Feasibility Study on the implementation of room control automation to realize smart green buildings

T Arfiansyah* and A S Arifin

1 Department of Electrical Engineering, Universitas Indonesia, Jakarta, Indonesia

Email: thara.arfiansyah@ui.ac.id*

Abstract. Currently, the level of carbon dioxide (CO2) emissions is at the highest level. One of the causes is the waste of electricity used. One of the most significant contributors to electrical energy consumption is in the High Rise Building (HRB) sector. This paper proposed an automation system in Heating, Ventilation, and Air Conditioning (HVAC) systems, lightings systems, and electronic systems, especially in the guest room area, where electrical energy consumption very much depends on the guest's behavior. The purpose of the proposed system is to save energy and to realize smart green buildings. The result shows that the proposed system provided an average energy saving of 294.882 kWh per month. This system could save the cost of electricity bills by 21.38% each month. Those results confirmed that the implementation of a room control automation system is feasible to realize smart green buildings.

1. Introduction
According to data as of 6 June 2019, Indonesia is one of the largest CO2 contributors globally, with 2.1 billion tons of CO2 [1]. Indonesia cannot manage electrical energy effectively and efficiently, which is causing high CO2 emissions. If we look at the statistics report issued by Perusahaan Listrik Negara (PLN) from 2016 - 2019, electric energy, especially in Jakarta, has been increased [2]-[5]. According to the World Green Building Council (WGBC), High Rise Building (HRB) sector contributes 36% of electrical energy [6]. Meanwhile, according to data from the Ministry of Energy and Mineral Resources Republic Indonesia, the waste of electrical energy is caused by 80% human factors and 20% technical aspects [7].

In general, HRB in tropical countries such as Indonesia uses the most electrical energy for Heating, Ventilation, and Air Conditioning (HVAC) systems 70%, lighting systems 18%, elevators and escalators 7%, electronic equipment 5% [7].

The main problem is how to reduce electrical energy in the HRB sector, primarily because of human behavior. The Indonesian government has provided regulations to solve the problem of wasted electrical energy in the HRB sector, the regulation of the provincial governor of Jakarta number 38/2012 regarding green buildings [8] and the regulation of the Minister of Public works of the Republic of Indonesia number 02/PRT/M/2015 concerning the green building [9]. Unfortunately, enforcement of these regulations is not effective because of the large number of HRB in Jakarta [10]. There are only five buildings that have adopted the green building concept [11].

Existing studies have discussed smart green buildings in energy management at HRB [12]–[14]. However, smart green building research is still in its early stages. Most of the research proposed theoretically, conceptually, and prototypically. Theoretically and conceptually of the smart green building's implementation provides benefits to the building being intelligent, energy-efficient, green,
and sustainable [15–21]. There are several prototypes for smart green building design that optimizes HVAC system only [22]-[23] and lighting system only [12]-[13]. Compared to the previous research, the proposed system controls all building systems, including HVAC, lighting systems, and electronic systems, to improve energy efficiency. We implemented the proposed system in the guest room because electrical energy consumption in this area is the largest compared to other areas.

We have structured the development of this paper into five sections. The second section described the room automation system's design, which consisted of System architecture, sensor deployment, and Automation algorithms. The third section of data acquisition. The fourth section described the results and discussion, while the conclusions are in the fifth section.

2. Design of Room Automation System

2.1. System Architecture

Figure 1 shows room automation architecture, consisting of physical infrastructure, Local Area Network (LAN), and several sensors. One of the most critical factors in smart green buildings implementation is physical infrastructure [24]. The infrastructure uses Ethernet switch technology by using transmission media in fiber optic cables and Unshielded Twisted Pair (UTP) cat-6 cables. We implement the proposed system in the Grand Hyatt Hotel Jakarta. The design of the building physical infrastructure consists of three areas:

- **Control room area.** A room control automation server that functions as a client, a data storage center for an energy management system, manages, receives, sends various data through the Internet Protocol (IP) based protocol. A Core Switch is a switch that functions as a backbone or physical core of the network, functions as a gateway to a Wide Area Network (WAN), or internet. A core switch can provide the final aggregation for a system that allows various aggregation modules to work together.
- **Shaft area.** A distribution switch device functions as a liaison between the core switch and the access switch. The distribution switch ensures that packets are routed correctly between the sub-network and the Virtual Local Access Network (VLAN) in the Grand Hyatt Jakarta network. Access Switch functions to connect the room control automation to the Local Area Network.
- **Guest room area.** A room control automation functions as the processor or as the main panel connecting the Passive infrared (PIR) sensor, door contact sensor, digital thermostat, and electric...
switch. Also, room control automation devices operate as; control automation devices, including HVAC, lighting systems, and electronic systems.

The proposed system of room control automation works as a following:

- When the door contact sensor and the PIR sensor receives a response from the guest's motion, the sensor's output is sent to room control automation.
- Room control automation gives commands to a digital thermostat and electric switch based on predetermined conditions.
- The results of the command from room control automation are received by the digital thermostat and forwarded to the HVAC controller to adjust room temperature and fan speed.
- The room control automation command is received by the electric switch to set them on or off the lighting and television sets.

2.2. Sensor Deployment

![Figure 2. Wiring Installation.](image-url)
Figure 2 shows the wiring installation in the guest room area. Room control automation has an important role as the processor and the central panel connected to sensors (PIR sensors and door contact sensors), and several devices (digital thermostats, electric switch) used UTP cable for transmission media. The sensors used in the implementation of room control automation are PIR sensors and door contact sensors. These sensors work as a following:

- The digital thermostat (with build-in PIR Room occupancy sensor) is linked to the door contact sensor at the main entrance door (coverage = 6 m, 120°) and linked to the HVAC controller.
- The door contact sensor is connected with the PIR occupancy sensor for actual status occupancy.
- The electric switch is linked with the PIR occupancy sensor for actual status occupancy.

2.3. Automation Algorithm

![Automation Algorithm Diagram]

Figure 3. Three Automation Scenario.
Figure 3 shows the step the automation algorithm works and three automation scenarios in the guestroom. A local IP is assigned to each room for real-time monitoring by management. Initialization, room control automation is seated with PIR Sensor, door contact sensor, digital thermostat (room temperature settings), and electric switch (status on or off lamp and television). There are three scenarios of conditions in room control automation:

- The first scenario is unoccupied. In this scenario, the room conditions are for door contact sensor, PIR sensor, and all the guest room lights are off. The room temperature is set at 24°C (standard temperature for 5-star hotels) with a low fan speed.

- In the second scenario, a guest occupies the master bedroom, and the guest's motion is detected by the door contact sensor and the PIR sensor when a guest enters the room. Then the sensor sends a response to room control automation for giving commands to the digital thermostat and electric switch. In this condition, the room temperature in settings less than 22°C. There are three scenarios for the change in room temperature; the first condition is when the room temperature is greater than 24°C, the high fan speed. The second condition is when the room temperature has reached 23°C, the fan medium speed. The last situation is when the room temperature has reached less than 22°C, the low fan speed. For master bedroom lamps, vestibule lamps, bathroom lamps, and televisions are turned on, while the balcony lamps are turned off.

- The third scenario is occupied in the balcony. When a guest enters the balcony area, the PIR Sensor detects the guest's motion in this area. The room temperature automatically changed to a temperature is greater than 24°C with low fan speed. In this condition, only the balcony lamp and electric switch in the balcony are turned on.

3. Data Acquisition

3.1. Data collection

In this study, the data are collected as:

- The average electrical energy use in the lobby, kitchen, guest room area. This data is necessary for us to identify which areas contribute the most to energy use.

- The average electrical energy use in HVAC systems, lighting systems, lifts and escalators systems, and electronic systems. This data is necessary for us to identify which systems contribute the most to energy use.

- The average use of electrical energy each month to carry out a savings analysis after room control automation is applied.

We obtained data by a visited object, the Grand Hyatt Jakarta Hotel, and conducted interviews with building managers. We selected respondents with 2-3 years of experience criteria in building management in the interview stage.

3.2. Measurement

Measurement of electrical energy consumption was carried out for 3 months from 23 October 2019 to 23 December 2019 or 62 days. This measurement is carried out at the Grand Hyatt Jakarta with the type of grand room. Measurements are made by comparing the kWh of room 1014 with room control automation and room 1023 without room control automation. These measurement results are used to compare the electrical energy consumption of 1014 and 1023 during the measurement period and determine how much it saves energy.
4. Results and Discussion

4.1. The condition of electricity consumption at Grand Hyatt Jakarta

The data obtained from interviewed and benchmark best practices the guest room area contributed 80% of electric energy used each month. For each system's proportional energy consumption, the HVAC system, lighting system, lifts, escalator system, and electronic systems were 68%, 17%, 8%, and 7%. The detail of the data is given in Figure 4.

![Figure 4. The percentage of each area and each system of electrical energy consumption.](image)

Other data obtained are average monthly energy usage of 1,378,666 Kilowatt Hours (KwH) per month. The proposed system of room control automation focused on making saved in the guest room area, so the lifts and escalators system is excluded in these savings. Hence, the guest room area's total contribution is 73.6% of the total energy use each month. The detail of the data is given in table 1.

| System                  | The percentage of each system of Electric Energy Consumption (All Area) | The percentage of each system of Electric Energy Consumption (Guest room Area) |
|-------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------|
| A                       | B = 80% * A                                                            |                                                                            |
| HVAC                    | 68%                                                                    | 54.4%                                                                     |
| Lighting                | 17%                                                                    | 13.6%                                                                     |
| Electronic              | 7%                                                                     | 5.6%                                                                      |
| lifts and escalators    | 8%                                                                     | Excluded                                                                  |
| Total                   | 100%                                                                   | 73.6%                                                                     |

4.2. Comparison of electric power consumption room 1014 and room 1023

The measurement results for three months from 23 October 2019 - 23 December 2019 or 62 days, we selected some data, with the equally occupied criteria for room 1014 and 1023, to get more accurate results. The results of the data selection were 41 days in which the two rooms were both occupied. The results obtained in measurements for three months are as follows:

- Total use of kWh in room 1014 is 371,18 kWh or with an average of 9.05 kWh per occupied
- Total use of kWh in room 1023 is 523,24 kWh or with an average of 12.76 kWh per occupied
- The average savings obtained per occupied is 3.7 kWh or 29.06%.

Based on the results of measurements carried out in the guest room area, the automation carried out by room control automation could reduce electrical energy consumption by 29.06%. The detail of the data is given in Figure 5.
4.3. Feasibility analysis

Table 2. Feasibility analysis.

|                        | Average Electricity Consumption All-Area (kWh) | Electrical Energy Consumption in the guest room area (kWh) | the real average measuremnt of savings | Average Savings / Month (kWh) | Savings in all-area (percentage) | Average Electricity All-Area (kWh) after implement ed Room Control automation |
|------------------------|-------------------------------------------------|----------------------------------------------------------|----------------------------------------|------------------------------|---------------------------------|----------------------------------|
| A                      | 1.378.666                                        | 1.014.698                                                | 29,06%                                 | 294.882                      | 21,38%                          | 1.083.783                         |
| B = A * 73.6%          | C                                               | D = B * C                                               | E = D / A                              | F = A * E                    |

The proposed room control automation system's analysis results could provide additional revenue for the owner building to save electricity bill costs by 21.38% per month or 294.882 kWh per month. In line with the reduced consumption of electrical energy, CO₂ levels could automatically be reduced. Those results confirmed that the implementation of a room control automation system is feasible to realize smart green buildings.

5. Conclusion

This paper proposed a feasibility study for the implementation of room control automation to reduce electrical energy consumption in the High Rise Building (HRB), such as a hotel, that contributes to the largest CO₂ emission. Moreover, we identified that the guest room was the greatest electrical energy consumption in the hotel due to the guest's behavior. We implemented the room control automation system to control and reduce electrical energy consumption. We took measurements for 62 days. We showed that the room with room control automation provided 29.06% electricity savings. In general, the proposed system provided an average monthly savings of 294.882 kWh or 21.38% of the total electrical energy consumption each month.

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