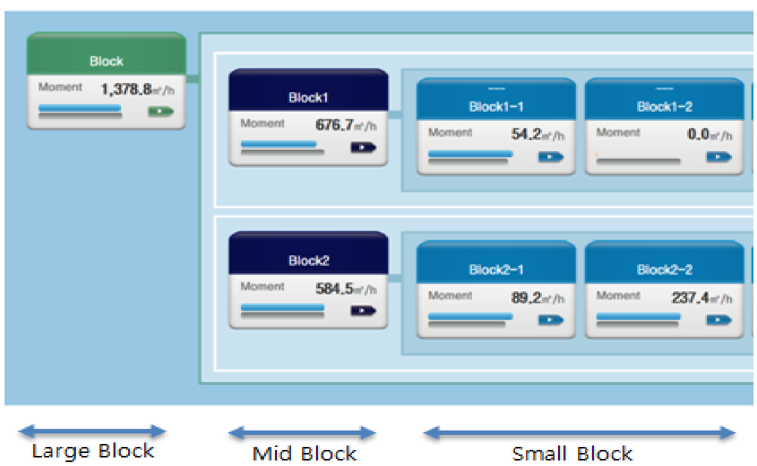

Figure 5. View of Water Supply Rate

Figure 6. Real Monitoring Trend Graph

3.3. Detection of Abnormal Flow through Flow-Pattern Analysis

Use of water has a very flexible nature in accordance with the temporal and environmental factors. Thus, the one suitable for the operational attributes for each of the relevant blocks would form learning threshold levels to provide more scientific and rational judgment grounds for flow abnormalities rather than passive detection of abnormalities through designation of maximal and minimal flow in order to identify flow abnormalities for each block. [5]

Figure 7. Detection of Abnormal Flow

Water supply flow violating the analyzed flow pattern is detected and utilized as basic data for the analysis of leakage and flow abnormalities.

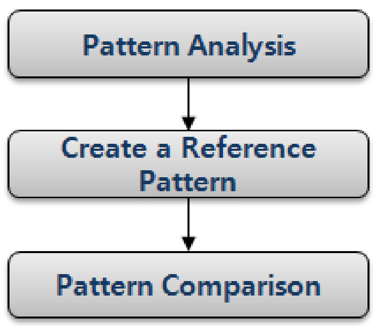

Figure 8. Management Based on the Analyzed Flow Pattern

4. Performance Assessment

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With the application of water supply block monitor system based on real-time water supply analysis, which is the proposed system,

1) the increase in managerial efficiency due to reduction of targets for monitoring,

2) the improvement of detection success rate of abnormal flow customized for each block through flow pattern analysis and

3) the operation of stable system under the implementation of real-time analysis function are utilized as an index.

Generally, a middle block would be formed as including 5 to 10 of small blocks when designing the block projection to establish a block monitor system[2]. As a result, the management target is as follows when assuming that each site of middle block would include 7 sites of small blocks on average. Thus, it would cause an effect of reducing the number of management targets to less than 20 percent; thereby, improving the managerial efficiency.

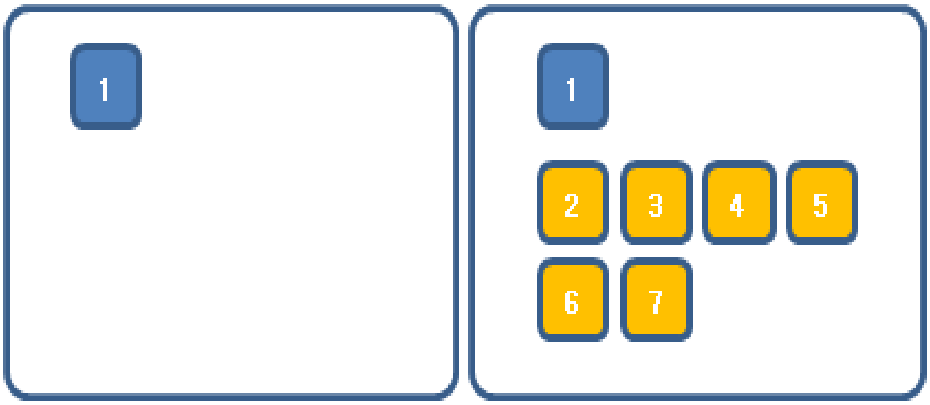

Figure 9. Comparison of Maintenance and Repair Management Target at Ordinary Time between the Proposed System and the Existing System

In addition, it would cause an effect of setting automatically flexible threshold levels for each temporal interval by conducting self-learning the flexibility in accordance with the temporal and environmental factors; thereby, creating an effect of significantly reducing the false detection rate of abnormal flow[5].

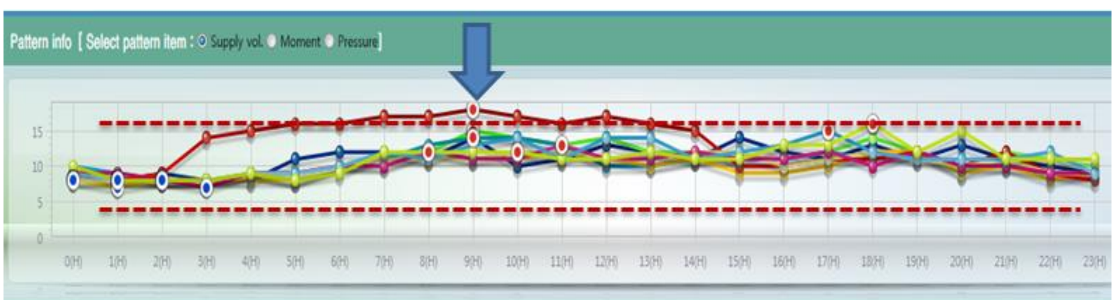

Figure 10. Detection of Abnormal Flow by Setting the Fixed Threshold Levels

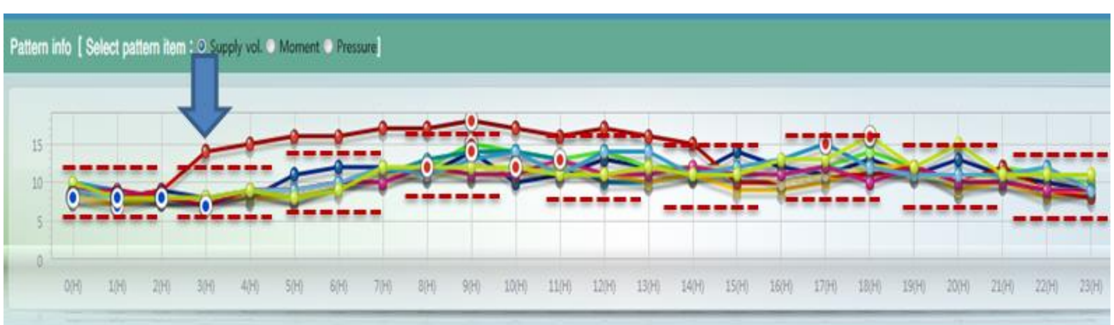

Figure 11. Detection of Abnormal Flow through Flow Pattern Analysis

Moreover, the system reliability in terms of performing the function of real-time water supply analysis was proved through GS certification of TTA (Telecommunications Technology Association, Korea) as shown in Table below.

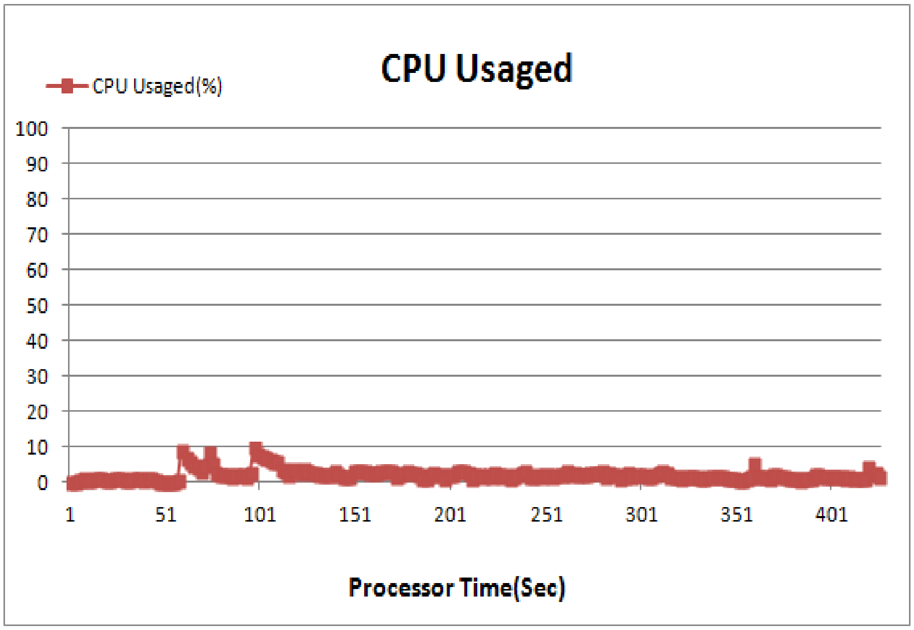

Figure 12. Resource Efficiency Test Results of TTA (CPU Usaged)

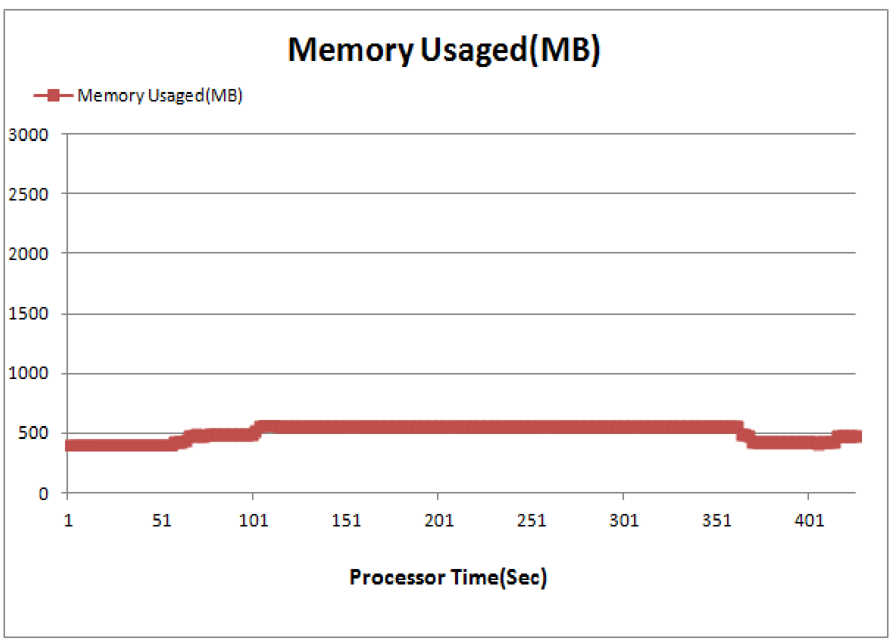

Figure 13. Resource Efficiency Test Results of TTA (Memory Usaged)

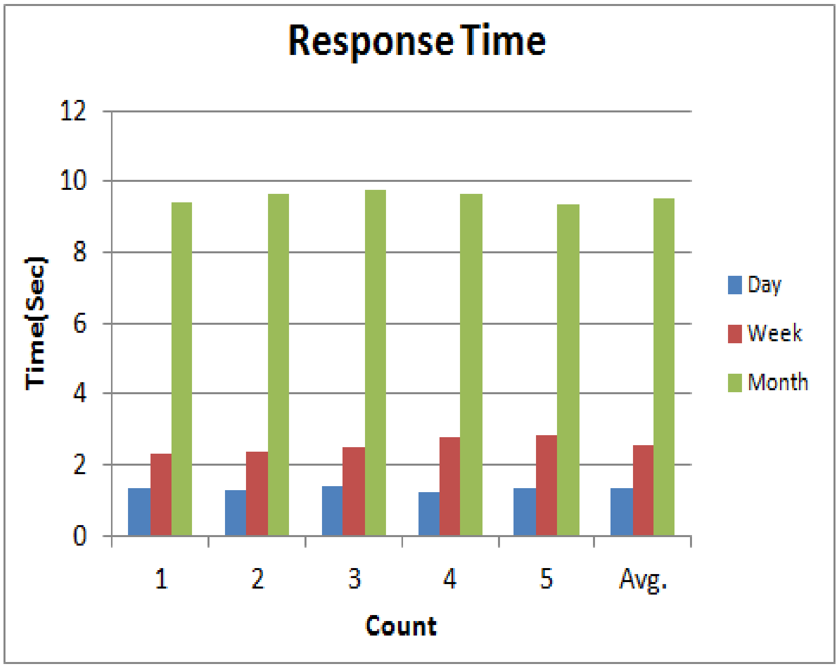

Figure 14. Temporal Efficiency Test Results of TTA (Response Time)

5. Conclusion

The existing system would provide the operation function based on real-time block monitor for each block. Thus, the managerial efficiency is low due to the problem that an administrator should monitor a large number of block targets at the same time and also there is a difficulty of analyzing the soundness of water transmission pipeline as for water supply system. Furthermore, it has the shortcoming in terms of providing a sufficient amount of evidences for judging abnormal flow of water supply piping having a large degree of flexibility.

As a result, this thesis proposes a newly conceptualized water supply block monitor system based on real-time water supply analysis in order to enhance the problems and limitations of the existing inefficient block monitor system as for water supply monitor system. Through the performance assessment, the proposed system was proved to improve the managerial efficiency through the real-time water supply analysis that is applied by the abnormal flow detection method through flow pattern analysis in addition to supporting the block monitor operating method based on the inter-layer water supply rate. Also, it was proved to improve the accuracy of abnormal flow detection. Moreover, it was verified to conduct more reliable detection than the existing method through the performance assessment of GS(Good Software) certification when operating multiple block monitors.

It is believed that the developed block monitor system could be developed into a more efficient water supply integrated analysis system through the linked analysis with the AMR (Auto Meter Reading) system and the hydraulic distribution system, which are the consumer usage metering system, on the basis of the improved managerial efficiency.

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