A Study on Prediction Model of Energy Consumption for Demand Response Service of Wastewater Treatment Facility

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***Abstract*—Recently, high-power-demanding wastewater treatment processes have been introduced in the wastewater treatment facilities according to the strict water quality standard of the effluent water. The influent water quality of the wastewater treatment facilities differs according to environmental factors. However, the processes of the wastewater treatment facilities are operated with the maximum load to meet the effluent water quality standard. The wastewater treatment facilities can be utilized as a demand response resource by analyzing the wastewater treatment process and power usage patterns according to the influent water quality. In this study, we describe the power measurement system, the power usage pattern, and the power consumption prediction model of the wastewater treatment facility for the application of demand response service.**

Keywords-Demand Response; Energy Consumption Prediction; Neural Network; Power Measurement System; Wastewater Treatment Facility

I. INTRODUCTION

High-power-demanding wastewater treatment processes have been introduced in the wastewater treatment facilities. As of 2015, the electricity consumption of the Republic of Korea's public wastewater treatment facilities is 4,900 GWh, which accounts for 1% of total electricity consumption in the Republic of Korea.

Currently, wastewater treatment facilities are uniformly operated to attain the quality standard of the effluent water irrespective of the influent water quality. However, the quality of the influent water changes according to the weather, season, and time in which people are active. Therefore, by analyzing the quality of the influent water and the power usage patterns of the wastewater treatment facilities, it appears to be able to avoid power-load-peak-time through efficient operation. In addition, it is expected that the wastewater treatment facilities can be utilized as Demand Response (DR) resource through the development of operational scenario for DR. DR is that a consumer adjusts demand to avoid power load peak according to the amount of power supplied to the grid [1].

In this study, we describe the power measurement system, the power usage pattern analysis, and the power consumption prediction model of the wastewater treatment facility for the application of DR Service.

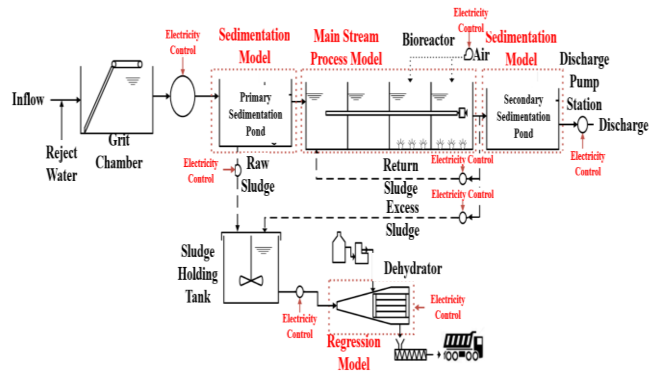

Figure 1. Flowchart of The Pilot System

II. CONSTRUCTION OF PILOT SYSTEM

Currently operated wastewater treatment facilities must ensure the quality of effluent water at the same time continuous inflow of wastewater, therefore it is impossible to change the experimental environment. Hence, we constructed the pilot system in order to analyze the changes of the quality of the effluent water and the power usage pattern of the processes due to changes in the quality of the influent water and operation scenario. The pilot system is that simplified the Sequencing Batch Reactor (SBR) process system. Figure 1 is a flowchart of the pilot system.

The SBR process consists in 6 steps such as Fill, Mix, React (Aerate, Mix), Settle, Decant, and Idle processes in one reactor and adjust the condition time according to the quality of the influent water [2].

In the Fill process, wastewater fills into the reactor and contacted with microorganisms. In the React process, organic and nutrient materials are removed by appropriate control of anaerobic, anoxic, and aerobic conditions through Mix and Aerate process. In the Settle process, separate the mixture into sludge and supernatant. In the Decant process, discharge the separated supernatant.

In order to apply DR service to the wastewater treatment facilities, it is necessary to analyze the power usage patterns of the individual devices and the overall power consumption measurement for the development of the operating scenario. The main devices of the pilot system used in this study are Influent Pump, Sludge Seeding Pump, Mixer, Submerged

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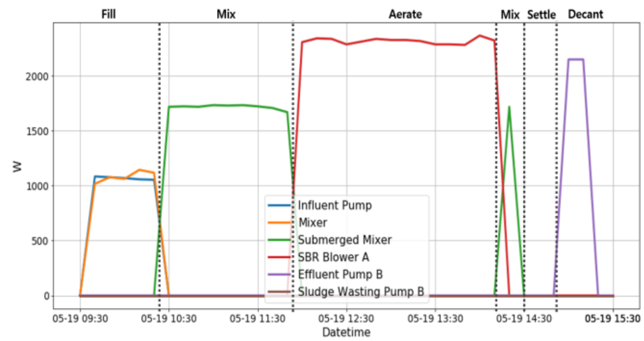

Figure 2. Power Usage Pattern of The Processes

Mixer, SBR Blower, Effluent Pump, and Sludge Wasting Pump. Therefore, we have developed a system that measures the total power consumption as well as the power usage of individual devices and stores them in a database. The power measurement system consists of the power meter, the gateway, and the server. In order to transmit and receive data wirelessly, the LoRa communication module is connected to a power meter installed in each device. The server receives the data through the LoRa Gateway and stores it in the database. The data includes voltage, current, power, and power factor.

III. DATA ANALYSIS AND MODEL DESIGN

The wastewater treatment process of the pilot system takes six hours in one cycle and proceeds in the order of Fill, Mix, Aerate, Mix, Settle and Decant process. Figure 2 shows the power usage patterns of the processes. There is no improvement point of efficiency in Fill and Decant Process because inflow and outflow of water must be fixed. However, Mix and Aerate process have a direct impact on the quality of the effluent water. In addition, the Mixer and SBR Blower used in the process can be variably controlled. Therefore, by controlling them variably according to the quality of influent water, it will be possible to reduce the power consumption and satisfy the effluent water quality standard.

In order to utilize the wastewater treatment facilities as DR resource, it is necessary to predict power consumption according to the influent water load and judge whether the effluent water quality standard and the power reduction amount can be satisfied through the variable control of the devices. In this study, we used the neural network model to apply features such as water quality and environmental factors in the future. The past power usage data of the pilot system is the result of the general wastewater treatment scenario. The data was measured in 10-minutes intervals and the unit is watts. Therefore, 36 data is stored in one cycle and 144 data is stored in one day. Based on this, we have constructed the neural network model that predicts one cycle (36 data) from past 24 hours data (144 data) [3]. The data looks like a time series. However, it showed poor performance when used in Recurrent Neural Network (RNN). Hence, we used Multi-Layer Perceptron (MLP) Model.

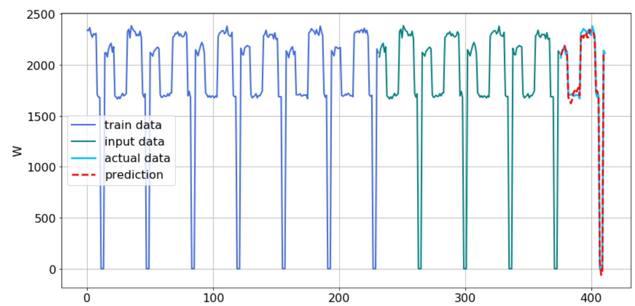

Figure 3. Train, Actual, and Predicted Data Pattern

IV. EXPERIMENT AND EVALUATION

Figure 3 shows train data, actual data, and predicted data pattern. The left of the graph is the train and the input data pattern. The result of predict data by the model is on the right of the graph. The predicted data shows about 45.39 Root Mean Squared Error (RMSE) and about 1.79% Mean Absolute Percentage Error (MAPE). We confirmed that the predicted data is very similar to the actual data. Thus adding effluent water and influent water quality to the model will predict power consumption and effluent water quality depending on influent water quality.

V. CONCLUSION AND FUTURE WORK

In this study, we have proposed the power measurement system, the power usage pattern analysis, and the power consumption prediction model of the wastewater treatment facility for the application of DR Service. The proposed system has collect power usage data from each device and predicts power usage pattern. The accuracy of the model in the experiments showed the feasibility of the proposed system. Adding the influent water quality and effluent water quality parameters to the model will enable the wastewater treatment facilities to be used as DR resource. For future research, we will add influent water quality and effluent water quality parameters to the model. We will then apply the model and system in large-scale wastewater treatment facilities and measure performance.

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