Analysis of Process Energy Measurement in Steam Intensive Use Factory

Jihyun Lee
Energy ICT Research Lab
ETRI
Dajeon, South Korea
jihyun@etri.re.kr

Il-Woo Lee
Industry Energy Convergence
Research Department ETRI
Dajeon, South Korea
ilwoo@etri.re.kr

***Abstract*— Steam is one of major energy source and energy saving target. In this paper, we did exploratory analysis of steam data and statistical analysis of process changes in the perspective of factory energy management. We applied the actual process operation data to our proposed method and could confirm the feasibility of the statistical based anomaly detection.**

Keywords—factory, steam, energy, analysis

I. INTRODUCTION

Among industrial energy resources, utility steam is produced in a boiler heated by burning coal, oil, gas, and etc. and used to obtain the temperature required in the heating, drying, and humidification processes.

In the paper production factory, steam is used in the drying process to dehydrate moisture from wet paper[1]. Domestic paper industry use about total 11% of the national heat energy consumption, so the saving of the use of steam is a great concern in paper factories.

We suggest hybrid analysis method combining exploratory analysis and statistical analysis[2] for the purpose of identifying process changes at the time when abnormal steam consumption occurred. We applied the actual process operation data to our proposed method and could confirm feasibility in finding anomaly symptom while steam is in use.

II. ACCURATE UNDERSTANDING OF INDUSTRIAL STEAM USE

A. *Necessary to integrate data collected from different sensors*

- Determining target to analyze: In a perspective of energy, we set a scope of a target machinery to analyze heavy steam-consuming process operated for paper dry.
- Data repositories: From the sensors installed for energy measurement, measurement data were collected and stored individually but need to be integrated and stored .
- Data types: For example, energy consumption, energy supply properties (e.g., steam pressure), internal and external operating properties of facilities (e.g., speed of operation, fluctuation values of factors influencing on supply), and quality of products exist.

B. *Hybrid analysis method with 2-steps of measurement exploration and anomaly detection*

- Exploratory analysis: It is used to review and recognize the data patterns from target variables.
- Statistical analysis: It is for identifying which dependent variables have changes at the time when abnormal steam consumption occurred in process energy pattern.

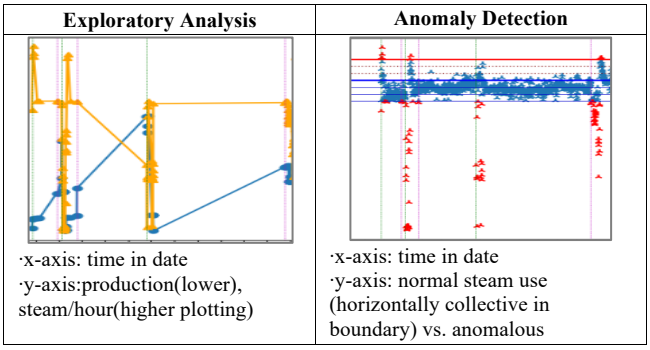

Fig. 1. Mixed Analysis Approach for Continuous Observation

Figure 1 shows the result from the suggested 2-step of analysis: the 1st step of exploratory analysis and the 2nd step of anomaly detection. We could assure that steam reflecting process events is a meaningful feature for identifying anomaly.

III. HYBRID ANALYSIS METHOD

In steam use, there is a general assumption, i.e. as production increases, the steam consumption is also increased. In other way, when production decreases, the amount of steam use decreases. The factory automatically controls the use of steam utilities in order to control demand-side response of steam, but the steam use is controlled according to the in-advance setting of control-range that maintain the steam demand. The suitable steam use moreover less steam can be consumed in paper production by considering the paper quality and the speed of the paper machine.

However, it is not yet applied that the advanced steam consumption including the analysis of the abnormal situation of steam use and the verification whether the degree of similarity to the general consumption pattern becomes deviated or not.

In our paper, we proposed hybrid analysis method for accurate understanding industrial steam use and applied to analyze real steam use data regarding to the case of paper factory.

Figure 2 represents the conceptual flow of the hybrid analysis method. From starting with calculating analysis indicator from data, hybrid analysis method flows. With the analysis indicator, the overall trend of the data can be visualized and if the deviation from the general pattern of the data is beyond of 99.73% data distribution, which is considered as abnormal.

Before anomaly detection and one more at this time, the exploratory analysis can be performed for data drilling of specific univariate or bivariate data influencing anomaly occurrence.

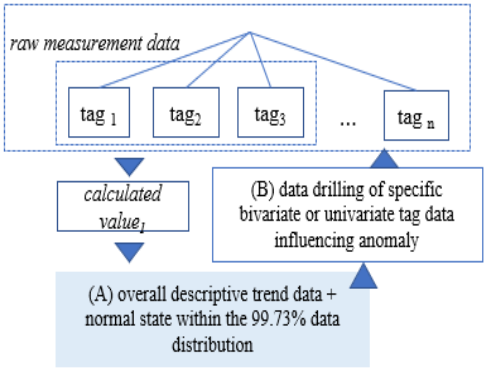

Fig. 2. Hybrid Analysis Flow

The analysis flow described above is composed of the following 10 tasks.

- Task 1. To decide which product data will be analyzed
- Task 2. To set which time range will be analyzed
- Task 3. To exploratorily analyze individual univariate data such as steam consumption and production
- Task 4. To calculate mean and standard deviation after preprocessing data meeting the conditions in task 1 and 2, plus reflecting process information
- Task 5. To apply ±3 sigma method on the result from task 3 and distinguish outliers before the next task runs
- Task 6. To visually identify anomalies from the ratio trend representing highly deviated steam consumption compared to production amount
- Task 7. To check the abnormal occurrence time information
- Task 8. To analyze the uni/bi-variate raw data at the time of anomaly occurs for checking which changes are diagnosed in detail
- Task 9. To review whether the presence or absence of abnormal process change history happened such as stop and production job change among the identified anomalous data points or ranges
- Task 10. To repeat periodic analysis

Each task can be mapped into the 2 types of analysis: the exploratory analysis and the descriptive analysis.

Table 1. The 2 Types of Hybrid Analysis Method

Exploratory Analysis	·Task 3: for data exploring ·Task 8: for data drilling
Descriptive Analysis	·Task 4: for calculating descriptive statistic values (ex. mean, median, standard deviation, distribution and etc.) ·Task 5: data identification from the distribution beyond boundary setting ·Task 6: for confirming data trend ·Task 7: for examining anomaly occurrence time ·Task 8: for digging premonitory data or transition influencing on anomaly occurrence ·Task 9: for checking abnormal event occurrence history during production

IV. Evaluation

Paper needs more steam because the more unit weight it has, the more water it needs to be dried when producing paper. Considering these production behaviors, the data was preprocessed after selecting the data when the same product is produced, in addition to the time range selection.

The ±3 sigma method was applied to analyze the abnormality by calculating the steam consumption ratio. When applied to the data in the area decided to analysis: the case 1 for outside ± 3 sigma, at this time steam use was considered abnormal. The case 2 for inside ±3 sigma was considered normal steam use.

We could confirm that the data above ± 3 sigma did not match 100% with the time of the process stopped or abnormal event history exist. The suggested hybrid analysis has advantage to considerably identify well the situation where production is going near to stop and steam consumption is not reduced. This situation resulted in a fairly bad control because steam supply is not reduced so wasted. The hybrid method can find these steam use anomaly occurrences.

V. Conclusion

With the exploratory and statistical analysis, we could steam consumption increase due to overheating and also decrease caused by process stop events. We applied the actual process operation data to our proposed method and could confirm the feasibility in finding anomaly symptom regarding to steam consumption.

Acknowledgment

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