

# Implementation of IoT-based Control System for Maintenance Operation of Long-distance Air Pollution Prevention Device RTO

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**Abstract** – In this paper, a control system for maintenance and operation of regenerative thermal oxidation (RTO) and scrubbers, which are air pollution reduction devices, is developed at VOCs-generating sites. VOCs reduction technology should reduce the amount of harmful substances in advance by controlling the operating conditions and maintenance work conditions of systems deployed at long distances. At this time, based on the sensor IoT linkage, the performance is evaluated by measuring the concentration of volatile organic compounds (VOCs) emissions according to the conditions for long-distance maintenance and analyzing the change in THC concentration.

**Keywords** – RTO, VOCs, Carbon-free, THC, Long-distance Maintenance, Sensor-IoT

## I. INTRODUCTION

Efforts are being made to reduce greenhouse gases due to global warming and to be carbon neutral (zero carbon). The global average temperature rise in response to climate change is maintained within 2°C compared to before industrialization, and 1.5°C is achieved in the long run. Korea has finalized its 37% reduction target (315 million tons) compared to its 2030 emission forecast (851 million tons), is promoting air pollution reduction technologies and research to reduce greenhouse gas emissions and minimize the impact of climate change.

There are VOCs that are discharged directly into the atmosphere or cause greenhouse gases with simple power generation and heat sources. Aromatic hydrocarbons such as benzene are strong carcinogens that cause leukemia, central nervous system disorders, and chromosomal abnormalities, and hydrogen chloride causes ozone layer destruction and global warming. The heat storage combustion system and heat storage catalyst combustion system are technologies that can effectively process VOCs processing rates above 95% [1].

VOCs reduction technology is largely divided into proactive and post-mortem measures, and the amount of harmful substances generated must be reduced in advance by adjusting operating conditions and working conditions. As a follow-up measure, VOCs reduction facilities should be operated, facilities should be improved, and various VOCs reduction facilities should be equipped. The energy costs are

consumed with a low heat recovery rate of more than 95%, and the technologies that can effectively handle VOCs treatment rate of more than 95% are heat storage combustion systems and heat storage catalyst combustion systems [2]. Representative companies that treat volatile organic compounds (VOCs) using heat-storage combustion oxidation devices (RTOs) are Alliance Corp. (US), Met Pro (US), Rauschert (Germany), Condor Chemenvitech (Germany), and Taikisha (Japan), and the U.S. and Germany have the best technologies. The RTO type for VOC treatment was developed from the damper method (1st and 2nd generations) to the 3rd generation of rotary valve, and it was developed that there was no pressure change and there were few failure factors with one valve. This rotary valve method was high with a VOC removal efficiency of 95 to 99%, but since the installation area is required more than the existing method. Some leading overseas universities are working with petrochemical companies to automate the process, and process simulation and optimization algorithms such as Carnegie Mellon University, Texas A&M University, Imperial College London University, and Denmark Technical University of Denmark are actively underway [3].

Recently, strategies to reflect carbon reduction in corporate environmental, social, and governance (ESG) management are spreading to a global trend, and as the interest of all members of society, including consumers, investors, and the government, is increasing, it is emerging as a key factor in corporate survival and not a choice. Figure 1 shows the VOCs emission device and the site of the VOCs gas explosion.



Figure 1. The VOCs emission RTO and gas explosion

In this paper, a control system for maintenance and operation of Regenerative Thermal Oxidation (RTO) and

scrubbers, which are air pollution reduction devices, is developed at VOCs-generating sites. VOCs reduction technology should reduce the amount of harmful substances in advance by controlling the operating conditions and maintenance work conditions of systems deployed at long distances. At this time, based on the sensor IoT linkage, the performance is evaluated by measuring the concentration of volatile organic compounds (VOCs) emissions according to the conditions for long-distance maintenance and analyzing the change in THC concentration.

## II. IMPLEMENTATION OF THE REMOTE CONTROL SERVICE

The Regenerative Thermal Oxidizer (RTO) is a high-efficiency energy-saving air pollution reduction device that oxidizes volatile organic compounds (VOCs) and organic odor gases at high temperatures of 800°C and recovers heat using ceramic heat storage materials for heat exchange. In the event of a failure due to 24-hour operation on weekdays, there are difficulties such as the exact location of the accident at the site, the treatment of VOC harmful substances, and immediate technical support services due to distance. In particular, if a complex equipment usage manual is immature, a lack of handover due to frequent turnover of field personnel, or a problem with factory operation occurs when it is located at a wide and long distance, such as a chemical complex, it cannot be immediately dealt with [4].

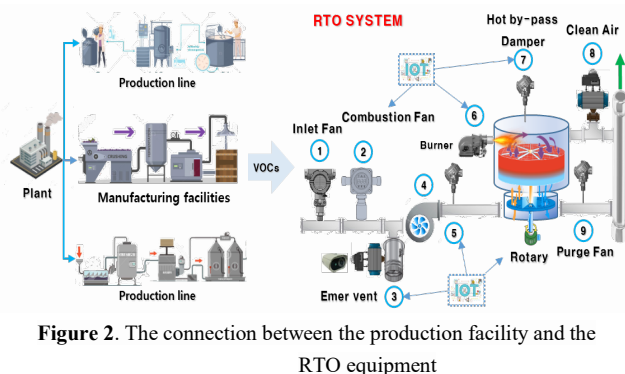


Figure 2. The connection between the production facility and the RTO equipment

Figure 2 shows the connection between the production facility and the RTO equipment, and the circle number in the RTO device is a picture of the sensor IoT attached to the location to be managed.

With the strengthening of environmental regulations on carbon reduction of plants, integrated operation and management of high-efficiency emission facilities became possible. The EU and the US EPA are systemizing using IoT to establish a smart management system for pollutants or indirect managers.

With the development of sensor IoT technology, it is possible to provide information to field managers through wired and wireless edge-IoT technologies to remote RTOs,

and this device is connected to the server to analyze detected data. At this time, the data acquired through the sensor IoT is transmitted to the artificial intelligence server, and real-time analysis, judgment, prediction, and visualization are possible. Monitoring service technology, which applies AI-based learning effects for various analysis and judgment, allows managers to expand areas that cannot be managed one by one. Figure 3 shows the on-site interactive service support, big data construction, and PC monitoring system diagram.

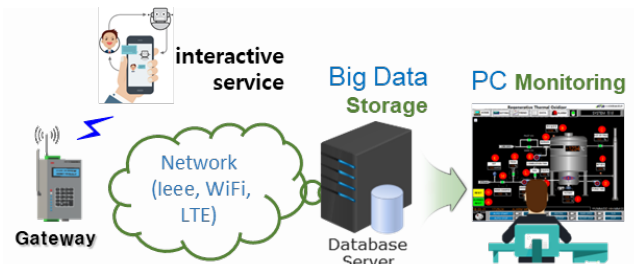


Figure 3. The on-site interactive service support, big data construction, and PC monitoring system.

Gateways can be installed depending on the distance of the site or the amount of IoT installed. At this time, it is data base on the data server through on-site low data and data logging. Figure 4 shows a sensor edge-IoT circuit. Sensors connected to Edge-IoT send data with IEEE 485, LoRa, and WiFi modules depending on wired or wireless.

The main service monitoring server program of each IoT is implemented as a middleware-based system for smooth monitoring between RTO operation status monitoring, control interface, and IoT devices installed in the field. At this time, location information, installation date, equipment replacement date, sensor replacement date, number of malfunctions, and alarm function using Flesch are added. At this time, the system-specific ID allocation, installation classification key, gateway access port are implemented, heartbeat processing per second, data network service (DNS), and the database is managed through the Graphic User Interface (GUI). Figure 4 shows the service monitoring configuration diagram of the main server.

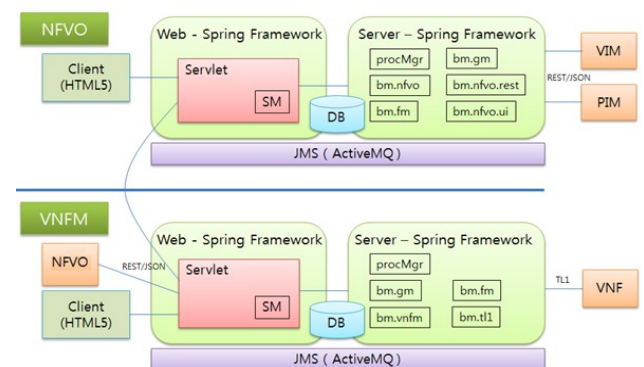


Figure 4. Service monitoring of configuration diagram

### III. BUILDING DATA ON SPECIFICATIONS

Sensor data acquisition specifications are required for detailed configuration specifications of RTO devices. There are duct size, discharge pressure, discharge temperature, and VOC emissions provided to RTO in the plant process. Figure 5 shows a detailed configuration example of an RTO device.

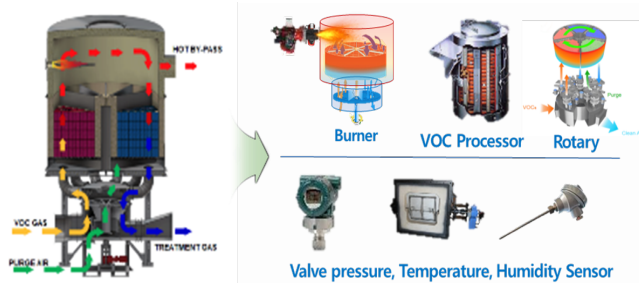


Figure 5. Configuration example of an RTO device

Table 1 shows the segmentation of RTO sensor IoT data acquisition.

TABLE 1. THE DATA SEGMENT OF SENSOR IOT

| Level3 Master Components | Level3 Master Components Data | Level3 Detail | Level3 Child (Detailed specifications) | Data (Multi Line Insert construction) | Algorithm (CBM/AI)    | Priority (Rating) |
|--------------------------|-------------------------------|---------------|----------------------------------------|---------------------------------------|-----------------------|-------------------|
| Fan (Impeller)           | Fan (Impeller)                |               | Fan (Impeller)                         | Type                                  | Temperature Airplane  | Minor             |
|                          |                               |               |                                        | Model number                          | Voltage Motor         | Critical          |
|                          |                               |               |                                        | Inhalation method                     | Voltage Pump          | Critical          |
|                          |                               |               |                                        | Driving method                        | Unbalanced Rate_Motor | Critical          |
|                          |                               |               |                                        | Production company                    | Motor talk            | Critical          |
|                          |                               |               |                                        | Memo                                  | Damper loss ratio     | Major             |
| Motor                    |                               | Motor         | Power (KW)                             |                                       |                       |                   |
|                          |                               |               | Blast Current (A)                      |                                       |                       |                   |
|                          |                               |               | Number of rotations (rpm)              |                                       |                       |                   |
|                          |                               |               | Production company                     |                                       |                       |                   |

In data segmentation, Level 0 is classified as an RTO facility, Level 1 is classified as a ventilation facility, Level 2 is classified as a ventilation facility-A to segmentation A-Z, and Level 3 is classified as an exhaust-A to segmentation A-Z. Figure 6 shows the combustion chamber temperature and emission gas temperature data obtained from the sensor.

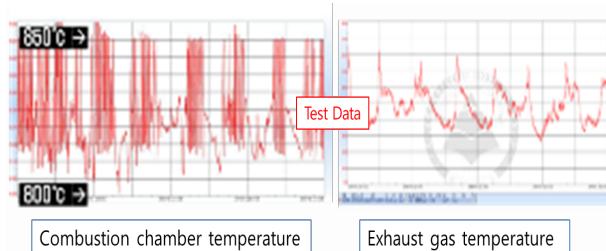


Figure 6. Combustion chamber and emission gas temperature data

The optimization of combustion efficiency from the fuel properties of RTO and the load on the burner will shows in

Figure 6. There is a risk of explosion when driving in a rapid incomplete combustion section and monitor, and notify an alarm message.

Table 2 is sensor data of nine channels and shows the built sensor database.

TABLE 2. BUILT SENSOR DATABASE OF NINE CHANNELS AND THE SETTING UP DATA PACKET

Figure 7 shows that sensor data from nine channels build a sensor database on a server. The right shows the database to be observed.

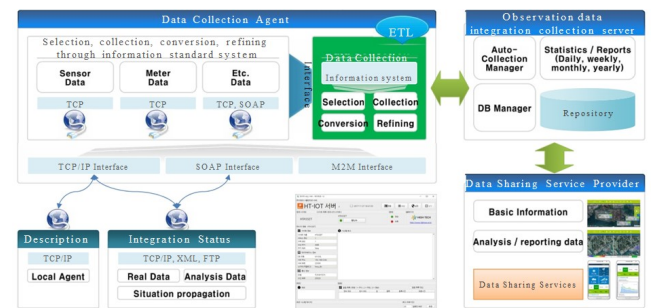


Figure 7. Sensor database on a server

The data obtained from the sensor are data generated by physical sensors such as temperature, flow rate, and pressure of the RTO. By combining them, the concept of virtual sensors is applied to software calculate new indicator values such as the status of RTO emissions.

As real-time data collection of field operations becomes possible, various artificial intelligence machine learning techniques can be applied to preserve the system's prediction. A prediction algorithm may be applied using the acquired data. Table 3 shows the configuration diagram of the monitoring operation program.

TABLE 3. CONFIGURATION OF THE MONITORING SERVICE

| Description         | Observation Information management | Sensor measurement management |
|---------------------|------------------------------------|-------------------------------|
| Status              | Measure risk                       | Data analysis Tools           |
| Analysis            | Setting                            | Information management        |
| Facility Management | Equipment management               | Customization                 |
| Setting             | Customizable                       |                               |

Figure 9 shows the visualization of temperature, gas and pressure and humidity.

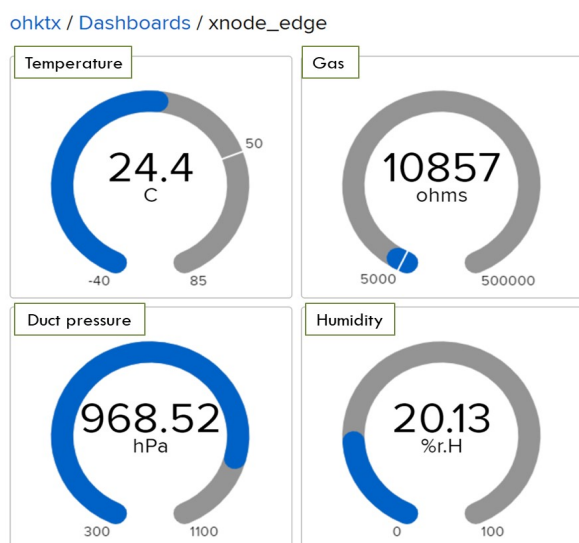


Figure 9. View of temperature, gas and pressure and humidity

After the RTO reaches a stable operating state, the test results obtained by continuously measuring for 30 minutes were as shown in Table 4. Here, the nitrogen oxide is an actual value not corrected by the standard oxygen concentration.

TABLE 4. TEST RESULTS

| Sortation               | Unit | Inlet    | Outlet |
|-------------------------|------|----------|--------|
| Total hydrocarbon       | ppm  | 6,221.27 | 155.55 |
| nitrogen oxide          | ppm  | -        | 2.49   |
| Exhaust gas temperature | ℃    | -        | 70.13  |

Figure 10 is a visualization diagram showing the amount of decrease in VOC.

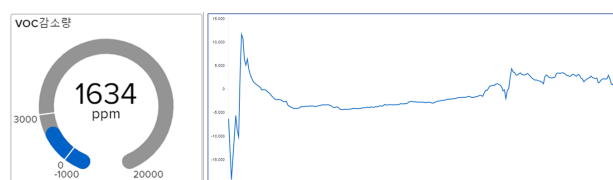


Figure 10. Showing the amount of decrease in VOC

In the RTO simulation, the average concentration of inflow gas according to the operating temperature of the combustion chamber was 6,224 ppm (THC), and the temperature of the RTO combustion chamber was 815°C. The range of change in the temperature of the combustion chamber was the lowest 808°C, and the characteristic of changing periodically up to 825°C be shown in Figure 10.

#### IV. CONCLUSIONS

As a result of the experiment, the heat generated by VOC combustion was 346,766 kcal/hr, and the exhaust loss heat was 185,758 kcal/hr using the operating inflow gas

temperature (49°C) and emission gas temperature (70°C). Therefore, considering only the generated heat and exhaust loss heat from VOC oxidation, it is calculated that 171,008 kcal/hr heat is used as a "regenerated heat energy" inside the RTO system. IoT/ICT technology acquires data from sensors, and machine learning algorithms are used to predict the condition of facilities and equipment before failures occur, and maintenance is planned in advancement to minimize equipment downtime. In the process of predicting, analyzing, and coping with failure causes of equipment in advance, we can expect to grow together with new materials and coating-related technologies that are more resistant to wear and corrosion.

In order to more accurately measure the condition of the facility, the resolution and precision of the sensor are required, and technologies related to the development of higher-performance sensors can be advanced. In addition, by establishing a hardware foundation, a foundation has been created for various algorithms to be developed and applied.

It is expected that the use of failure recognition and prediction of integrated solutions will minimize the stable supply of parts and the shutdown of facilities due to failure, and that VOC will improve public health welfare and respond to the Serious Accident Punishment Act.

#### ACKNOWLEDGMENT

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