ENERGY AUDIT ANALYSIS BY BUSINESS INTELLIGENCE APPLICATION

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ABSTRACT
Energy audit is one of the first tasks to be performed in the accomplishment of an effective energy cost control program. To obtain the best information for a successful energy audit, the auditor must make some measurements during the audit visit. One of the tools that primarily used in audit visit is the portable Power Quality Analyzers (PQA) for measuring single to three-phase lines with a high degree of precision and accuracy. It is utilized for monitoring and recording power supply anomalies. For most survey applications, changing currents makes it mandatory for data to be compiled over a period of time with enormous amount of electricity data. Hence, this paper proposed a Business Intelligence approach that can facilitate the auditor to quickly analyze the PQA data. There are five Key Performance Indicators (KPI) to be displayed for analyze in form of dashboard. The method that uses to construct the dashboard is classification and association rules with the help of orange dataminer tools. Classification method is utilized to display the data distributions by frequency on a bar chart. Once we got the frequent sets, they allow us to extract association rules among the item sets, where we make some statement about how likely are two sets of items to co-occur or to conditionally occur. The result of this paper is a dashboard of five scorecards, namely unbalanced voltage, unbalanced currents, voltage harmonic, currents harmonic, and power factor.
Keywords: *PQA Data, Classification, Association Rules, Dashboard*

INTRODUCTION

An energy audit consists of a detailed examination of how a facility uses energy, what the facility pays for that energy, and finally, a recommended program for changes in operating practices or energy-consuming equipment that will cost-effectively save money on energy bills. The energy audit is sometimes called an energy survey or an energy analysis, so that it is not hampered with the negative connotation of an audit in the sense of a financial audit. Energy audits are performed by several different groups. Large commercial or industrial customers may hire an engineering consulting firm to perform a complete energy audit. Other companies may elect to hire an energy manager or set up an energy management team whose job is to conduct periodic audits and to keep up with the available energy efficiency technology. The Indonesian Ministry of Energy and Mineral Resources also funds a program where energy consultants perform free energy audits for small and medium sized manufacturing companies and commercial buildings.

Getting the correct information on facility equipment and operation is important if the audit is going to be most successful in identifying ways to save money on energy bills. That is why the critical stage of energy audit is the audit visit, where we use some equipment to capture primary data. The amount of equipment needed depends on the type of energy-consuming equipment used at the facility, and on the range of potential Energy Conservation Opportunities (ECO’s) that might be considered. Basically there are two types of utility that examined during energy visit, which is electric utility and thermal utility. Common equipment that utilized for the electric utility is the portable Power

Quality Analyzers (PQA), which uses to assess power supply problems such as voltage drops, flicker, harmonics, and other electrical issues. Currently, there is no specific method to assist the auditor in analyzing the PQA data.

Due to non trivial volume of data (PQA can capture every second of waveform so the auditor can determine how the voltage, current and frequency values are interacting), we must find a method that can classify and associate the data. The benchmarking is based on whether the PQA values are still on the KPI conformity range or not. Each component of the system started from transformators, main distribution panels and sub distribution panels must be checked for an opportunity to reduce electrical losses. Thus, the objective of this paper is to assist the auditor in analyzing the PQA data by constructing a dashboard which uses classification and association rules method.

RELATED WORK

In recent years, there has been a significant growth in research activities directed at conserving energy and natural resources [1]. It is with a common aim at environmentally conscious / benign manufacturing [2,3] of creating goods and services using processes and systems that are non-polluting. This has motivated numerous research programs to investigate energy consumption within a manufacturing facility so as to gain a better understanding of the energy use and breakdown.

The existing research in this area can be broadly viewed under two different perspectives of ‘plant’ and ‘process’ level. The first area, the ‘plant’ level perspective, has focused on the energy consumed by infrastructure and other high level services that are responsible for maintaining the required production conditions or environments. Examples of such energy consuming activities would be ventilation, lighting, heating and cooling within a facility [4]. Energy management systems (EMS) are commonly used to monitor these activities [5]. For example, Boyd et al. [6] utilized a statistical analysis approach to determine the manufacturing Energy Performance Indicators based on ‘plant level’ variables.

On the other hand, the research targeting the energy consumption at the process level has concentrated on individual equipment, machinery and workstations within a production system [7]. Substantial research has been targeted to document, analyze and reduce process emissions for a wide range of available and emerging manufacturing processes [8,9].

Overcash et al. [10] along with a group of other engineers are working to produce an engineering rule-of-practice-based analysis of separate unit processes used in manufacturing and the information is collated in the form of a unit process life cycle inventory (UPLCI) which would help the evaluation of manufactured products through the quantification of various parameters including: input materials, energy requirements, material losses and machine variables.

In addition, the specific energy of various manufacturing processes was previously summarized by Gutowski et al. [11]. They had developed generalize ‘equipment-level’ energy models, using average energy intensities of different manufacturing processes to evaluate the efficiency of processing lines. However, the considerations of energy flows at plant or process level cannot provide an overview of ‘‘how much energy is required to manufacture a unit product’’.

This paper, though, will focus on the ‘plant’ level perspective where we utilized a business intelligence approach to determine the Electricity Performance Indicators with 5 (five) scorecards for user interface such as Voltage Unbalanced (V_{unb}), Current Unbalanced (I_{unb}), Voltage-Total Harmonic Distortion (THD-V), Current-Total Harmonic Distortion (THD-I), and Power Factor (cos ϕ).

METHODOLOGY

a. Collecting the Data

An energy auditor will often need to conduct or commission energy survey to identify energy efficiency opportunities in the plant/facility. They need a useful energy survey to assist them in the energy audit process. The overview of energy audit method is as shown in Fig 1.

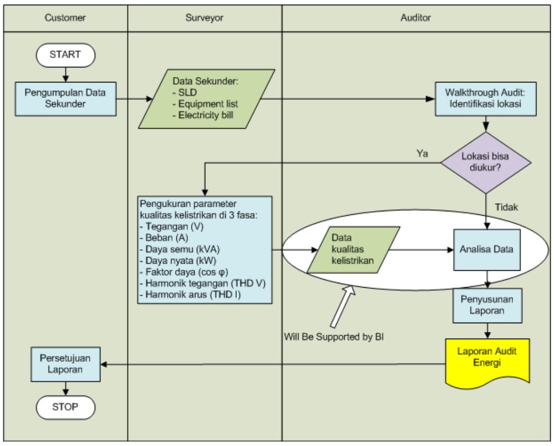

Figure 1. Energy Audit Method

The data of electricity quality is obtained by the operation of portable PQA as seen on Fig 2, which measures the electric panel.

Figure 2. Portable PQA

b. Data Preprocessing

The data from PQA can be read by the PQA-HiVIEW Pro software as seen on Fig 3. Then we can transform into a CSV (Comma-Separated Values) file by selecting several item sets as seen on fig 4.

In the CSV file, the real measurement data then can be modified into binary data by classifying it. The classification is based on the KPI. If the data is ‘OK’ then it should be classified as ‘0’ and if the data ‘Need Further Investigation’ then it should be classified as ‘1’.

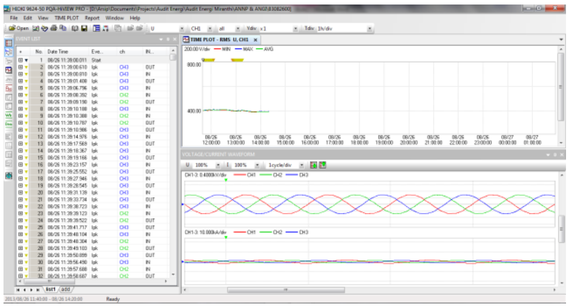

Figure 3. Display on PQA-HiVIEW Pro software

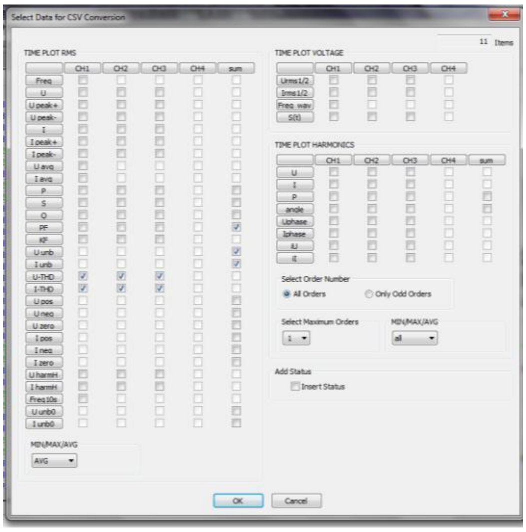

Figure 4. Transform the Data into CSV File

The basis of KPI is as follows [12]:

- Voltages and currents should be evenly balanced as closely as they can. The voltages and currents unbalanced have the possibility of damage to the electricity equipment. Operation of the electrical system with more than 3-percent of voltage unbalanced and 20-percent of current unbalanced is not recommended (based on ANCI C84.1). The voltage and current unbalanced in percent may be defined as follows: Percent of Unbalanced = 100 × (maximum deviation from average / average).
- Harmonics are components of current and voltage that are multiples of the normal 60Hz ac sine wave. Harmonics, if severe, can cause motor, transformer and conductor overheating, capacitor failures, misoperation of relays and controls and reduce system efficiencies. Compliance with IEEE-519 "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems" is strongly recommended, where it recommends the value of THD - V $\leq$ 5% and THD - I $\leq$ 15%.
- Power factor (cos ϕ) is the mathematical ratio of active power (W) to apparent power (VA). Power factor may be "leading" or "lagging" depending on the direction of VAR flow. Low (or "unsatisfactory") power factor is caused by the use of inductive (magnetic) devices and can indicate possible low system electrical operating efficiency. Operation of the electrical system with more than 0,85 of cos ϕ is recommended.

c. Data Processing

The data that has been preprocessed is then imported by Orange Dataminers software to run the classification and association rules. An association rule is an expression $X\ ^{s,c}$ Y , where X and Y are item sets and they are disjoint, i.e., $X, Y \subseteq I$, and $X \cap Y = \emptyset$. The support of the rule is the number of transactions in which both X and Y co-occurs as subsets. The relative support is defined as the fraction of transactions where X and Y co-occurs, and it provides an estimate of the joint probability of X and Y. The confidence of a rule is the conditional probability that a transaction contains Y given that it contains X. Let the item set $X \cup Y$ be denoted as XY. A rule is *frequent* if the item set XY is frequent, i.e., $sup(XY) \geq minsup$ and a rule is *strong* if $conf \geq minconf$, where *minconf* is a user-specified minimum confidence threshold [13]. The knowledge flow of the data is as follows:

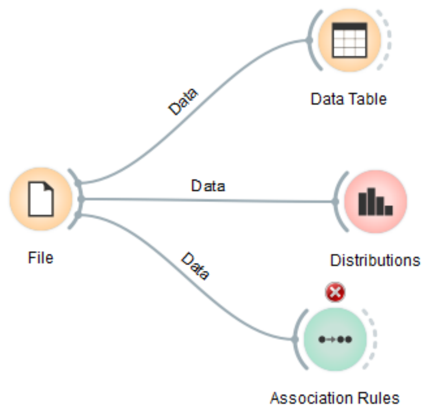

Figure 5. Knowledge Flow of the Data

d. Analyze the Data

The data can be analyzed by the display of a dashboard that consist five scorecards, namely unbalanced voltage, unbalanced currents, voltage harmonic, currents harmonic, and power factor.

With a glance view at the dashboard, one knew whether the electrical system is running on its KPI or not.

RESULT

The data for trial of the model is gained by the author from previous audit energy work. As we can see on Fig 6-10, the distribution of the data are displayed by the frequency and value of unbalanced voltage, unbalanced currents, voltage harmonic, currents harmonic, and power factor.

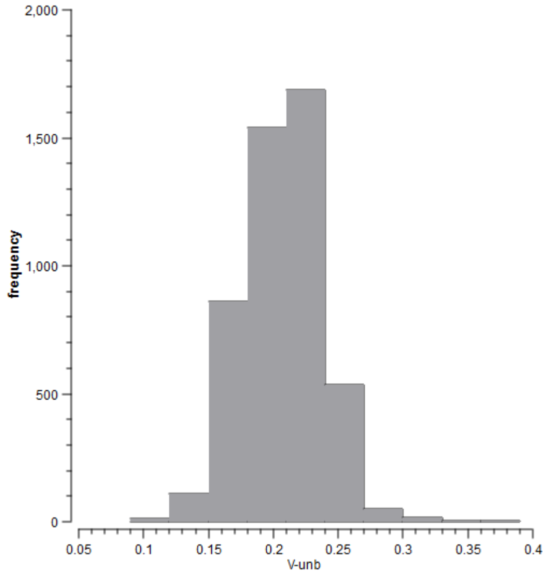

Figure 6. Distribution of V-unb

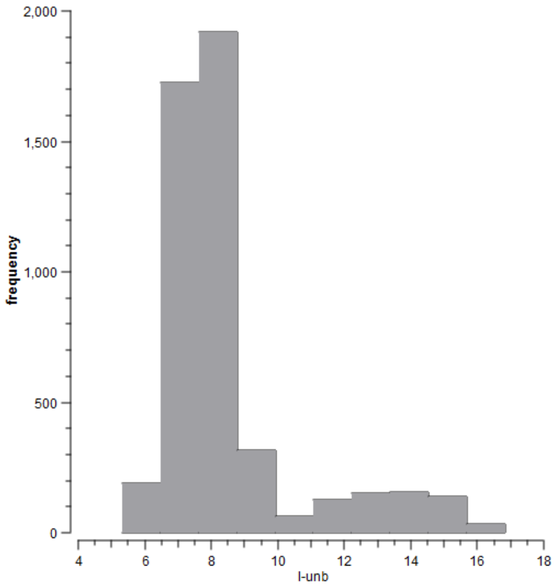

Figure 7. Distribution of I-unb

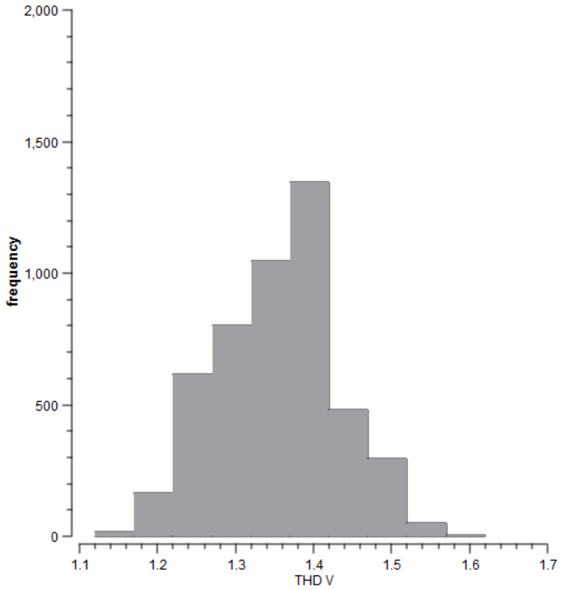

Figure 8. Distribution of THD-V

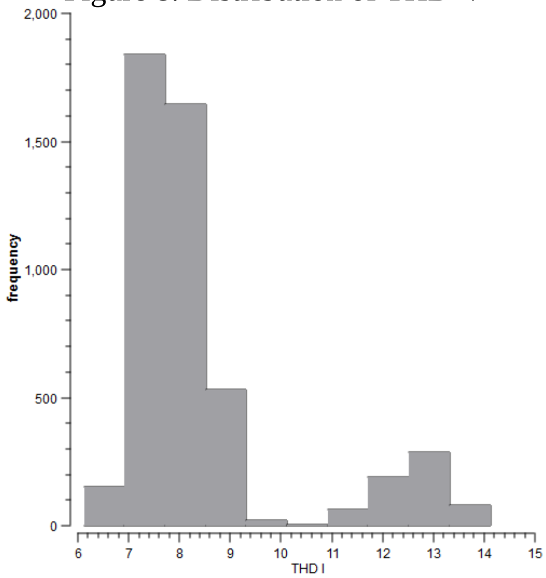

Figure 9. Distribution of THD-I

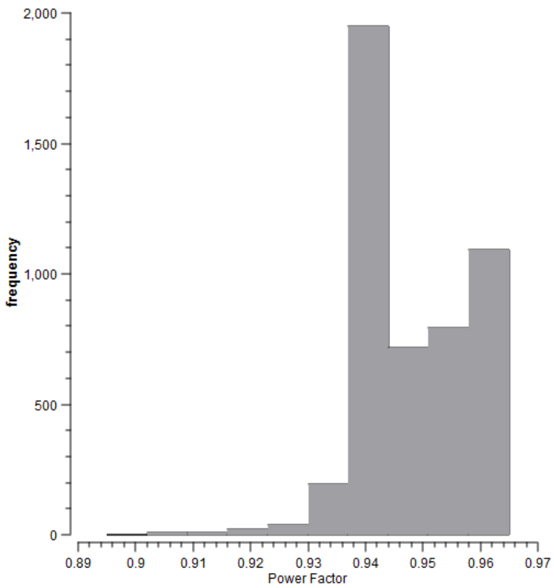

Figure 10. Distribution of Power Factor

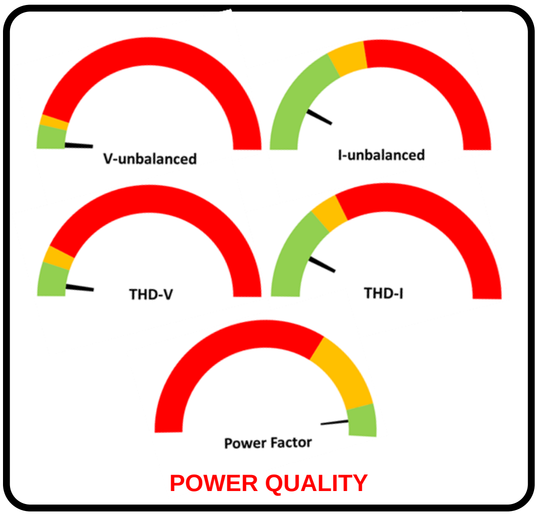

Figure 11. Dashboard of Power Quality

As for the dashboard, we can see the display example of power quality on Fig 11, where the green zone is set on the recommended value (basis of KPI). The value that displayed on Fig 11 is the modus value of the Power Quality data. If the entire needles are still point on the green zone, it means the power quality is 'OK'. Otherwise, it should need further investigation.

From association rules that has been applied on the PQA data, we can draw a knowledge discovery based on the support and confidence value that current harmonic distortion is strongly related to current unbalance. It means that if the value of current harmonic distortion is high, most likely the value of current unbalance is also high.

CONCLUSION

The work has addressed the data mining application in energy audit of an industrial or commercial building with a case example of PQA Data. The method can be used for minimizing the time in analyzing a large amount of analysis data. The work has shown the new combined energy audit method with method of data mining. After tested with the case example, the method has shown its capability to give the correct assessment using the existing calculated data.

Further work extensions in calculating the savings measures and in other type of energy audit data can be extended to gain the maximum benefits with more emphasize in data mining model.

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