# ENERGY AUDIT FOR THE ELECTRICAL SYSTEM IN THE COMMERCIAL BUILDING

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**ABSTRACT**

**ENERGY AUDIT FOR THE ELECTRICAL SYSTEM IN THE COMMERCIAL BUOLDING .** This papers presents some results of the energy audit that was conducted in the commercial building i.e a hotel to recommended measures to decrease energy costs every month by identifying of energy loss. This audit focused on the electrical system. The performance of this system was examined to identify opportunities for improving energy efficiency. It is concluded that approximately 65 % of electricity use in the object study is for its central air conditioning system. Therefore, automatic energy saving adjustments towards the air conditioning system will provide a significant amount of savings.

**Keywords**: Energy audit, electrical system

***ABSTRAK***

***AUDIT ENERGI UNTUK SISTEM ELEKTRIKAL PADA GEDUNG KOMERSIAL.*** *Tulisan ini menampilkan beberapa hasil dari audit energi yang telah dilakukan untuk gedung komersial dalam hal ini hotel untuk menurunkan biaya energi setiap bulan dengan cara mengidentifikasi kehilangan energi. Audit ini difokuskan pada system elektrikal. Kinerja system ini telah dievaluasi untuk mengidentifikasi oportunitas memperbaiki efisiensi energy. Disimpulkan bahwa sekitar 65 % dari penggunaan energi pada objek studi adalah untuk system pengkondisian udara sentral. Oleh karena itu, pengaturan penghematan energi otomatis pada system pengkondisian udara akan memberikan jumlah yang cukup siknifikan.*

***Kata Kunci :*** *Audit energi, sistem elektrikal*

## INTRODUCTION

An energy audit is an examination of an energy consuming equipment/system to ensure that energy is being used efficiently. Conducting an energy audit can directly benefit commercial building operators, power plants and industrial facilities by optimizing energy use and incorporating energy efficient practices which help reduce overall expenses.

The efficiency improvement of the steam power plant as well as the nuclear power plant result primary from reduction in waste heat energy losses in the stack gases and expelled water. Procedures that reduce the mass flow and energy content of these flow streams directly benefit unit performance. Other losses occur from surface heat transfer to the atmosphere and incomplete combustion of the fuel. The number of pieces of equipment that required to be run during shutdown is optimized to reduce station energy consumption. Continuous trend monitoring of heavy water and light water collection during reactor operation will help stations in taking appropriate remedial measures.

A hotel is a typical commercial building that behaves quite differently in comparison to other commercial buildings. The energy consumption of a hotel depends on the rate of occupancy and the hotel type. Due to the economic crisis which directly affected the tourism sector in Indonesia, the hotel business experienced significant deflation. The number of hotels decreased to 20% from the year 1997 to the year 2000. To sustain the hotel business from falling into economic crisis, due to rapidly increasing energy prices, it is highly recommended that the hotels participate in energy saving projects and energy efficiency campaigns including energy audits as well. The energy saving project requires an energy audit to be conducted on all systems within the hotel building. It is hoped that the energy audit activity will improve the awareness of energy saving activities especially for star and non-star hotels in Jakarta.

The objective of the energy audit is to find ways to decrease energy costs (electrical and thermal) per month by identifying sources of energy loss within the hotel. It is important to boost the efficiency of every utility component to optimize electric usage.

## THEORY

### ● Electrical system description

Figure 1 shows the electric supply of the object study of Twin Hotel that located in West Jakarta. There are two sources of electrical power for the hotel and the apartment buildings. The first source is from PLN (the State Electric Company) with the voltage of 20 kV, 3 (three) phases, frequency of 50 Hz, and a total power capacity of 1800 kVA. The second source is from two generator units each with a capacity of 1500 kVA with parallel connections to the PLN line. The two electrical generators function as backup power supply and are only operated when power supply from PLN fails.

The electrical energy from PLN travels through the middle voltage main panel (Panel Utama Tegangan Menengah, PUTM) and is then distributed through the low voltage main distribution panel (LVMDP) through 2 units of voltage reducing transformers to the capacity of 2000 KVA, then the electrical energy goes to the loads through bus bars.

To compensate the excess kVARh (Kilo Volt Ampere Reactive hours), two sets of capacitor banks have been installed and are arranged in parallel connections with the transformers. The banks capacity for the apartment is 10 x 2 x 50 KVAR, and for utilities is 6 x 50 KVAR.

The electrical energy load distribution is divided into three loads, i.e.: the load for utilities and supporting facilities of the hotel and apartment; the total load for the hotel; and the total load for the apartment. The energy audit activity was focused only on the total load of the hotel.

## METHODOLOGY

### ● Study approach

An energy audit is one of the first steps in any comprehensive energy management program. Without conducting an energy audit it would be difficult to quantify the energy consumption, energy distribution, performance levels and energy saving potential for all energy intensive systems within a hotel. By definition, an energy audit is an activity to measure energy consumption, energy distribution, performance levels, and energy losses of some energy consuming systems.

Energy audits require the use of measurement equipment, measurement points and measurement activity. Measurement equipment should be calibrated and certified. Measurement points should be located appropriately within the heat balance boundary. And the measurement activity should not disturb process operation and damage the equipment function of energy consumer systems.

The main purpose of measurement is to obtain accurate data based on actual operating conditions of the systems studied. Measurements can be carried out either through online or offline methods.

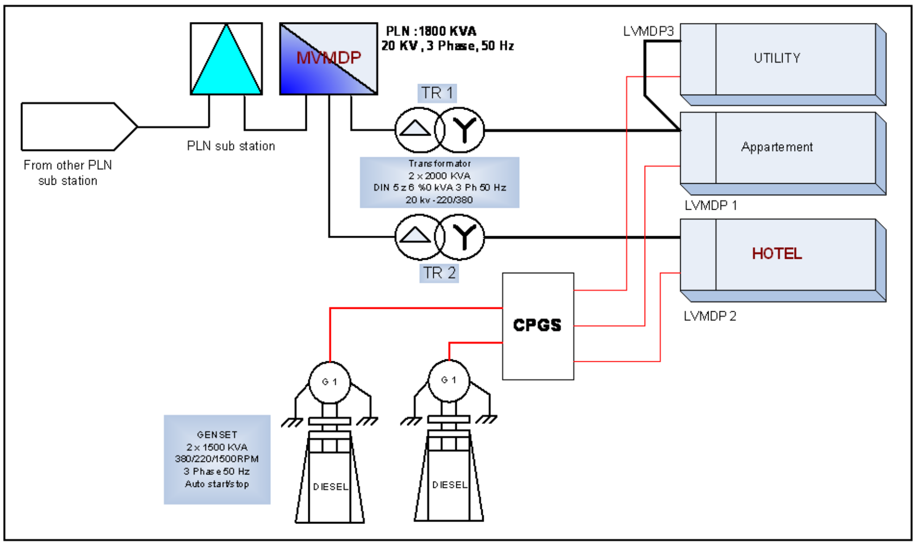


Figure 1. Electrical Power Supply for the object study[2]

Online measurement is a method where all or some data are recorded directly, automatically and continuously in the same time by using data logger or data acquisition systems. On the contrary offline measurement is a method where all or some data is also recorded directly and continuously but manually using handheld equipment.

**● Energy audit equipments and tools**

The main equipment required for the purposes of conducting an energy audit is:

- A computer system, other hardware, software, special tools and programs for analyzing and evaluating the data accurately and efficiently.
- Data acquisition system, for measuring, calculating, and recording data during the system's normal operation. With the data acquisition system, on-line measurements could be conducted to graph multiple data fields simultaneously; curves or diagrams of load characteristics and load distributions can also be displayed.
- Measuring equipment consists of sensors, transducers, and several hands held measuring equipment.
- An energy measurement and logger set, consists of a computer set, data acquisition system, censor and tranducer, and VA instrument.

## RESULTS AND DISCUSSION

The energy audit was carried out in the hotel that based on the Guidelines of Energy Audit which given in reference 1. And then all the collected data and the results of calculations were analyzed and evaluated to identify the sources of energy losses. From these calculations the potential amount of energy savings were determined, and this information was also used to asses the operation of equipment to make it more efficient and economical.

### ● Load system

The electrical power system in the hotel is distributed through several panels highlighted below:

- Center Panels at Low Voltage Main Distribution Panel (LVMDP)
- Panels at Transformer I
- Panels at Transformer II

All panels are connected to subsequent sub panels for the hotel and the apartment. In the hotel sub panel namely the center panels at LVMDB, is divided based on the number of floors within the building. During the energyaudit in the hotel, only the sub panels up to the 11th floor were studied.

The present balance of electrical power in the apartment and the hotel can be seen in Figure 2. The electrical load distribution in the hotel building can be seen in Figure 3. From figure 3, it can be seen that the largest electrical energy consumer is the central air conditioning system. Therefore, automatically energy saving adjustments towards the air conditioning system will result in a significant amount of savings. Furthermore, any modification toward other systems, including the lighting system, will augment total electricity saved from this project.

The average electrical power consumption for the hotel is 355.5kW, while the maximum can reach 441.9 kW (455.6 kVA). The maximum electrical power consumption in the hotel is relatively small when compared to the installed transformer capacity which is 2000 kVA and the installed PLN capacity which is 1800 kVA (for the hotel and apartment).

The electrical system in the hotel is a 3 phase system. It means that the electrical power is distributed through three power cables; R, S and T. Each power cable has its own voltage, ampere and load. Results from the online measurement results (Figure 4) depicted an imbalance between loads in the three phases R, S and T. The imbalance within the system was measured as 1.46 % and falls below the 3% that is considered to represent a poor power system. Hence the power system in the hotel is still considered to be adequate.

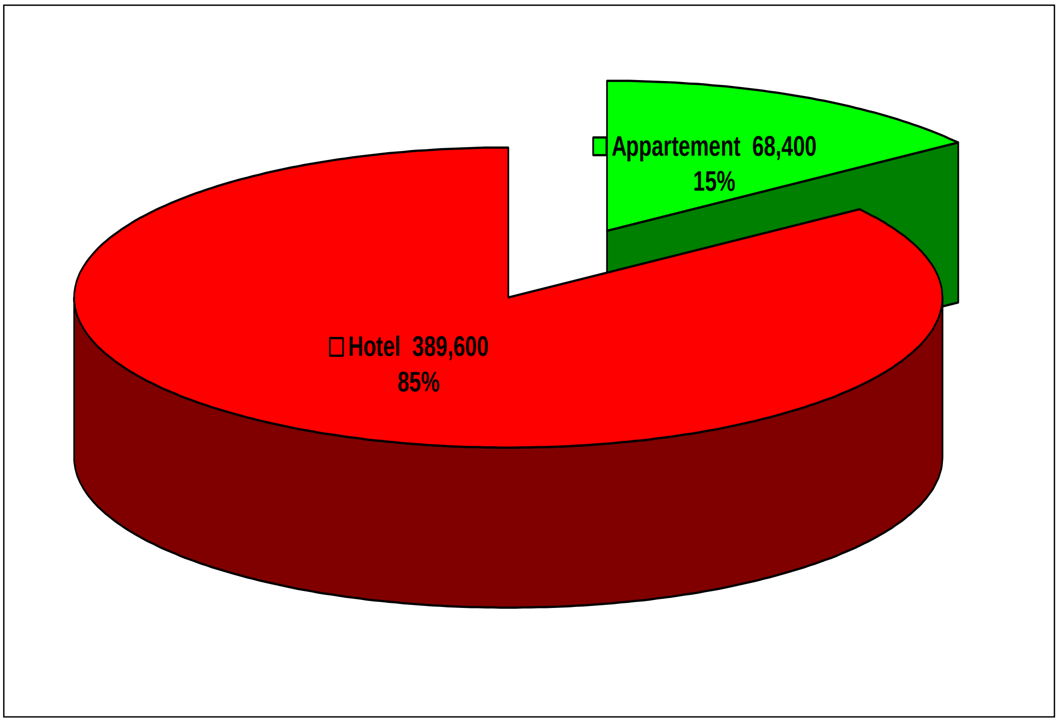


Figure 2 Electrical power balance of apartement and hotel [2]

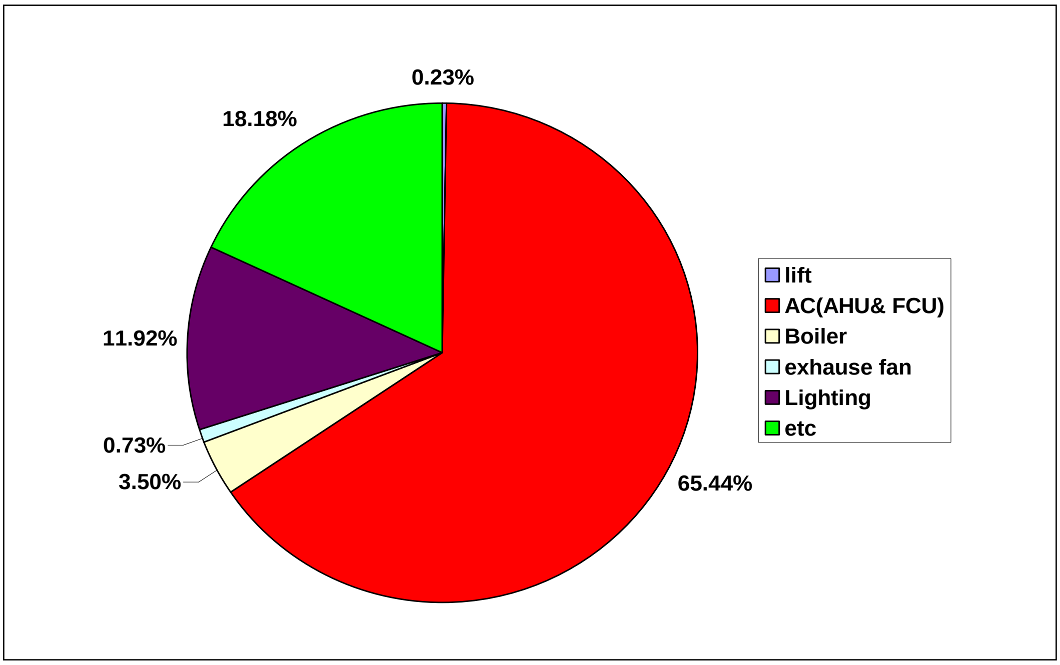


Figure 3. Electrical load balance in the hotel [2]

- **Power factor**

Power Factor is the ratio of actual power being used in a circuit, expressed in watts or kilowatts, to the power that is apparently being drawn from a power source (or in this case the power that is being supplied by PLN), expressed in volt-amperes or kilovolt-amperes. A high power factor value indicates that the electricity distribution system is performing well. An online measurement shows that the power factor of the hotel's electricity system varies slightly from 0.965 to 0.995, as provided in Figure 5 The power factor reading implies that the hotel has applied a good practice for load distribution. This is a result of installing capacitor banks to increase the existing capacity, to reduce cable and distribution losses and to improve the total system voltage.

Due to the high power factor in the hotel, it is free from the penalty charged by PLN to customers with a power factor value below 0.85. A penalty from PLN is also usually charged to customers with ratio of kVARh to kWh below 0.62.

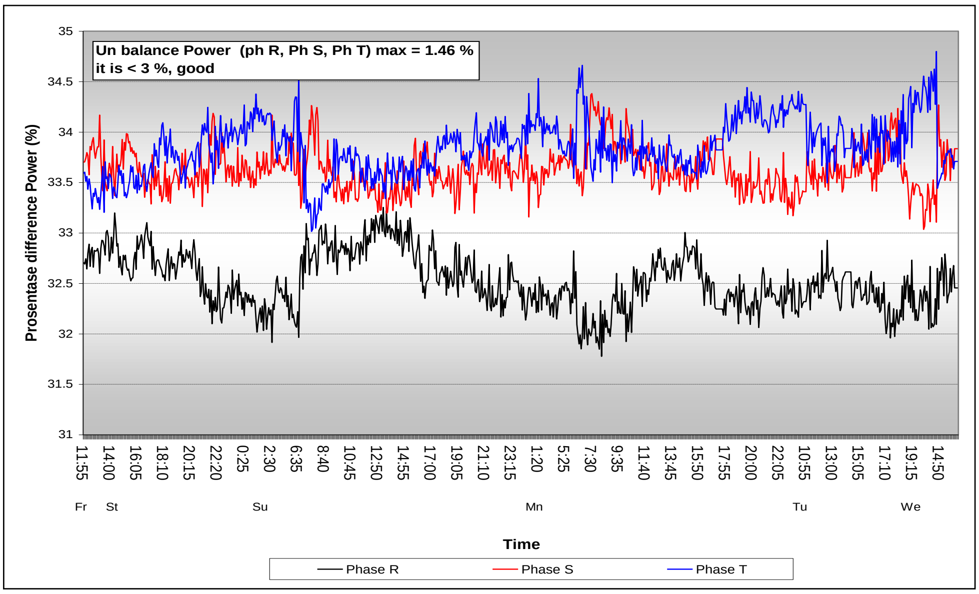


Figure 4. Power balance between the phases in the input panel of hotel loads

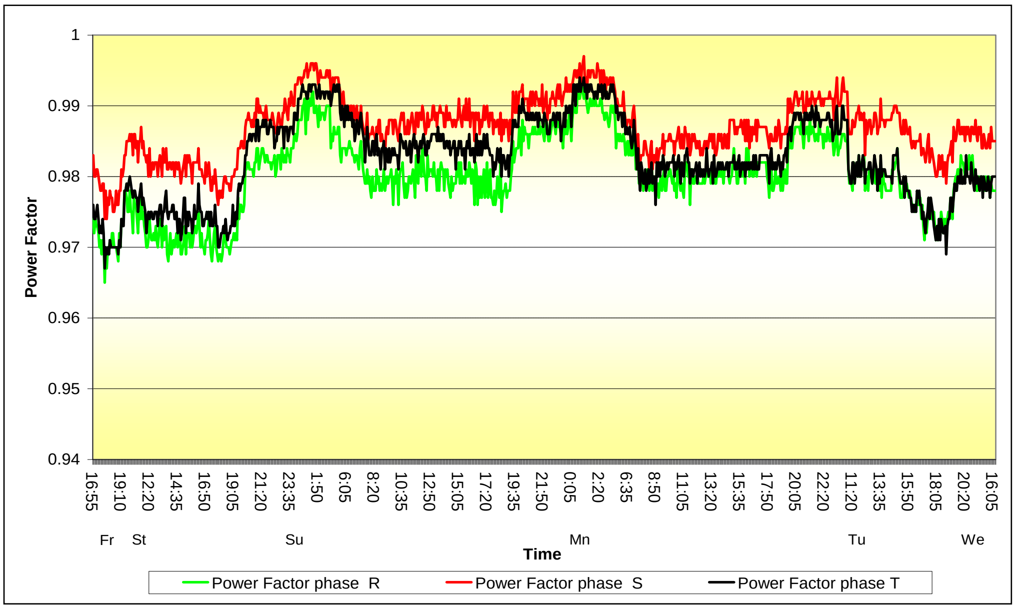


Figure 5. Power factor for system in Transformer #2

**● Demand factor**

Demand Factor is the ratio of the maximum demand on an electricity generating and distribution system to the total connected load in the system (installed capacity); usually expressed as a percentage. The maximum daily power consumption may reach up to 441.9 kW, as shown in figure 10. If the average power factor is 0.97 and the PLN installed capacity is 1800 KVA, then the demand factor value of the system is.

During the energy audit study it was observed that the energy consumption in the hotel is relatively small, i.e. only 25.3 % of the total installed power capacity. This is because the hotel has developed and is utilizing only 11 of the 24 floors existing within the building. The contracted power from PLN is for all 26 floors.

**● Load factor**

Load Factor is defined as the ratio of average energy demand (load) to maximum demand (peak load) during a specific period. It shows the level of load fluctuation at a certain period of time. Figure 8 depicts a stable fluctuation of monthly electricity consumption of the hotel. This indicates a healthy load distribution system.

**● Power quality**

The quality of the electrical power is determined by the stability and reliability of supply and the harmonics power problem.

The term "power quality" can be defined in multiple ways. One definition is that power quality is the relative frequency and severity of deviations in the incoming power supplied to electrical equipment from the customary, steady, 50 Hz, sinusoidal waveform of voltage or current. These deviations may affect the safe or reliable operation of equipment such as computers, TVs, and other sensitive appliances.

Poor power quality affects the reliable operation of computers and computer-based equipment, which are now ubiquitous. More important than the physical effects on the equipment is the loss of productivity resulting from computer equipment failure, miscalculations and downtime.

Every year, the number of cases for electrical equipment damage caused by harmonics, is increasing significantly. For this reason, the government since 1994 has implemented a regulation to overcome the harmonics problem.

Results from the energy audit for existing Total Harmonics Distortion (THD) in the electric current can be seen in figure 6 and the total harmonics distortion in the voltage can be seen in figure 7. Figure 6 indicates that the magnitude of THD in the electric current for the three phases (R, S and T) is still less than 15%. This means that the electrical equipment connected to the system transformers is still safe from disturbances. However, the capacitor bank, which is connected in parallel to the transformers especially for phase T needs to be checked routinely for any irregular temperature levels and/or harmonics voltage, levels. A capacitor bank improves power factor within a system but can also result in harmonics distortion.

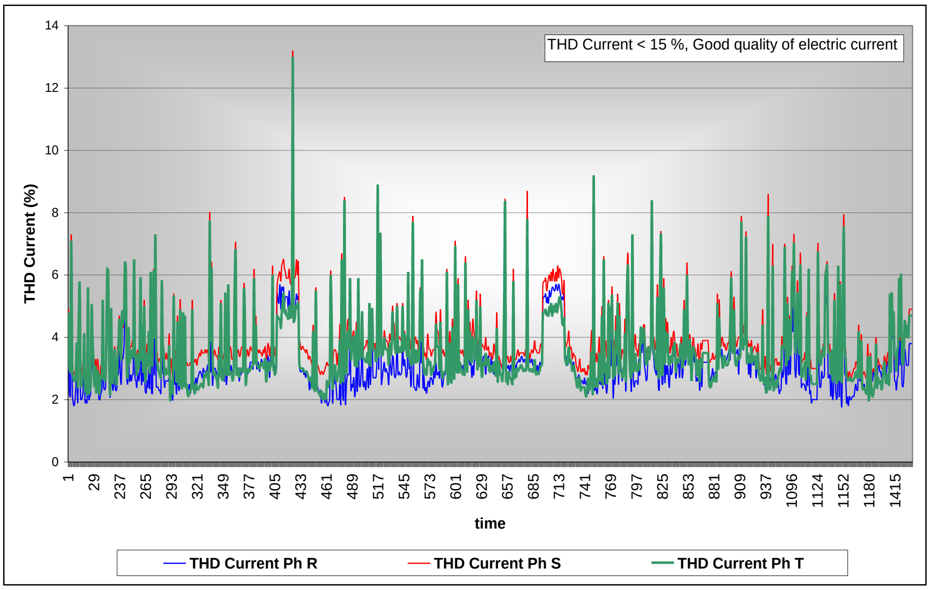


Figure 6. The total harmonics distortion for electric current   at transformer #2

The harmonics distortion for voltage which is measured at the outgoing transformer 2 meets system requirements as it falls within the allowed 3%.  Therefore, any additional analysis of harmonic distortions related to voltage and current is not required as the existing rate falls within the standard value.

The total harmonics distortion of current depicts a higher value than the total harmonics distortion of voltage as seen in figures 6 and 7. The effect of harmonics on the power factor is lower than it should be when measured in the PLN kWh meter. Therefore even though it is a small amount it still affects the electrical power measurement in the PLN meter.

## Electrical consumption and cost

PLN records monthly electrical power consumption in the hotel for two types of use -- off peak tariff and peak tariff. Data for monthly electrical expenses is presented below in figure 8. From this figure , it can be observed that there are hikes in the electricity tariff for specific months. The comparison between average electrical use at peak hour time (WBP) to off peak hour time (LBWP) is 21%. Therefore it can be determined that the existing levels of energy use during peak hours (WBP) is still tolerable.

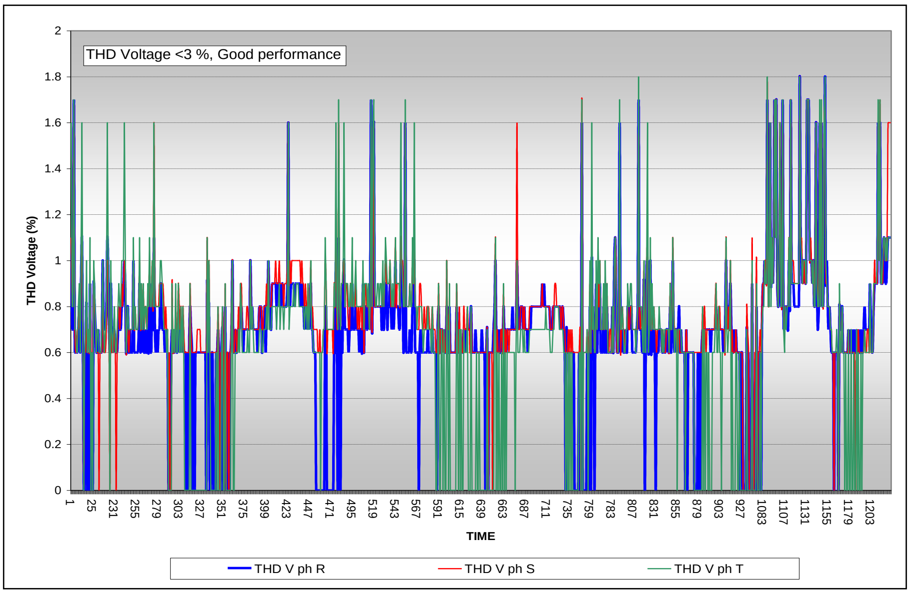


Figure 7. The total harmonics distortion for electrical voltage at transformer 2

From the histogram above it can be observed that the average energy consumption in the hotel tends to be constant at 333 MWH per month. The tariff for electricity per kWh from the PLN electricity bill was constant. This was approximately 0.0502, - US$/kWh/month (at off peak hour time).

Usually in addition to the electrical energy costs (kWh) and contract capacity costs that are paid monthly, an electrical consumer in a commercial building must also pay penalty costs. The penalty cost is an expense that is paid due to inactive electrical energy produced by electrical appliances.

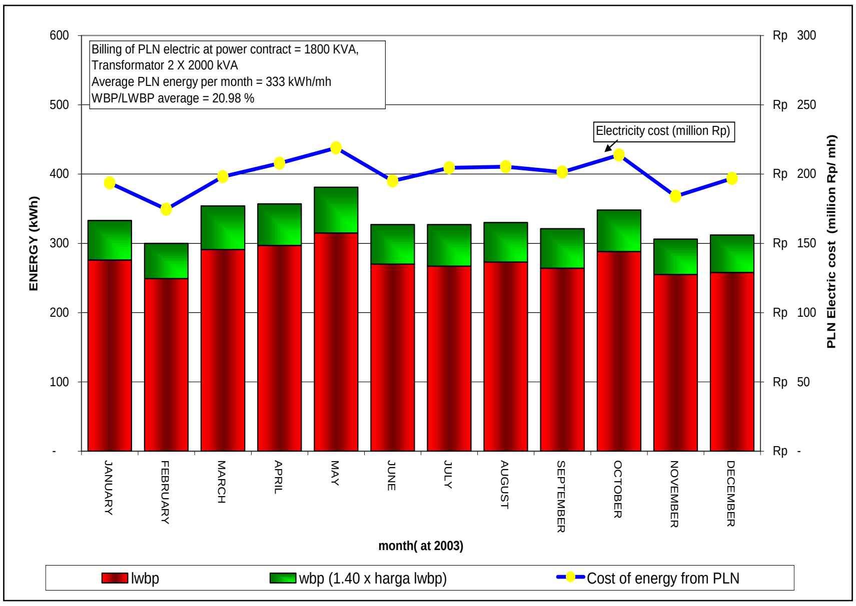


Figure 8. Annual trend of electricity bill

The penalty cost should be paid if the comparison of kVARh to kWh is not more than 0.62. However, the hotel is not required to pay this additional cost, as it has installed capacitor banks to compensate for excessive KVARh use. The hotel should pay special attention to the quality of its Total Harmonics Distortion (THD) based on the current load to ensure peak performance from its capacitor banks.

**● Electrical power balance**

Electrical power balance is studied to observe the hotel's energy consumption and distribution data for a specific period of time. This can be obtained by measuring the electrical load in the center panel (Low Voltage Main Distribution Panel -- LVMDP) and in the sub-distribution panels (Low Voltage Sub-distribution Panel).

The electrical power balance can be presented in types of grouped load distribution, which can reveal the power that is not utilized or not clearly utilized within the system.

Figure 9 depicts the average monthly electrical energy balance in the hotel. The electricity supply from PLN (1821 MWh/month) is utilized mainly by the central air condition system (approximately 1191.7 MWh/ month or 65.44% of the total consumption). The hotel utilizes 217 MWh/month for lighting purpose (11.92% of the total consumption) and 412.3 MWh/month (22.64%) for other purposes.

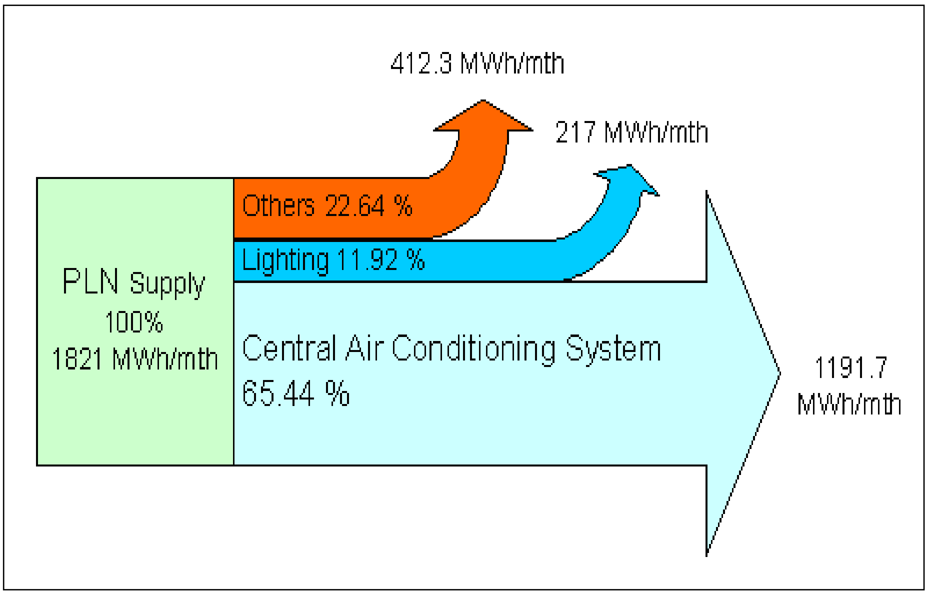


Figure 9. Electrical power balance based on the electrical load type[2]

The electrical load consumption for the hotel is depicted in figure 10. From the curve it can be observed that the maximum load appears during the evening. The maximum load actually depends on the occupancy rate of the hotel at that point in time. The magnitude of the maximum load differs from day to day. The maximum electrical power consumption in the hotel could reach 441.9 kW, and the average is approximately 355.5 kW. From the figures above, it is clear that the hotel consumes more electrical power than the apartment. The total maximum power consumption for both the hotel and apartment is 570.2 kW. With the installed contract capacity from PLN of 1800 kVA and the power factor of 0.97, the total maximum active power is 1746 kW. Thus, the percentage of maximum power consumption for both the hotel and apartment is 570.2 divided by 1746 or is equal to 32.66 %.

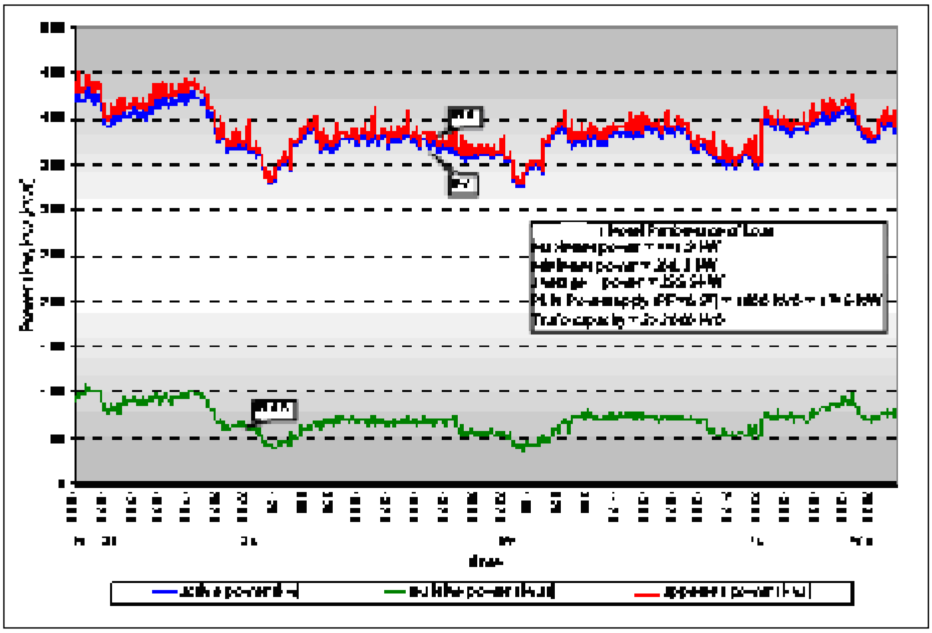

Figure 10. The pattern of electrical power consumption in the hotel

***CONCLUSION***

From the composition of electrical power consumption, it is known that the biggest opportunity to save electricity would require implementing modifications in the central air conditioning system and the lighting system. 65% of electricity consumed by the hotel is used by the central air conditioning system and 12% by the lighting system.

From the audit process, it was recommended that the following actions to be implemented to improve efficiency in electricity usage :

**■ Optimization of chiller operation**

Based on the electrical power consumption curve, the energy saving oppor-tunities within the Central Air Conditioning (AC). System can be realized through the optimization of chiller operation. The electrical energy consumption of the central AC system can be reduced by decreasing the chiller operation time without lowering the thermal comfort of hotel rooms. No costs required to implement this recommendation. To implement this recommendation the operation and maintenance manager for the central AC system should conduct data simulation to ensure that the the appropriate starting time and shutdown time of the chiller is met without sacrificing the thermal comfort. To improve the performance of chillers, seve-ral actions must be implemented. These actions include:

- Reducing chiller operation time from 22 hours per day to 18 hours per day
- Cleaning of the AHU's and FCU's heat exchanger, and the chillers evapora-tors and condensers. This needs to be followed with a regular preventive maintenance program, to avoid a return to the system's previous ineffi-cient condition.
- Adding automatic control system equipment in the chiller system inclu-ding regulating valves, motorized valves, and variable speed drives, among others will increase the overall

performance of the chiller system by 1.5%.

- At the moment the level of hotel room thermal comfort is lower than the standard thermal comfort. The level of hotel room thermal comfort can be increased by adjusting the air volume rate and air change rate in every room. This can be done by conducting air balancing within the central air conditioning system. It is recommend-ded to conduct the air balancing process after chiller maintenance.

**■ Housekeeping Management**

By maximizing the utility of electrical appliances, the kW factor value will reach the maximum level ($\cong 1$). This means that power consumed by the appliances to do the work will be the same as its design.

**■ Modifying the key tag system**

Currently the key tag system is widely used in star hotels. The use of the key tag system in the hotel increases the efficiency of electricity use. However, there is an opportunity of improved energy savings if the system is modified. For example, usually when guests use a key card upon entry, it will automatically activate the room's main lamps, bathroom lamp and the A/C system. This setting can be modified to ensure that when they use the key card the bathroom lamp does not turn on instantly. Instead, guests can turn the bathroom lamp on when required.

**■ Reducing the contracted power from PLN from 1800 kVA to 1500 kVa**

From the load consumption curve, it can be observed that the maximum consumption for both the hotel and apartment is only 570.2 kW, equivalent to 600 kVA. If it is assumed that given the safety factor for contracted power that is 2.5 times the maximum load consumption which is 600 kVA, then there' is a possibility to decrease 300 kVa of contracted power from PLN. This implies reducing the capacity to 1,500 kVA. By doing so, there will be a reduction in electrical energy payments by approximately 945 US$/month (1 kVA/month= Rp. 28,500 = $ 3.15). Reducing the contracted power only requires Rp. 150,000 (equivalent to $ 16.67) as administration fee.

**■ Maintain capacitor bank performance**

**■ Proper maintenance of electrical equipment**

Proper maintenance and operation of electrical equipment can help energy saving efforts in addition to lengthening electrical equipment lifetimes.

**REFFERENCE**


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