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Identification of High Significance Product Items Through the Analysis of Energy Consumption in Steel Factory

A.B.M.Salman Rahman, Myeongbae Lee, Vasanth Ragu, Jonghyun Lim, Yongyun Cho, Jangwoo Park, Changsun Shin*

Department of Information and Communication Engineering, Sunchon National University

ABSTRACT

Analysis and modeling of industrial energy are currently a time-insertion process because more and more energy is consumed for economic growth in an industrial factory. Industrial energy consumption analysis and prediction play a very important role in improving the energy utilization rate to make profitable things for industrial companies or factories. Industrial factory owners are also starting to realize the importance of energy analysis and predictions to make a plan for better energy utilization for their factories. So, this is the high time to work as a technological supportive hand with an industrial factory in order to improve their energy utilization for making some profitable things for industrial organizations and also for our society. It is not so easy process to analyses energy and realizes accurate predictions of industrial energy consumption. Therefore, this study deals with analysing total usages of 24-hours energy consumption for every month and also total usages of energy for the year 2017. We find out the difference between total usages of energy and demands of energy for the year 2017. We make relation curve between per-day usages of energy and different types of materials weight for different types of manufacturing product, and also make a relation curve between per-day usages of energy, demands of energy and total materials weight for manufacturing products for the year 2017. We use the correlation method to find out the relationship of usages of energy with different types of materials weight for manufacturing products. Finally, we find out the total usages of energy for manufacturing every product and make a decision about the energy utilization.

KEYWORDS: Correlation method, Data analysis, Energy consumption, Electricity pricing, Demands of energy, Manufacturing products.

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*Corresponding author is with the Department of Information & Communication Engineering, Sunchon National University, Suncheon-si, Republic of Korea,57922. E-Mail address: csshin@sunchon.ac.kr

1. Introduction

Nowadays, more and more energy is consumed for economic growth and also for populations increasing. So, we have to think about how we can utilize energy to make industrial companies or factories more profitable. Industrial customer's facilities and equipment use electricity for processing, producing, or assembling goods, including such diverse industries as manufacturing, mining, and construction. Overall, these industrial sector usages more than one-third of electrical energy from countries total usages of energy. Therefore, it is necessary to give technological support to propose some effective strategies to promote the industrial energy utilization rate. Industrial energy consumption analysis and predictions can help us to make a decision so as to reasonably control all kinds of equipment for reducing energy consumptions rate or utilize energy in a systematic way to reduce the energy cost for getting more profit from industrial factories.

Industrial factory owners are also starting to realize that analysing and predicting the energy data with manufacturing data is so much essential thing for their companies or factory's profit. For improving the energy utilization of an industrial factory, this is the best time to work as a technological supportive hand with industrial factories managing board to improve their energy utilization better. By working together, we can make our industry more profitable by giving valuable results and suggestions.

In this study, we have two types of dataset and the dataset were collected from Daewoo Steel Factory in South Korea. The first one is industrial energy consumption data and another one is industrial manufacturing dataset or productions dataset. This study deals with analysing total usages of 24-hours energy consumption for every month and also total usages of 24-hours energy for the year 2017 to find out the maximum usages of energy time duration in each 24-hours. The major focus is to findout the relation curve between the total usages and demand of energy consumptions for the year 2017 by hourly. We make a relationship curve between total usages of energy, different types of the material weight of manufacturing products for every day in the year 2017 and also make a relation curve between per-day usages of energy, demands of energy and total materials weight for manufacturing products for the year 2017. Finally, we use the correlation method to find out the relationship of usages of energy with different types of materials weight for manufacturing products and also to find out the high significant factor for most usages of energy.

2. Related Works

Se-Hark Park has been published a paper about decomposition of industrial energy consumptions with an alternative method [1]. Yemane

Wolde-Rufael has published a paper about disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952-1999 [2]. Ramazan Sari and et al, has been published a paper to find out the relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach [3]. Zheng_Xin and et al, has published a paper an improved grey multivariable model for predicting industrial energy consumptions in China [4]. Luis M.Candanedo and et al, has been published a paper data driven prediction models of energy use in a low-energy house [5]. Yue-Jun Zhang and et al, has been published a paper about the decomposition of energy- related carbon emission and its decupling with economic growth in China [6]. ZZhi-Fu Mi has been published a paper on potential impacts of industrial structure on energy consumption and CO_2 emission: a case study of Beijing [7]. Yansui Liu and et al, has been published a paper about assessing the impact of population, income and technology on energy consumption and industrial pollutant emission in China [8]. Elias Duran has been published a paper on Analysis and decomposition of energy consumption in the Chilean industry [9]. Qunwei Wang and et al, has been published a paper about Measurement and decomposition of energy ‐saving and emissions reduction performance in Chinese cities [10]. Elham Delzendeh and et al, has been published a paper on the impact of occupants' behaviours on building energy analysis: a research review [11]. Fabrizio Ascione and et al, has been published a paper about a new methodology of the multi-objectives optimization of building energy performance [12]. Jianli Pan, Raj Jain and et al, has been published a paper about an internet of things framework for smart energy in building: designs, prototype, and experiments [13]. Mehmet Yalcinkaya and et al, has been published a paper about patterns and trends in building information modeling (BIM) research: a latent semantic analysis [14]. Seema Narayan and et al, has been published a paper on an investigation of renewable and non ‐renewable energy consumption and economic growth nexus using industrial and residential consumption [15]. Qinghua He has been published a paper on mapping the managerial areas of building information modeling (BIM) using scientometric analysis [16].

2.1 Correlation

Correlation is usually defined as a measure of the linear relationship between two quantitative variables. Normally correlation tends to be used when there is no identified response variable. It measures the strength (qualitatively) and direction of the linear relationship between two or more variables.

The most common measure of correlation is Pearson's product-moment correlation, which is commonly referred to simply as the correlation or the correlation coefficient. The characteristic features of the correlation are given below:

- A correlation of 1 indicates a perfect positive correlation.
- A correlation of -1 indicates a perfect

negative correlation.

- A correlation of 0 indicates that there is no relationship between the different variables.

- Values between -1 and 1 denote the strength of the correlation.

We assumed a model:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad [1]$$

Where, n for number of pairs of scores, $\sum xy$ for sum of the products of paired scores, $\sum x$ and $\sum y$ for sum of scores. $\sum x^2$ and $\sum y^2$ for sum of squared scores.

3. Materials and Methods

In this study, there are two types of dataset are available which gained from Daewoo Steel Factory, South Korea. Among these two data sets, one is for steel factory energy consumption data set and another one is steel factory manufacturing or productions data set. From energy data set, we get twenty-four hour usages of energy, demands of energy, lagging reactive power of the current, leading reactive power of the current, percentage of leading power and also the percentage of lagging powers are available for every day of the year 2017. From manufacturing or productions data set, we get the details about materials and productions like date of manufacturing product, product name, materials length, materials weight, material size, product item, product length, product weight, product size product standard and also lots of information are available. For checking per-hour usages of energy for every day we analysis, 2017 energy consumption data. We analysis energy consumption data of the year 2017 to find out every hour usage of energy and determine the time period of the high amount of energy usages for every day and also to determine the time period of less amount of usages energy. Figure 1 shows for 24-hours usages of energy consumptions for every day of the steel factory in the year 2017. In this figure the x-axis shows for the time in hours and the y-axis shows for the total usages of energy in kWh of every day in the year 2017. From the figure, we can see that most of the days from morning 8 am to night 10 pm usages of energy consumptions is very high and some of days it's going on till 11 pm and we also see that after 11 pm to till 8 am energy consumption is low.

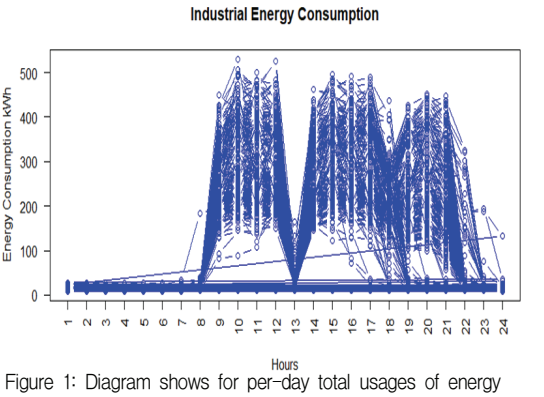

Figure 1: Diagram shows for per-day total usages of energy consumption of steel factory in the year 2017.

From figure we can also see that in the

year 2017 some of the day's energy consumptions are very low and those days are mostly weekly holidays and government holidays for the factory. Based on the figure we can easily say that Daewoo steel factory working hours are from 8 am to 10 pm and from 12 pm to 1 pm for lunch break and from 6 pm to 7 pm for dinner break.

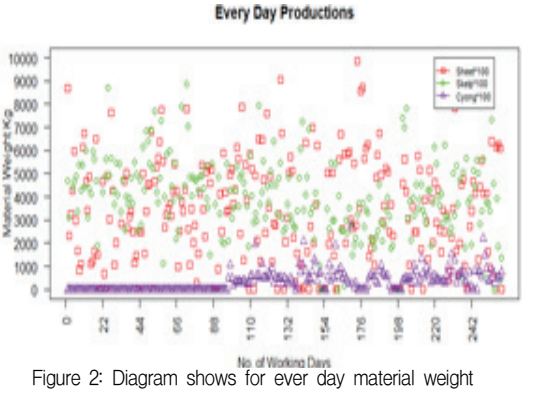

Figure 2: Diagram shows for ever day material weight manufacturing product in steel factory in the year 2017.

<Figure 2> shows the different types of material weight of manufactured products for every working day. From the figure, we can see that there are three types of product are manufactured in the Daewoo steel factory and the products are "sheet", "skelp", and "cyong". In this figure, the red color points show for per-day total material weight for sheet productions, the green color points show for per-day total material weight for skelp productions, and purple color points show for per-day total material weight for cyong productions.

Based on two dataset, we analysed 24-hour usages of energy consumption for every day in the year 2017. We make total energy consumption data in four groups as per Korean season's winter, spring, summer, autumn and then make one analysing curve to find out in which season this factory usage maximum or high amount of energy. We analysis total usages of 24-hours energy consumption for every month and also total usages of 24-hours energy for the year 2017 to find out the maximum usages of energy time duration in every 24-hours. We identify the relation curve between the total usages and demand of energy consumptions for the year 2017 by hourly. We make a relationship curve between total usages of energy, different types of the material weight of manufacturing products for every day in the year 2017 and also make a relation curve between per-day usages of energy, demands of energy and total materials weight for manufacturing products for the year 2017. Finally, we use the correlation method to find out the relationship of usages of energy with different types of materials weight for manufacturing products and also to find out the high significant factor for most usages of energy.

3.1 Calculating Usages of Energy for Product Items

$$PU = \frac{TU * TPM}{TM} \quad \text{..... [2]}$$

Here, PU – Product of Usage of energy,

TU – Total Usages of energy, TPM – Total Product Material weight, TM – Total Material weight.

4. Result and Discussion

In this sector, we can see the analysis results of 24-hours usages of energy consumptions for every day of the year 2017, find out the seasonal usages of energy, find out 24-hours usages of energy consumptions for every month of the year 2017. We can see the relationship curve between total usages and demands of energy for 24-hours of the year 2017. We can see the relationship between total usages, demands, and materials weight for every day for the year 2017. We usages correlations method to show the relationship of usages of energy with different types of materials weight for manufacturing products and also to find out the high significant factor for most usages of energy.

4.1 Energy Data Analysis

In this section, we show the analysis results of every month usage of energy, Korean seasonal energy analysis, and one-year total usages of energy with a corresponding demand for energy of the year 2017.

4.1.1 Per-Month Energy Analysis

To determine the per- hour usages of energy consumption of twelve months we analysis 2017 energy consumption data. We analysis total energy consumptions of per-hour for every month from energy consumption data of the year 2017 to find out every hour usages of energy and to determine the time period of the high amount of energy consumption usages and determine the time period of less amount of usages energy.

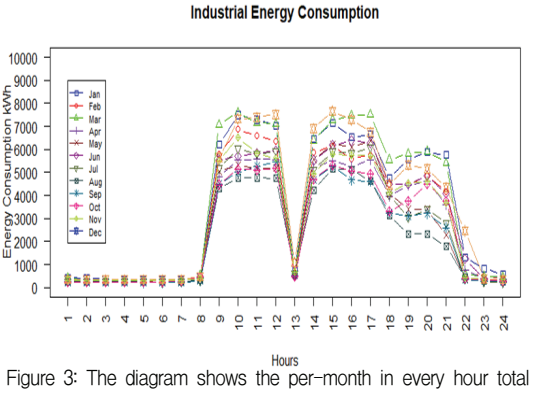

Figure 3: The diagram shows the per-month in every hour total usages of energy for steel factory of the year 2017.

<Figure 3>, shows every hour total usages of energy for working days consumption of every month in the year 2017. In the figure, the x-axis shows the time in hours and y-axis shows for total usages of energy in kWh. From the figure, we can see that every month from morning 8 am to night 10 pm energy consumptions is so high and we can also see that after 11 pm to till 8 am energy consumption is low. Based on the figure we can easily say that Daewoo steel factory working hours are from 8 am to 10 pm but sometimes they work till 11 am.

4.1.2 Seasonal Energy Analysis

In this study, we have energy data set of the year 2017. In Korea for seasons are available and they are winter, spring, summer, and autumn. We split 2017 energy consumptions data into four groups as four seasons to find out in which seasons this steel factory used the maximum amount of energy. Here, December to march for the winter season, April to June for the spring season, July to September for the summer season, and October to November for the autumn season.

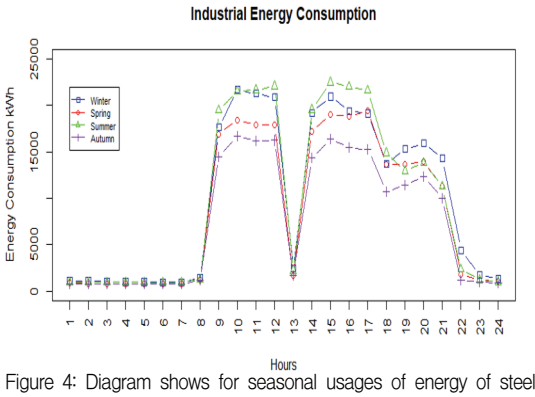

Figure 4: Diagram shows for seasonal usages of energy of steel factory for the year 2017.

<Figure 4> shows the seasonal usages of energy of steel factory for the year 2017. In figure x-axis shows the time in hours and y-axis shows for total usages of energy in kWh in the year 2017. From the figure we can see the four seasons usages of energy consumptions for the year 2017. In the figure blue line shows for the total usages of energy of winter for every hours, red line shows for total usages of energy of spring for every hours, green line shows for total usages of energy of summer for every hours, and purple line shows for total usages of energy of autumn for every hour in the year 2017. From the figure we can say that this steel factory usages maximum energy in summer season and winter season.

4.1.3 Analysis One Year Usages of Energy Data with Corresponding Demand

For checking per- hour usages of energy consumption and the demands of energy for one year we analysis 2017 energy consumption data. We analysis per-hour energy consumption data of the year 2017 to find out every hour usages of energy and demand for energy. We determine the time-period of the high amount of energy consumption usages and demand for energy, and determine the time-period of less amount of usages energy demand for energy.

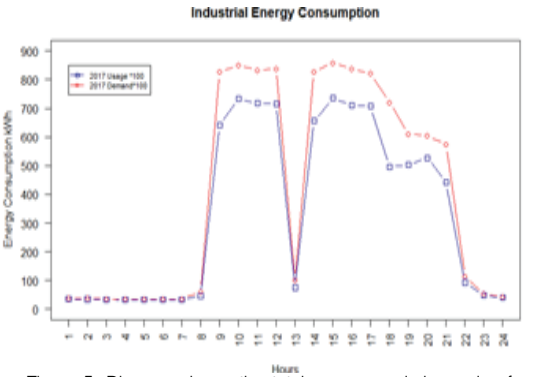

Figure 5: Diagram shows the total usages and demands of energy of steel factory for the year 2017.

<Figure 5> shows the total of twenty four hours usages and demands of the energy of working days for the year 2017. In the figure, the x-axis shows the time in hours and the y-axis shows for total usages of energy in kWh in the year 2017. In the figure, the blue line shows for the total usages of the energy of every hour for the year 2017 and the red line shows for the total demands of usages of energy for every hour for the year 2017. From the figure, we can from night 10 pm to morning 8 am usages of energy and demand of energy are close to same but when working hours start usages of energy and demands of energy start to increase and in working hour's demands of energy is higher than usages of energy.

4.2 Analyzing Energy data with materials weight of manufacturing products

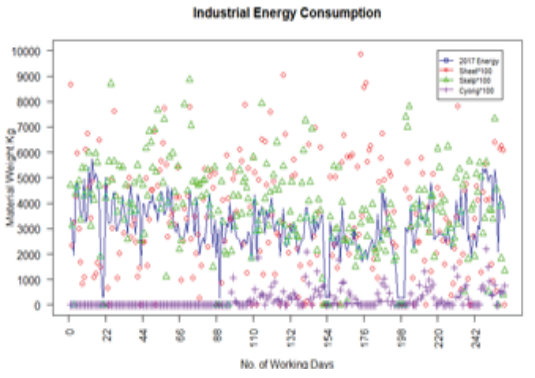

Figure 6. Diagram shows for the different type's material weight of manufactured products with usages of energy for number of working days in 2017.

As we discussed before that three types of products are produced in Daewoo Steel Factory. Here we analyze different types of the material weight of manufacturing products with total usages of energy for the number of working days.

<Figure 6>, shows the different types of material weight of manufactured products with per-day total usages of energy for the number of working days. In the figure, the x-axis shows the number of working days and the y-axis shows for material weight in kg in the year 2017. In this figure blue line shows for per-day total usages of energy for working days, red color points show for the per-day material weight for sheet productions, green dots show for per day material weight for skelp productions and purple color points show for the total material weight for cyong productions. From figure, we can say that when the density of materials increase that usages of energy consumptions also increase it means when productions are high usages of energy consumption also high.

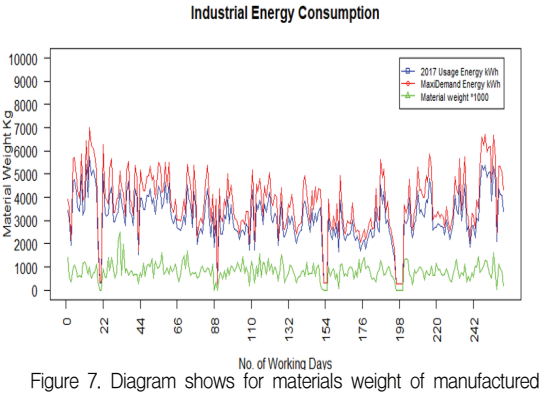

Figure 7. Diagram shows for materials weight of manufactured products with usages of energy for number of working days in 2017.

<Figure 7>, shows the everyday total material weight of manufactured products with total usages and demands of energy consumptions for the number of working days. In the figure, the x-axis shows for the number of working days and the y-axis shows for material weight in kg. From the figure, we can see that blue line shows for usages of energy for the number of working days, red line shows for a maximum demand of energy and green line shows for the total weight of materials for the number of working days. From the figure, we can see that when productions are increased usages of energy also increased and productions low means usages of energy also decreased.

4.3 Correlations

The correlation coefficient is the measure of relations between two or more variables. In this study, we use correlations method to determine the strength of a relationship and the strength between two variable we can easily calculate by through of correlation coefficient. We find out the correlation between total usages of energy with three different types of manufactured products.

In <figure 8>, histogram plot shows for the total usages of energy, total material weight of sheet, total material weight of skelp and last total material weight of cyong. The correlation value of total usages of energy with total sheet weight is 0.29^{***}. The correlation value of total usages of energy with total skelp weight is 0.49^{***}. The correlation value of total usages of energy with total cyong weight is 0.15^{*}. The star (*) values refers to the significant factor. Form histogram plot we can see that the relation among total skelp and total usages of energy is better than the other two products.

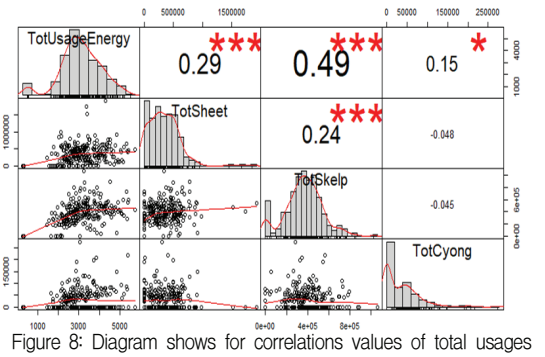

Figure 8: Diagram shows for correlations values of total usages of energy with manufacturing products.

4.4 Discussion

All results and analysis provided us the acuteness between usages of energy and the different type's material weight of manufactured products. Those results show us about the status of usages of energy and demands of energy with corresponding materials weight for manufactured products. Now we know about when energy consumption is very high and when the energy consumption is low. Now we know about the seasonal usages of energy and know that in which season usages of energy consumptions are very high. We use equation 2 to find out the total the usages of energy

for every product in the year 2017.

Table 1: Usages Energy Table of Steel Factory for year 2017

Names	Usages of energy kWh	Using Parentage
Sheet	322522.80	39.70%
Skelp	404568.10	49.82%
Cyong	45508.81	5.62%
Others	34836.55	4.32%
Total	807436.97	99.46%

From <table 1> we can know about the total usages of energy for manufacturing sheet, skelp, and cyong. <Table 1> also shows the percentage of usages of energy for manufacturing different types of products. From Table, we know for producing skelp they used the highest amount of energy than sheet and for producing cyong they used very less amount of energy.We know about the relationship between yearly total usages of energy and the total demands of energy. In this study, we find out the correlation value between the usages of energy and three manufacturing products. In correlations value, we see the correlation of total usages of energy with total sheet productions and the correlation value is 0.29^{***}, total usages of energy with total skelp productions and the correlation value is 0.49^{***}, also the total usages of energy with cyong and the value of the correlation is 0.15^{*}. From there we find out skelp has gotten high correlations then other two products and the value of the correlation is 0.49, and between skelp and usages of energy got high significance factor also (***). From result, we also see the in

Table 2. Electricity Pricing in South Korea [18]

Classification		Demand Charge (won/kW)	Energy charge (won/kWh)			
			Time period	Summer (Jul.1~Aug31)	Spring/Fall (Mar.1~Jun.30/ Sep.1~oct.31)	Winter (Nov.1~Feb. 28)
High voltage(A)	Option I	5710	off-peak load	45.80	45.80	49.30
			mid-load	87.30	59.30	85.90
			Peak-load	147.00	77.60	120.70
	Option II	6540	off-peak load	41.60	41.60	45.20
			mid-load	83.20	55.20	81.70
			Peak-load	142.90	73.50	116.60
High voltage(B)	Option I	5710	off-peak load	44.40	44.40	47.90
			mid-load	84.80	57.70	83.30
			Peak-load	141.80	75.40	116.70
	Option II	6540	off-peak load	40.20	40.20	43.70
			mid-load	80.60	53.50	79.10
			Peak-load	137.70	71.30	112.60

summer and winter season electric energy consumption is also very high. In Korea electricity cost is calculated in three types of daily rates and the three daily rates exist like off-peak (11 p.m. to 9am), on-peak (11 a.m. to 12 p.m., 1 p.m. to 5 p.m.), and mid-peak (9 a.m. to 11 a.m., 12 p.m. to 1 p.m., 5 p.m. to 11 p.m.). Customers are also offered different voltage levels, low voltage (220V and 380V) and three voltage levels ranging from 3.3kV to 345kV [18]. A major price difference exists with peak rates, where on-peak rates can be 325 percent higher than off-peak rates.

The table of information collected from KEPCO, (The Smart Grid in Asia, 2012-2016: Markets, Technologies, and Strategies). From <Table 2> we can easily say that off-peak hour's energy load price lower than mid-load and peak-load energy. From the result, we see that in summer and winter factory energy consumption is very high and we also find out skelp production is highly correlated with usages of energy with high significance factor. So, if factory authority starts to run two shifts in the factory for day time and night time like in peak hours and off-peak hours then the energy cost will reduced for this factory. As we find out skelp production is highly correlated with usages of energy so we can manufacture skelp in night shift.

5. Conclusion

In this study, we analyzed energy consumption and manufacturing data sets to define the usages and demands of energy corresponding to the weights of the materials of manufactured products. We found every month total usage of energy for every hour, see the seasonal usages of energy, the total usages and demands of energy for every hour in the steel factory in the year 2017. We see the relation curve between per-day usages of energy and different types of materials weight for different types of manufacturing product and see the relation curve between per-day usages of energy, demands of energy and total materials weight for manufacturing products of steel factory for the year 2017. We see the relationship of total usages of energy with different types of materials weight for manufacturing products in the steel factory.

This paper is focused on Industrial energy consumption analysis and prediction to improve the energy utilization rate to make profitable things for steel factory. From this study, we know about the working hours of the steel factory, seasonal usages and know about the correlations between total usages of energy and different types of manufacturing products. Factory working hour from 8 a.m. to 10 p.m. and this time factory maximum energy. Seasonal energy shows summer and winter time factory usages energy is very high then other two seasons. From correlations histogram, we can see that skelp productions are correlated with usages of energy better than other products. From <table 1> we see that using parentage of energy is for sheet producing 39.70%, for producing skelp 49.82% and for producing cyong 5.62%. This factory

used maximum energy for producing skelp in the year 2017. On the other hand In Korea electricity cost is calculated in three types of daily rates and the three daily rates exist like off-peak, on-peak, and mid-peak. Customers are also offered different voltage levels, low voltage (220V and 380V) and three voltage levels ranging from 3.3kV to 345kV. We see a major price difference exists with peak rates, on-peak rates, and off-peak hours. Peak hour and mid-peak hour energy rate is higher than off-peak hour energy rates. So, for Utilize energy to make a profitable thing for factory, our suggestions are to run two shift in the factory for day and night time like in peak hours and off-peak hours than energy cost will reduce for this factory. As we find out skelp production is highly correlated with usages of energy, we can manufacture skelp in night shift.

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철강공장의 에너지 소비량 분석을 통한 중요도가 높은 제품 품목의 식별

A.B.M. 살만 라호만[1], 이명배[1], 바산트 라구[1], 임종현[1] ,조용윤[2], 박장우[2], 신창선[2]

[1]*순천시 순천시 정보 통신 공학과 연구원*
[2]*순천시 순천시 정보 통신 공학과 교수*

요 약

산업 공장에서 경제 성장을 위해 점점 더 많은 에너지가 소비되기 될 것이기 때문에 에너지 소비량에 대한 분석이 필요하다. 에너지 소비 분석과 예측은 공장에서 제품을 만들기 위한 에너지 활용률을 개선하여 수익성을 높이는 데에 매우 중요한 역할을 한다. 공장주들 또한 에너지 활용률을 높이기 위한 계획을 수립하는 데 에너지 분석과 예측의 중요성을 깨닫기 시작했다. 그래서, 지금은 산업체 및 우리 사회의 수익성을 높이기 위해 에너지 활용도를 개선하고자 산업 공장과 기술지원을 함께 할 중요한 시기이다. 에너지를 분석하고 산업용 에너지 소비에 대한 정확한 예측을 실현하는 것은 쉬운 과정이 아니다. 따라서, 본 연구에서는 매월 24시간 에너지의 전체 사용량과 2017년 총 사용량과의 관계를 분석하였고, 2017년의 총 에너지 사용량과 에너지 요구량의 차이를 찾아내었다. 우리는 다양한 유형의 제조 제품에 대한 일일 에너지 사용량과 재료 중량 간의 관계 곡선과 제조 제품에 대한 일일 에너지 사용량, 에너지 수요 및 총 재료 중량 간의 관계 곡선을 도시했다. 마지막으로, 우리는 상관관계 분석을 사용하여 다양한 유형의 재료 중량을 가진 에너지 사용의 관계를 확인하고 모든 제품을 제조하기 위한 에너지의 평균 사용량을 알아본다.

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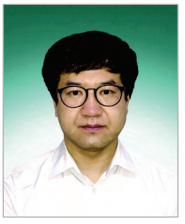
A B M Salman Rahman received the Bachelor degree on Electronics and Telecommunication Engineering from Southeast University, Dhaka, Bangladesh. Currently pursuing Masters leading Doctorate degree in information and Communication Engineering at Sunchon National University in South Korea. His area of interest includes Forecast Model, Ubiquitous Computing, and Big Data Processing.

E-mail address: salman01717@gmail.com



Myeongbae Lee completed Bachelor degree in Computer Engineering from Korea. He received Master degree on Computer Science in South Korea. And currently pursuing Doctorate degree in the Information and Communication Engineering. He area of interest includes Advanced Agriculture Technology, IT Convergence, Cloud and Ubiquitous Computing.

E-mail address: lmb@scnu.ac.kr

Vasanth Ragu completed Master of Computer Application (MCA) degree at Indo-American College from India. He is pursuing a Doctorate degree in information and Communication Engineering at Sunchon National University in South Korea. His area of interest includes Forecast Model, Ubiquitous Computing, Machine Learning, and Big Data Processing.

E-mail address: vasanth4224@scnu.ac.kr

Jonghyun Lim completed Bachelor degree in Information and Communication Engineering from Korea. He currently studying for master degree in Information and Communication Engineering at Sunchun University. His area of interest includes System Software, Ubiquitous Computing, and Big Data Processing.

E-mail address: sshb56@s.scnu.ac.kr

Yongyun Cho received the PhD degree in computer engineering at Soongsil University. Currently, he is an assistant professor of the Department of Information & communication engineering in Sunchon National University. His main research interests include System Software, Embedded Software and Ubiquitous Computing.

E-mail address: yycho@sunchon.ac.kr

Jangwoo Park received the BS, MS and PhD degrees in Electronic engineering from Hanyang University, Seoul, Korea in 1987, 1989 and 1993, respectively. In 1995, he joined the faculty member of the Sunchon National University, where he is currently a professor in the Department of Information & Communication engineering. His research focuses on Localization and SoC and system designs and RFID/USN technologies.

E-mail address: jwpark@sunchon.ac.kr

Changsun Shin received the PhD degree in Computer Engineering at Wonkwang University. Currently, he is a professor of the Dept. of Information & Communication Engineering in Sunchon National University. His researching interests include Distributed Computing, IoT, Machine Learning, and Agriculture/ICT Convergence.

E-mail address: csshin@sunchon.ac.kr