Study on an Energy-IoT Service Platform for Energy Saving in Legacy Manufacturing Site

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***Abstract*—In this paper, an E-IoT service platform that provides energy saving solutions at legacy factory sites is presented. The E-IoT service platform collects process data through E-IoT module, transfers it to analysis system through E-IoT platform, and predicts power consumption through correlation analysis with process variables in E-IoT analysis system. Among the 1,556 raw material process data collected from paper mills, the largest correlation coefficient between raw material and high voltage power was obtained, and a prediction model for raw material high voltage power was established. With this model, the factory can establish the process plan according to the predicted power range, and the energy simulation model can be created for each process.**

***Keywords*—E-IoT, Energy saving, oneM2M, Data analysis**

I. INTRODUCTION

With the emergence of the fourth industrial revolution, the world is paying attention to improving energy efficiency through the fusion of ICT technologies. Countries around the world are pursuing policy support to achieve energy efficiency, and ICT companies are launching energy management solutions that utilize energy big data to achieve visualization and optimization of energy flow and usage. [1]

The largest consumer of energy is the manufacturing sector. [2] Applying energy saving technology in the manufacturing sector can lower manufacturing costs, and improve productivity and quality of products. [3] To reduce energy costs, the manufacturing industry has adopted hardware-based energy efficiency methods such as replacing high-efficiency equipment.[4] This approach incurs initial investment costs and requires time to obtain ROI (Return on Investment). In order to overcome this limitations of existing energy efficiency methods in the manufacturing sector, it is necessary to create a software-based energy saving solution by merging with the fourth industry technologies.

We are designing Energy-IoT service platform for legacy paper factory site to study energy saving and efficiency. The Energy-IoT service platform is an on-site technology that uses software to reduce energy in the manufacturing industry, which is the largest consumer of energy. The main idea is to improve energy efficiency in manufacturing plants by analyzing and tracking energy consumption patterns while maintaining production efficiency based on energy consumption factor data and environmental data.

In this paper, we designed the E-IoT service platform for energy saving. The correlation coefficients between raw material process high - voltage power and raw material process variables were derived using PI data collected from the field. A predictive model for high - voltage power of raw materials was established using one of the variables with the highest correlation coefficient. By using this, it is possible to predict the trend of raw material high-voltage power and apply it to the production process, and energy-saving model can be created through power simulation based on the process.

II. ENERGY-IOT SERVICE PLATFORM

The E-IoT service platform is a comprehensive solution that collects all the data from the legacy manufacturing process and analyzes the data to find ways to save energy. Generally, the papermaking process consists of a raw material process, a papermaking process, and a complete process, and a large amount of electric energy and thermal energy are used in each process. The E-IoT service platform collects data corresponding to each process step and performs data analysis based on process procedures. The E-IoT service platform designed in this study was structured to meet the paper manufacturing process and designed in accordance with the oneM2M standard.

A. Configuration

The E-IoT service platform consists of E-IoT module, E-IoT platform and E-IoT analysis system. The E-IoT module collects data from sensors, PI (Plant Information), and MES (Manufacturing Execution System) for each process and corresponds to the Application Dedicated Node (ADN) of oneM2M standard. PI is process-related data at the factory, and MES is data that can obtain the production status in real time. The E-IoT platform collects data from the E-IoT module and delivers it to the E-IoT analysis system, which corresponds to the infrastructure node(IN) of the oneM2M standard. The E-IoT analysis system analyzes and predicts the various energy data collected. It interfaces with E-IOT platform and oneM2M standard interface.

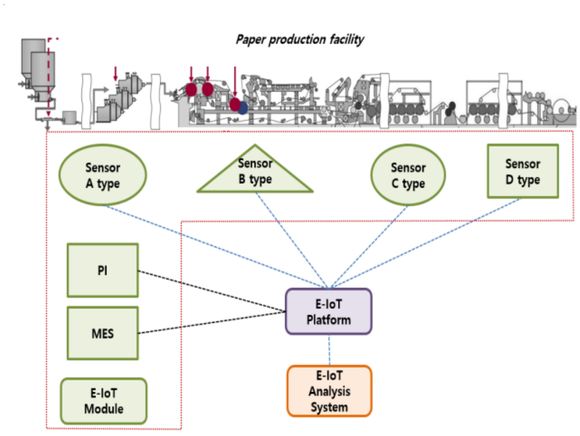

Fig. 1. Configuration of E-IoT service platform

B. Data Binding Structure

We used the TCP-based WebSocket protocol to transfer high-speed real-time measurement data between the E-IoT module and the E-IOT platform. The E-IOT platform manages the collected energy consumption factor data in a oneM2M resource tree structure. The E-IoT platform and the E-IoT analysis system are interfaced with the Message Queue Telemetry Transport (MQTT) protocol, which is oneM2M standard interface, for real-time delivery of collected Big Data to the E-IoT analysis system. E-IoT platform is designed to operate as MQTT Publisher and E-IoT analysis system to operate as MQTT subscriber.

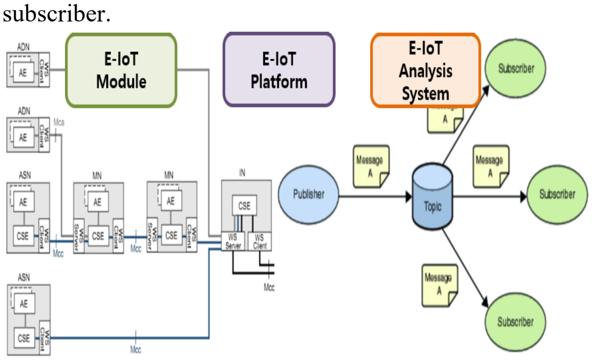

Fig. 2. MQTT binding structure between E-IoT platform and E-IoT analysis system

III. E-IoT Analysis System

We have designed a system that collects PI data, binds data, and analyzes and predicts power consumption using the E-IoT service platform structure. It is important to understand the relationship between power values and process variables in order to find the energy savings factor according to the process flow. In particular, as shown in the figure 3, high-voltage power in the papermaking process consumes most of the raw material process power, so it is necessary to find process parameters that affect the change of high-voltage power value. The E-IoT analysis system analyzes the correlation between high-voltage power and process variables to derive key variables and predicts power consumption.

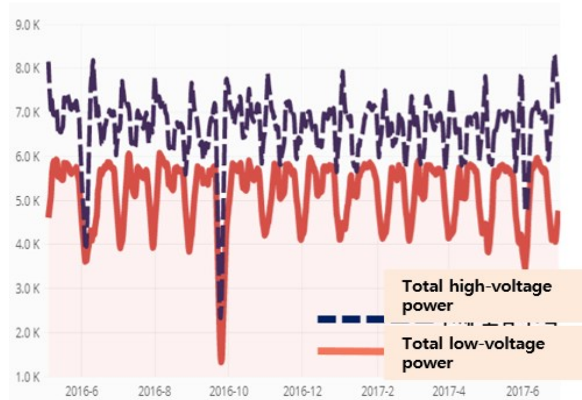

Fig. 3. Changes in high and low voltage power consumption over Time

A. PI data Collection

The PI system is a tool that allows you to check the tag information of the real-time operation (production) facility with a virtual window that helps you to see the production process directly. PI data was collected at legacy factory sites for energy savings. The data collected for this study is the accumulation of three years (2014.07 ~ 2017.06) as the size of 50GB. The collected data is stored in a time series database, InfluxDB, for ease of data analysis. The data stored in the database is 1472 excluding the tag variables that have no substantial value such as Null in the 1556 tag variables collected. Of the 1472 tag variables, 1382 are raw process tag variables and the remaining 90 are power tag variables including high voltage power variables. It is necessary to remove non-numerical data to facilitate correlation analysis. Basic statistical analysis such as standard deviation and quartile can be used to reduce the number of raw process tag variables. In this way, it is possible to exclude 142 tag variables near the first quartile, quartiles near zero, and 168 tag variables with almost no data change, with a standard deviation of zero. Therefore, correlation with high - voltage power was performed with a total of 1162 raw process tag data.

B. Correlation Analysis

Correlation analysis used Pearson correlation coefficient, which is closely related to the two variables. The Pearson correlation coefficient derived from Pearson correlation analysis is a value between -1 and 1, which is a positive correlation if the value is positive, and a negative correlation if it is negative. Usually an absolute value of 0.6 or higher means a high correlation between two variables. In order to carry out the correlation analysis, the number of data and the viewpoint must be the same between two variables. The resampling method was used to match the raw material high-voltage power data with the raw process tag data. First, we resampled the high - voltage power parameter data in seconds, in 1 - minute increments. Then, we derived the correlation between the resampled high-voltage power tag data and raw process tag variable data at the same point in time. The results of the correlation analysis are shown in Table 1.

TABLE I
THE NUMBER OF RAW PROCESS TAGS PER CORRELATION COEFFICIENT SECTION

Pearson Correlation coefficient	Number of raw process tags
0.7 or more	1
0.6 ~ 0.7	3
0.5 ~ 0.6	20
0.4 ~ 0.5	45
Less than 0.4	1093

C. *Prediction of Power Consumption*

A predictive model for the raw material high - voltage power was established by using one parameter with a correlation coefficient of 0.7 or higher with the raw material high - voltage power. This model uses linear regression analysis. The data for one year (2016.05~2017.04 : Learning area) was learned and the data for three months (2017.05~2017.07 : Prediction area) were predicted. The results are shown in the figure 4. Figure 4 is divided into a learning area and a prediction area. As can be seen in the prediction domain, the prediction value follows the trend of the real value. This means that past learning data enables future prediction of high-voltage power. However, a more precise prediction model is needed for peak points in the prediction domain.

This result shows that the power consumption trend can be predicted based on past data. If the corresponding variables are obtained by the process, power simulation based on the process becomes possible. The plant is capable of planning the process according to the expected high voltage power range.

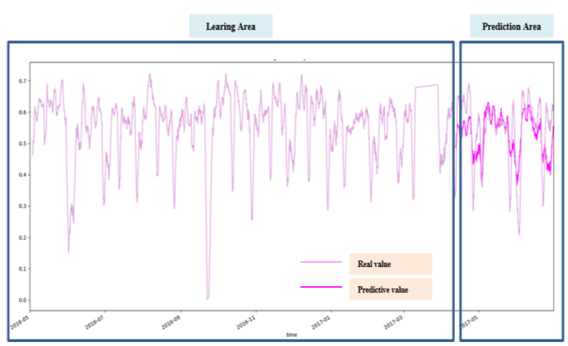

Fig. 4. Prediction of power consumption

IV. CONCLUSIONS

We proposed an E-IoT service platform that collects data from paper factory sites and analyzes data to find ways to save energy. The E-IoT service platform designed in this paper is structured according to the paper manufacturing process and designed according to the oneM2M standard. The collected energy data is transferred from the E-IOT platform to the E-IoT analysis system according to the oneM2M standard interface, Message Queue Telemetry Transport (MQTT) protocol. Using this data, we derived the correlation coefficient between raw material process high voltage power and process variables. A predictive model for high - voltage power of raw materials was established using one of the variables with the highest correlation coefficient. By using this, it is possible to predict the trend of raw material high-voltage power and apply it to the production process, and energy-saving model can be created through power simulation based on the process.

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