Energy Database Management System (EDBMS)-based data acquisition audit for electricity savings analysis

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Abstract. State Polytechnic of Malang (POLINEMA) has taken a part of a joint action to energy savings. The load profile of POLINEMA has specificity in the intensity of electricity energy (IKE) consumption due to its characteristic as a vocational higher education. This specificity has caused POLINEMA to have many laboratories and workshops in each building. Energy savings can be done if it is supported by an energy consumption data audit system. The data will be calculated and compared to IKE standard. For that purpose, this research is aimed to design and implement an Energy consumption monitoring device based on Energy Database Management System (EDBMS). In this research, the energy audits were carried out on the lighting and cooling systems of seven buildings in POLINEMA, namely AB, AC, AD, AE, AF, AG, and AH buildings. After auditing of each building is as follows, the IKE value in the AB building is 30.5 kWh/m²/Year, the AC building is 7.5 kWh/m²/Year, the AD building is 15.2 kWh/m²/Year, the AE building is 24.3 kWh/m²/Year, the AF building at 71 kWh/m²/Year, AG building at 79.5 kWh/m²/Year, and AH building at 22.6 kWh/m²/Year. In conclusion, Energy consumption in POLINEMA is classified as efficient where the standard of a building for Commercial/Education is 240 kWh/m²/Year.

1. Introduction

Increasing the number of students each year will trigger the construction of new buildings as new classrooms. With the addition of new buildings, of course there will be additional new facilities to support learning process. Furthermore, it’s increased the consumption of electrical energy. The electricity system at the State Polytechnic of Malang (Polinema) is centered at the UPT.PP office which functions as a controller and monitors electrical energy. Currently, UPT.PP has two LVMDPs that supply each group of buildings. And as a back up from the PLN source, there are two generators that will be operated by the operator when occurs a blackout by PLN.

Recently, energy saving becomes an issue of the world because of the increasing electricity needs of all aspects of life. Indonesian government through mandatory circular number 302.E / 07 / DJE / 2010 issued by the Ministry of Energy and Mineral Resources (KESDM) obliges users of electric and non-electric energy equivalent to 6000 tons of oil or 69780 MWh per year to conserve energy [1].

One of the steps to conserve energy is to conduct regular energy audits. An audit can be done if the data electricity consumption is already collected. The data collection is carried out by measuring the required energy conventionally not in short time. Even, it requiring a professionals person in the retrieval of data in each building will be energy audits. The collection of energy consumption data that was done
by means of conventional measurement way needs energy, budget, and time. Even, it needs professional worker in data taking at each building which will be audited. The problem is the conventional measurement cannot be used to carry out the energy audit regularly. To cope with such problem, an EDBMS has been designed as a facility the data collection in terms of accuracy, easiness, and retrievability.

The designed EDBMS integrates 7 Polinema’s buildings. For this purpose, an energy monitoring tool is installed in each building’s Single Distribution Panel (SDP). It is equipped with a current transformer to get current data from each line (R.S.T) which is then connected to Power Monitoring (PM) and transmitted to the web. By this way, the auditing worker can get the required data easily. The energy audit consists of lighting system and cooling system audits. Electrical standard for Energy Consumption Intensity (IKE) for Office and commercial Educations in Indonesia is 240 kWh/m$^2$/year based on energy audit set for ASEAN and APEC countries. If from the analysis it the energy used is not according to the regulation, then energy saving will be carried to fit the IKE standard.

2. Material and methods

2.1. Energy Database Management System (EDBMS)
EDBMS is an application software that enables user to define, create, collect the electrical energy data, and control the access to database [2]. It is design to monitor the electrical energy unit at POLINEMA and uses cloud as the data storage central from the monitored buildings [3]. The kWh usage data in each building is taken through PM and delivered to the cloud storage. The collected data will be analyzed to calculate the value of the Energy Consumption Intensity in each building. There are five main components of the designed EDBMS, namely:

a) Hardware which can be in form of one personal computer/laptop, one mainframe, and computer network.
b) EDBMS software, namely a web-based application program.
c) Database which contains data and meta-data, as well as database structure called scheme.
d) Procedure that shows the impact of instructions and rules to the design, and the use of database.
e) Humans who are related to the system such as database designers, application developers, and end-users.

2.2. Energy audit
Audit energy is a mandatory and a first step to identify the energy saving potentials. The results of the audit will be used as a reference and information regarding the appropriate steps to run energy efficiency program. It is also the basis for determining the efficiency target as a reference in constructing action plan which consists of energy saving recommendations [4]. The procedure of energy audit includes planning, base data collection, tools testing data, data analysis, no-cost or low-cost recommendation, capital investment, implementation plan, and reporting.

2.3. Energy Consumption Intensity (IKE)
IKE is a terminology used to state the amount of energy usage per gross squared meter of a building at a certain range time. The energy usage can calculated if the followings are known [4]:

a) Details of the building area and the total building area (m$^2$).
b) Building energy consumption per year (kWh/year).
c) Building IKE (kWh/m$^2$/year).
d) Building energy cost (Rp/kWh).

According to ASEAN-USAID research in 1987, the electrical IKE in Indonesia is as follows [5].

- IKE for offices (business) : 240 kWh/m$^2$/year.
- IKE for shopping centers : 330 kWh/m$^2$/year.
- IKE for hotels/apartments : 300 kWh/m$^2$/year.
- IKE for hospitals/industries : 380 kWh/m$^2$/year.
Some calculations are needed to obtain IKE, kWh average or occupancy rate, room factor value (RK), light flux of room total (Q total), lighting strength, and required AC capacity as shown in (1) to (6).

\[
\text{Average}(\text{kWh/month}) = \frac{\text{Total kWh in 1 Year}}{\text{The Number of Months in 1 Year}} \tag{1}
\]

\[
\text{Occupancy Rate} = \frac{\text{The Number of Usage Time}}{\text{The Number of Available Time}} \times 100\% \tag{2}
\]

\[
RK = \frac{2x(\text{room width}) + \text{room length}}{6 \times (\text{room height})} \tag{3}
\]

\[
\text{Total Light Flux} = \text{The Number of Lamps (n)} \times \text{Lamp Lumen} \tag{4}
\]

\[
\text{Lighting Strengh} = \frac{\text{Total Light Flux} \times \text{Lighting Efficiency (\%)} }{\text{Room Area}} \tag{5}
\]

\[
\text{Required AC Horse Power} = \frac{\text{Length} \times \text{Width} \times \text{Height}}{3} \times 500 \tag{6}
\]

3. Results and discussion

Electrical energy needs at Polinema is supplied by PLN sources that are included in the electricity tariff class S3/TM. It is supplied with 2 transformers which each one is 500kVA. The electricity system at Polinema is centered in the UPT.PP which function as a controller and monitors electricity energy. It is also supplied with 2 genset which each a capacity is 250kVA. The generator is activated by the operator if in case of a blackout.

The distribution system at Polinema is divided into 2 LVMDP (Low Voltage Main Distribution Panel). LVMDP 1 is loaded as much as 795,827 VA and LVMDP 2 is loaded in the amount of 801,221 VA. So that the total power is 1,597,048 VA. The total installed power looks beyond the power provided. This can happen because the installed power is not used at the same time, for example PJU lights that only light up at the night.

3.1. Analysis of energy audit

The energy consumption data below is obtained based on data retrieval using the Energy Database Management System. Figure 1 shows the energy consumption data of each building.

![Figure 1. The energy consumption data in each monitored building.](image-url)
From the figure 1 it is used to obtain data to calculate IKE in the lighting system. The light intensity for each area in Polinema building is calculated according to the light installed. Then it will compare with the national lighting standards contained in SN 03-6197-2000. Table 1 shows the results of energy audits in 7 buildings that have been monitored based EDBMS.

**Table 1. Calculation of average consumption power (kWh) and energy intensity.**

| Buildings | Consumption Power (kWh/Year) | Total Month per year | Average of Consumption Power (kWh/month) | Wide (m²) | EI (kWh/m²) | EI Standard (kWh/m²) |
|-----------|-----------------------------|----------------------|------------------------------------------|-----------|-------------|---------------------|
| AB        | 22680.58                    | 12                   | 1890.048333                              | 736       | 30,81600543 | 240                 |
| AC        | 5145.86                     | 12                   | 428.8216667                              | 640.8     | 8,03036829  | 240                 |
| AD        | 11475.12                    | 12                   | 956.26                                   | 752       | 15,25946809 | 240                 |
| AE        | 20685.69                    | 12                   | 1723.8075                                | 817       | 25,31908201 | 240                 |
| AF        | 54886.46                    | 12                   | 4573.871667                              | 776       | 70,72997423 | 240                 |
| AG        | 64084.26                    | 12                   | 5340.355                                 | 834.2     | 76,8212793  | 240                 |
| AH        | 16987.86                    | 12                   | 1415.655                                 | 924.96    | 18,36604826 | 240                 |

The table show EI of some buildings in Polinema is lower than EI standard. That means the building is very efficient because it used natural lighting.

The lighting in each classroom as shown in the table 2 which shows the light intensity is not according to the standard. Based on field observations, each class has sufficient room lighting during the day, so that the installation of lights in each room is adjusted according to the needs. Besides that, the classrooms at Polinema are only used during the day. To conduct an audit of the cooling system in Polinema, will be calculated to the install AC (Air Conditioner) then compared to the applicable standards.

**Table 2. The calculation of lumen building AB in second floor.**

| No | Room               | Dimension (m) | Area (m²) | The Number of Lamps | QI Lamp (lumen) | Qt Total Light Flux Installed (lumen) | Rk | Efficiency (lux) | E Calculation (lux) | E Standard (lux) | Noted |
|----|--------------------|---------------|-----------|--------------------|----------------|--------------------------------------|----|------------------|---------------------|------------------|-------|
| 1  | Computer Lab 1     | 8, 7.75, 3   | 62        | 6                  | - 4100         | - 24600                              | 1.3| 0.52             | 206.32              | 500              | < SNI |
| 2  | Computer Lab 2     | 8, 7.88, 3   | 63        | 6                  | - 4100         | - 24600                              | 1.3| 0.52             | 203.05              | 500              | < SNI |
| 3  | Auditorium        | 15.6, 8, 3   | 125       | 8                  | - 4100         | - 32800                              | 1.7| 0.57             | 149.57              | 300              | < SNI |
| 4  | Classroom m V      | 6, 8, 3      | 48        | 4                  | - 4100         | - 16400                              | 1.2| 0.51             | 174.25              | 250              | < SNI |
| 5  | Classroom m VI     | 5.88, 8, 3   | 47        | 4                  | - 4100         | - 16400                              | 1.2| 0.51             | 177.96              | 250              | < SNI |

Table 3 shows the calculations for air conditioning requirements in the AB building, it can be seen that many of the air conditioners installed are not in accordance with the cooling required. Polinema can still make savings from the cooling system, if the classroom has sufficient air ventilation.
Table 3. The calculations for air conditioning requirements in the AB building.

| No | Room            | Dimension (m) | The Number of AC installed | P (W) | Capacity of AC installed (PK) | BTU/hour installed | BTU/Hour required |
|----|-----------------|---------------|----------------------------|-------|-------------------------------|--------------------|-------------------|
| 1  | Classroom 1     | 8 7.75 3 1   | 1472                       | 2     | 18000                         | 31000              |
| 2  | Classroom 2     | 8 7.88 3 1   | 1472                       | 2     | 18000                         | 31500              |
| 3  | Lecturer room 1 | 8 7.88 3 1   | 1472                       | 2     | 18000                         | 31500              |
| 5  | Lecturer room 2 | 8 8 3 2      | 2944                       | 2     | 36000                         | 32000              |

4. Conclusion
This paper has proposed an Energy Database Management System to be used as a data collector. It is used to facilitate periodic energy audits. The conclusions that can be summarized based on the results of the energy audit are:
- The value of the Energy Intensity (EI) of some Polinema Buildings are still within standard.
- The lighting system has a lower standard based on SNI 03-6197-2000.

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