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Power Monitoring and Passenger Classification on Logistics Elevator

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ABSTRACT

The elevator has an important role in assisting transportation and logistics activities in a building. However, if the elevator is not used wisely, power consumption will be inefficient. A policy of elevator usage is necessary to ensure the effectiveness of elevator power consumption. Therefore, in this study, elevator power consumption monitoring is proposed. The power consumption behavior can be learned to make a reasonable policy accordingly Two elevators in Telkom Campus Surabaya are monitored to understand the daily electrical energy usage. Internet of Things (IoT) based real-time power monitoring system is used to monitor the electrical energy usage of the elevator. A raspberry pi is used to collect electrical usage data via a current and power sensor. The data is sent to the cloud, which later is displayed through a dashboard website. The result shows that the elevator usage on weekdays and weekends is different. The peak power on weekdays is obtained from 15.00 to 16.00. Meanwhile, on weekends, the peak occurs from 9:00 to 10:00. On weekdays, the total power consumed by the elevator is 51.74kW, while on weekends, it is 11.94kW. Restrictions on the use of lifts are applied to periods when the lift has few passengers and has a short distance. The total power consumed can decrease by an average of 37% from the results obtained. It is expected that the suggested policies can reduce elevator power consumption and the monthly cost of electrical energy.

Keywords*:* Internet of Things, Logistics Lift, Real-Time Power Monitoring

INTRODUCTION

The elevator is a device that consumes electrical energy which has intermittent properties. When operating, the instantaneous power of the elevator has a greater value than when it is on standby. The loading profile of this tool can vary depending on the direction, duration, and weight of the load. These conditions can affect the elevator energy consumption and efficiency factor, especially in the long-term use of electrical components.

Currently, the building sector is the primary energy consumption priority [1]. Thus, global researchers are working on building a coordinated and real-time energy management system. 40% of the world total energy is used by buildings, of which one-third is greenhouse gases [2]. Other data is that 49% of energy was consumed by buildings in 2014, of which 60% was for heating and cooling systems. The effect of energy consumption on climate is a challenging issue in the building sector. Researchers investigate the implementation of energy storage in IoE. The hope is to maximize energy efficiency and minimize the impact of global warming [3].

Elevator modelling can assist humans in increasing the efficiency of using logistics and transportation tools in buildings. This benefit relates to society's current condition, especially in urban areas that support energy-saving devices. Currently, urban areas are one of the leading causes of climate change and have become one of the largest energy users [4]. Many kinds of research on Urban Energy Systems (UES) have been carried out, to reduce the greenhouse effect [5],[6]. The UES approach can be used for the electrical redesign of buildings and energy efficiency improvements [7],[8]. Policies in saving the use of elevators have been implemented in several countries with a larger target area. In the European region, it is calculated that the energy consumption of elevators exceeds 19 TWh per year. In addition, some studies calculate the potential savings with various levels of technological development. However, the analysis was not in-depth because it did not consider the load profile with survey data and old measurements [9]. This gives rise to research opportunities regarding the study of load power profiles for uncertain load conditions.

The researcher has developed the technical characteristics of the elevator work operation. These characteristics are analyzed by considering the flow to the number of passengers and comparing it with the lift power profile. The simulation method has been tested and tested accurately [10],[11]. However, there is still a need to discuss the broad and specific implementation of the tool in the technical characteristics section.

Referring to the increasing need for energy-saving strategies, especially in buildings, and the need for a reliable monitoring system for elevator energy use, this research proposed a development of elevator energy monitoring prototypes and saving schemes. The site plan is the logistics elevator in the Telkom campus with varying load characteristics. The work focuses on monitoring the power and use of elevators in the field of electric power systems in campus buildings. By doing this research, it is hoped that it can help campus authorities make policies on the use of elevators in buildings to reduce elevator power consumption.

METHODS

A. The Concept of Using Elevator in Logistics Building

The use of intermittent loads can affect power demand. There are challenges in modeling and linking a consumer group to the use of the tool at different times. In addition, there are various consumer variants, so that in some cases, it has its uniqueness. The probability approach can assist policymakers in modeling and predicting the use of tools.

Power transmission and distribution are the most common parts analyzed for load requirements, as in the case of electricity usage at peak loads. Substations need to be designed to distribute electricity efficiently and safely. The approach used is by modeling the total aggregate power consumption. This method uses a time series analysis approach to consumers [12], [13]. The analysis phenomenon of electricity demand, such as the load and diversity factors, is also investigated more deeply. This means that the company has consistent power utilization [14].

Calculation of AC voltage is processed using the calculation of RMS (Vrms). RMS voltage is an important quantity in AC circuits as it allows AC power to be delivered to the load. Three phase voltage and current can be written as follow.

$$P_{AC} = V_{RMS} \times I_{RMS} \tag{1}$$

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T V_L(t)^2 dt} \tag{2}$$

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T I_L(t)^2 dt} \tag{3}$$

Where $V_L(t)$ and $I_L(t)$ is periodic signal, and T is the period. Referring to the research on the energy efficiency of the elevator, the value of dispersity and the load factor can explain information about the pattern of elevator usage—both on a large and small scale.

B. Power Consumption Modeling based on Passenger Traffic

The visitors calculation is carried out using the Crowd Behavior approach at social events queuing for the elevator. Currently, the tool used is a Cctv camera located in front of the elevator on each floor. Vision-based people counters are widely used in various applications [15-17].

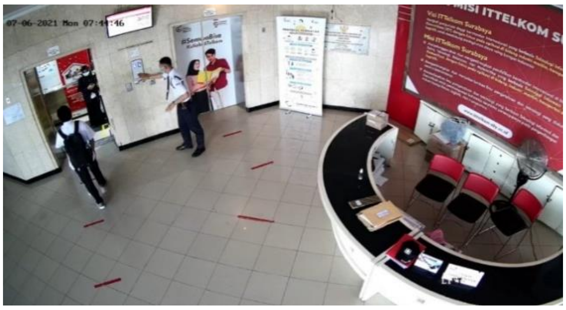

Figure 1. Condition of Logistic Elevator and Position of Camera Placement at Telkom Campus

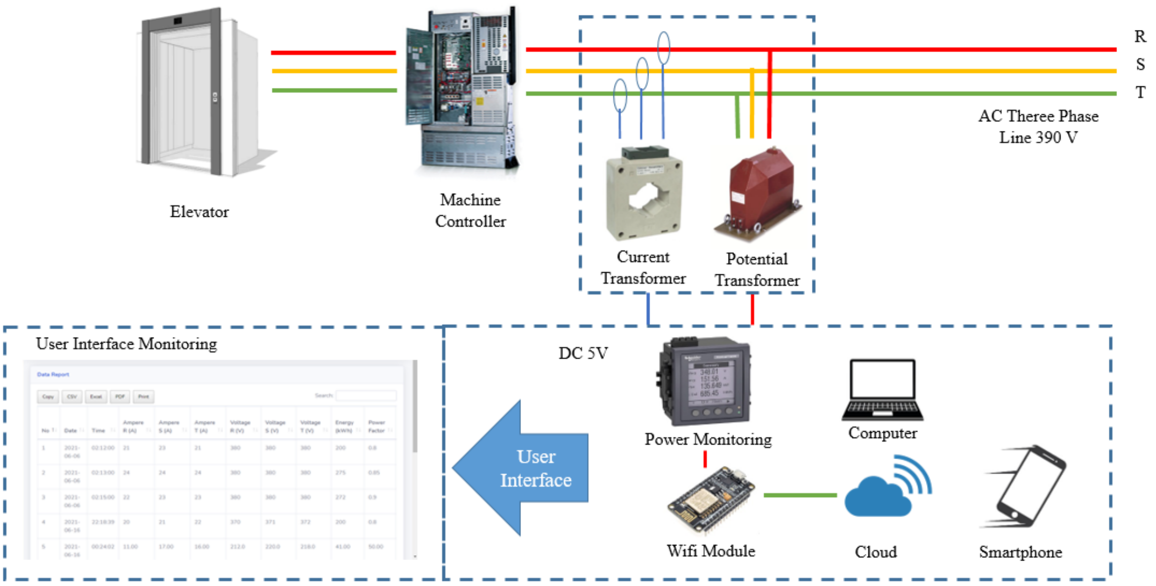

Figure 2. Condition of Logistic Elevator and Position of Camera Placement at Telkom Campus

Fig. 1 and Fig. 2 describes the implementation and placement of cameras used for video surveillance schemes, customer profiles, city planning, visitor number management. By knowing the consumer, it is hoped that the manager can manage it efficiently. In the event of a disaster, the calculation of building users is quite important.

The rescue team can determine the number of people and choose a strategy for the rescue process in the building. Elevator users in campus buildings include students, lecturers, and staff. Measurements are divided into two-time categories, including weekdays and weekends. The supporting device used is CCTV. The visitor calculation process is carried out automatically using the manual people counter calculation.

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C. Power Monitoring Lift

Internet of Energy (IoE) is the idea of combining the existing features on the smart grid and the Internet of Things (IoT) [18]. The work function of IoT refers to implementing internet-based tools to support the exchange of information and data. This concept has been widely used in various sectors, such as smart grid monitoring. In addition, the smart grid architecture can provide two-way communication between the grid and the energy management system to monitor and control electricity usage. IoT is widely used in buildings, distributed generators, industry, and electric vehicles [19]-[21].

The tool's workflow starts from designing electronics, IoT, and sensor devices. The next step is to create a user interface. If both data acquisition is successful, it is followed by hardware and user interface integration, accompanied by calibration. Calibration is done by comparing the results of standard power meter measurements with data processing results. Furthermore, the elevator response analysis is carried out with various load conditions both when going up and down. The lift and passenger activities were collected for analysis using the S-Curve, as show in Fig. 3.

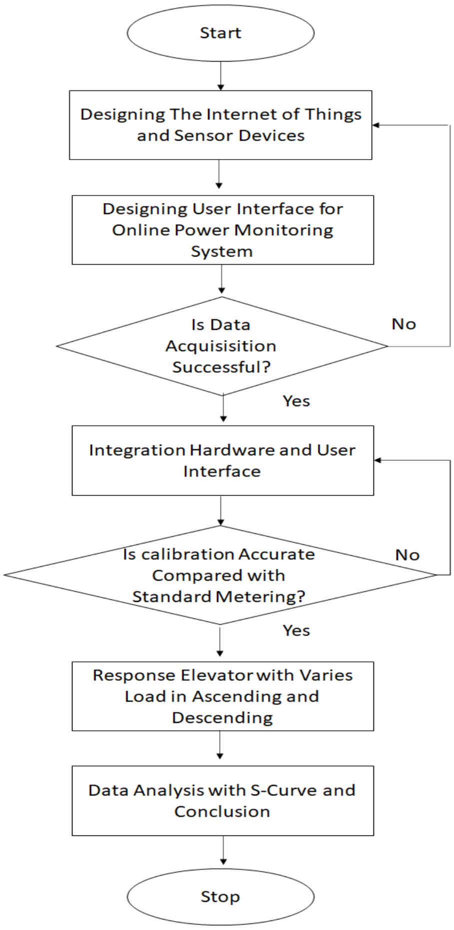


Figure 3. Flowchart Research of Device Power Monitoring For Elevator

Researchers use web hosting services to display the energy monitoring. The web hosting is chose because of the accessibility through smartphone browser of the user. Installing any application is not necessary. Also, the web hosting service provides a place to store data and documents on the web. Users can access data on elevator usage and power needed in real time and online. The web page that is sent is in the form of HTML and CSS files managed by the browser. It can be a good display and easy to read. The Wemos D1 Mini module has Web hosting functions as a data storage place for data. The stored data is then accessed via the global internet network.

D. Integration Sensor, Power Monitoring, and Web

Elevator monitoring hardware and software integration is divided into electronic and web parts. Figure 2 describes a chart of electronic devices and computers that are integrated with power monitoring lifts. Electronic components include power meters, Wemos communications, CCTV, and circuit breaker lift protection while the web component includes the display of the human interface and the calculation of elevator visitors.

Closed-circuit television (CCTV) is a tool that functions to record events at certain locations to be displayed on the monitor. The use of CCTV is limited to a particular area and time. This tool has a thermal camera feature to get pictures. In addition, there is an infrared camera to get objects from a dark room. The camera used is a pain, tilt, and zoom (PTZ) type with an image sharpness of 704 x 240 pixels and 1.3MP. The camera operates on 12 V and 1 A voltage and current.

The communication protocol used is esp8266, which connects the terminal unit with the building wifi network. The advantage of this tool is that it is compatible with Arduino and has standard IO pins. This tool can run stand-alone without a microcontroller connected. This device can execute programs faster than the 8 bit Arduino microcontroller. Schneider monitoring is installed to convert the current and voltage on the Current Transformer (CT) and Potential Transformer (PT) into digital data.

The Telkom Institute of Technology's web-based energy monitoring system was created to facilitate interaction between humans and machines so that humans can easily monitor the power used in the elevator. The components displayed include power, voltage, current, power trend in units of time. In addition, this system can display monitoring reports on the system. These features can be accessed online either on a computer or smartphone.

To be interconnected, the monitoring system has an IP address that the user with a web browser can access. The server pc must ensure that the program can run and is connected to the LAN network. The next step is to check and connect to a WIFI network.

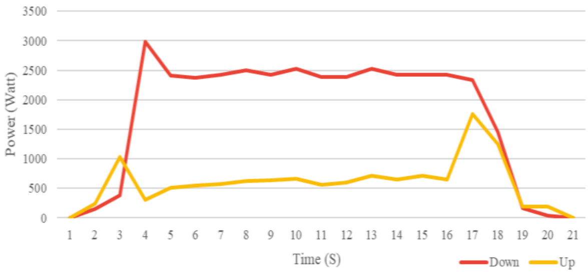


Figure 4. Elevator power consumption response when operating up and down

RESULT AND DISCUSSION

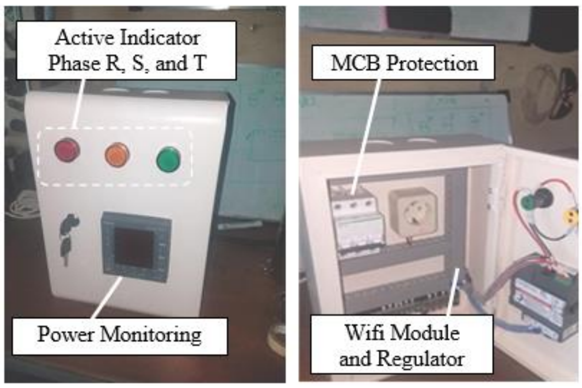
This section describes the instantaneous power profile achieved for weekdays and weekends as a case study. The number of elevators analyzed was two during pandemic conditions, both on weekdays and weekends. We propose a procedure for using an elevator based on the number of visitors compared to the frequency of use of the elevator. The point of view used is the amount of energy consumption used by the elevator. This policy has an impact on reducing elevator energy consumption by emphasizing the critical time of elevator user. Moreover, the policy can be updated accordingly due to measurement using the proposed elevator energy real time monitoring system.

A. Elevator Electric Power Consumption Response

The electric motor in the elevator is configured by the manufactured to operate at a constant speed. The elevator consumes more electricity when going downwards than when going upwards. The response of the motor working power of the elevator can be seen in Figure 3. The maximum number when it rises is 3kW, and then it can be stable at 2.5kW. Meanwhile, when it goes down, it has a maximum increase of 1kW, then it can stabilize at 0.5kW. The lift also uses more energy when move from the stop position. However, the lift does not have significant change in power when travel upward. Overall, in a single ride, the lift consumes 1.7kW of power for descending, whereas the lift consumes 0.5kW for ascending. In total, a single operation can consume 2.2kW of power.

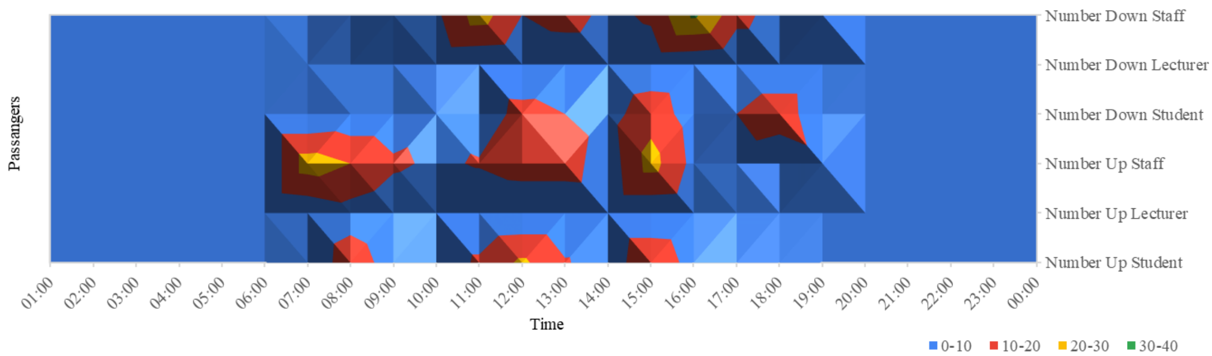
B. Prototype of Elevator Power Monitoring

The readings from power monitoring, which are connected to current transformers and potential transformers, are sent via the internet and web servers in the form of graphical displays. Figure 4, inside and out, shows a power monitoring box containing a power meter, esp 8266, and safety equipment. Monitoring tools

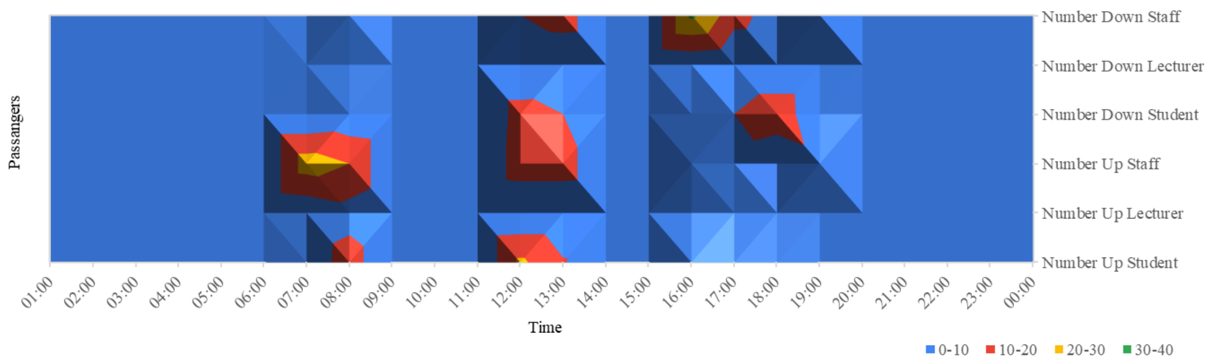


(a.) (b.)

Figure 4. Power monitoring box containing power meter, esp 8266, and safety equipment. (a.) View from the outside (b.) Inside



(a.)



(b.)

Figure 5. S Model Graph Showing The Three Most Dominant Destination Floors (a.) Before and (b.) Policy Implementation

process the current and potential transformer sensors contained in the power meter. Then, the parameters of current, power, and voltage are compared with time.

There is also a circuit breaker for security and anticipating a disturbance in the elevator or on the monitoring equipment. The graphic display, previously described in Figure 2, shows the current condition of the lift when it is working. The display shows that the power monitoring sensor data can display online graphic images from computers and smartphones. Users can also download processed data in CSV, Excel, or recorded pdf documents

C. Elevator Passenger Classification

This section describes the power requirements between different usage categories and passenger types as shown in Figure 4, where 4.a. is the working operation of the elevator in normal operation, while Figure 5.b. the lift restriction policy is implemented.

The maximum number of passengers is in the period from 15.00 to 16.00, it is estimated that there are 75 passengers, with an even distribution of elevator user categories. The second trend is seen during break hours, from 12.00 to 13.00 as many as 60 passengers, dominated by lab students and SMEs.

The last trend was continued from 7.00 to 8.00 am with 48 passengers, dominated by staff. Lecturers have the highest portion, which is in the afternoon from 17.00 to 18.00. The period when using the elevator is 06.00-20.00, which is the category of using the elevator up and down students, staff, lecturers. There are areas of time where the lift passengers are few but operate with a fairly high frequency. It is calculated that the consumption of elevator power on single weekdays is 51.74kW, while on weekends, it is 11.94kW. This is a particular concern in the efficiency of elevator use.

From the data that has been obtained, to overcome the use of elevators that are not crucial, an approach to limiting the use of elevators during working hours is proposed, which has a small number of passengers. It is known that several users use elevators for short distances in that period. This can lead to a waste of energy using the elevator. There are two periods of storage places. In the morning the lift operation is limited from 8.00 to 11.00 and in the afternoon is limited from 13.00 to 15.00. From the calculation results, it consumes 31.842kWh of power on weekdays and weekends, while on weekends, it is 7.94kWh. This approach can also affect the cost savings of electricity payments by almost 37% if applied long-term.

CONCLUSION

This paper proposes a model of elevator power consumption to study the elevator usage in Telkom Campus Surabaya building. The resesarch evaluates the power consumption characteristics of two lift units. The online monitoring system has been developed so the users can read the power monitoring sensor data on the website. The elevator uses more energy for descending than ascending. The peak power is obtained in the morning and evening, which is true for any passenger's type. To overcome this condition, the campus management should limit the usage of elevators when the passengers is few and has a short distance. Elevator users are directed to use the stairs during this period, which is 9 to 11 AM and 14 to 15 PM. From the calculation results, this approach can reduce the electrical energy consumption by 37%.

The research has achieved the desired output. However, although some progress on IoT, power monitoring, and policy recommendations have been made, there are still many challenges caused by equipment durability, multiple usage periods, multiple destination areas, multiple optimization goals, and building microgrid design. Those issues will be discussed in the future studies.

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