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System of smart detection and control to electrical energy for saving of electrical energy consumption

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ABSTRACT

Public campus has a mandate to saving of electrical energy. Electrical energy consumption is often wasteful in building. There is tendency wasteful by user. Electronic equipment is often still turn on at idle time. Only a few students want to turn off the equipment and shut down the computer. Saving of electrical energy is not only at idle time but it can be improved into operational hour. It is not depending on idle time or operational hours, but depends on human presence. Implementation of electrical energy saving has to be supported by frugal behavior and equipment technology. In this study, we name system of smart detection and control to electrical energy (Sisdece). This system is consist of hardware and software. Hardware applies passive infrared sensor (PIR) sensor, wireless sensor network (WSN), microcontroller ESP32, access point, relay. Software use C++, hypertext preprocessor (PHP), hypertext markup language (HTML) and android studio. Result of measurement has been done in a month during November 2020. Average of energy saved is 12.51 kWh and total of electrical energy is 105.86 kWh. Comparison of energy saved to electrical energy is 11.81%. This is a significant reduction to electrical bill. The result is expected as benchmark of electrical energy management in Politeknik Negeri Medan (POLMED).

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1. INTRODUCTION

Saving of electrical energy is a mandatory requirement for campus activity. Based on regulation of energy and mineral resources ministry No.13/2012 about electrical saving consumption at state buildings, official residences, public street lighting, decorative lights, and billboards. Public campus is one of state owned building. For this reason, public campus must carry out the mandate. Mandate must be implemented in all lines, namely academics, infrastructure, and buildings. The building sectors such as study room, office, library, laboratory, commercial place, and workshop need the highest of electrical energy consumption. Utilization of air conditioner (AC) is the highest of electrical energy consumption (57%), lighting (19%), lifts and pumps (18%), and other equipment (6%) [1]. Energy consumption is often wasteful and not for productive something. There is a tendency of wasteful by user. Several campuses have done mandate of energy saving namely doing optimization of energy saving device and providing energy saving guidelines to change user behavior. Study has done to find how far level of knowledge, attitudes and behavior impact to energy consumption [2]. Wasteful behavior is the biggest factor to be negative impact to energy consumption. Inefficiency of energy consumption is also caused by cheap energy policy applied by

Indonesian Government [3]. In general, all users must be considered that saving of electrical energy has to be supported by frugal behavior and equipment technology.

Idle time or break session is an unproductive time. It always happens in all office, both educational institution and goverment. Electronic equipment is often still turn on at idle time. There are two large building such as main office and laboratory/workshop. Electrical wasteful phenomenon often occurs in that place. Computers, alternating current (AC), electric lamps are always turn on although there is no human at main office. Only a few students want to turn off laboratory equipment and shut down the computer at laboratory/workshop. It takes many manpower and need a long time to turn off electronic equipment on each floor and each building. This is ineffective and inefficient. There are researches on saving of electrical energy such as monitoring electrical equipment using ATmega 328P-PU microcontroller [4]. Power consumption measurement in microcontroller based on system [5]. Energy efficiency in toilets and enclosed corridors by automatic switches and detection of human activities [6]. Home with energy management system (HEMS) [7]. Smart home control by raspberry pi and arduino uno [8]. Energy management and planning smart city [9]. Design of smart system to control energy in idle time [10]. All the researches above have been done and their technology controlled utilization of electrical energy at idle time.

Saving of Electrical Energy is not only at idle time (break session) but it can be improved into operational hours. Electrical equipment can be controlled by automatic according to presence of human using PIR sensor and LM35 sensor. According to this fact, electrical energy consumption can be controlled. It is not depending on idle time or operational hours, but depends on human presence. Therefore, we name our research with the system of smart detection and control of electrical energy (Sisdece). PIR motion sensor can detect human activity in workspace. If there is no human activity then Sisdece will turn off electrical current. If there is human activity then Sisdece will turn on electrical current again. Sisdece hardware design applies PIR motion sensor, wireless sensor networks (WSN), microcontroller ESP32 as IoT component, access point, relay and other supporting components. Sisdece software design use C++ programming, web programming (PHP and HTML) and android studio as graphical user interface (GUI) for mobile programming. Data storage use cloud based on thingspeak technology. Electrical energy load will be collected during idle time and operational hours. Collected data will be analyzed to predict saving of electrical energy consumption in a certain period. The result of this study is expected to use as benchmark of electrical energy management in Politeknik Negeri Medan (POLMED).

2. RESEARCH METHOD

This research was carried out in five stages. First, analysis of object detection. Passive infra red (PIR) sensor is used to detect human activity. There are 2 infrared in PIR sensor. Both infrared will produce the same output in idle stage. When an object moves, infrared will produce unequal output. This is due to object movement [11]. Type of PIR sensor is HC-SR501. Range of power supply is 4.2 V-20 V and consumes electrical current of 65 mA. PIR sensor will high stage (logic 1) when it detects object. Voltage is 3.3 V in high stage. Distance sensitivity of HC-SR501 is about 3 m to 7 m and time delay of high stage is 3 second to 5 second. Features of HC-SR501 as shown in Figure 1.

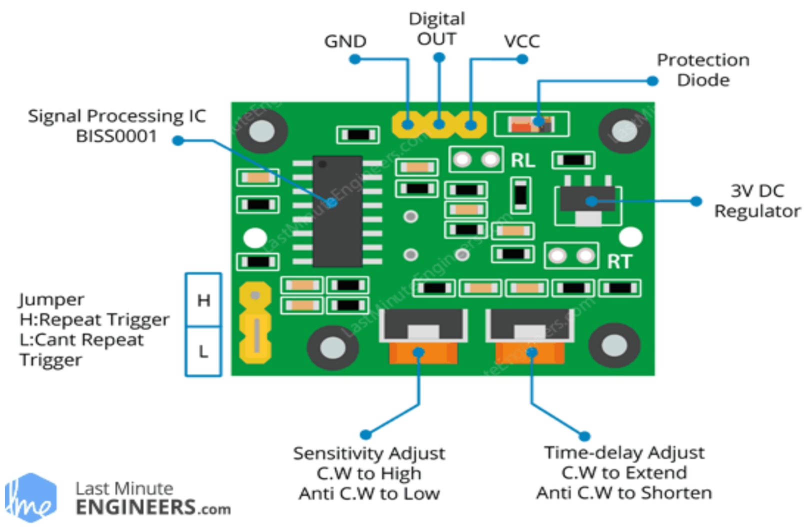


Figure 1. Features of HC-SR501 [12]

Second, analysis of proposed detection and control system. Problem analysis has been described before that electrical energy consumption can be controlled by depending on human activity. Sisdece will detect and cut off electrical current automatically during operational hours and idle time when there is no human in the room. PIR sensor provides boolean data when there is human and no human. PIR sensor gives logic ‘1’ for human activity and logic ‘0’ for no human activity. PIR sensor is connected to controller. Microcontroller ESP32 acts as controller of the system. Controller is connected to other devices and webserver as well. Controller use communication protocol RS485 to communicate to energy meter. Energy meter reads electrical data and feedback to controller (microcontroller ESP32) by digitally. Besides that power system is maintained by miniature circuit breaker (MCB). MCB as main power breaker. There is 2 MCB which is controlled by controller. MCB 1 keeps energy meter to stay safety. If there is short circuit (SC) in energy meter then MCB 1 breaks the electrical power or disconnection. MCB 2 as electrical termination and it keeps the electrical devices to stay safety. Air conditioner (AC) can be connected directly to MCB 2. Lamp is controlled by a relay in controller. Controller circuit as shown in Figure 2.

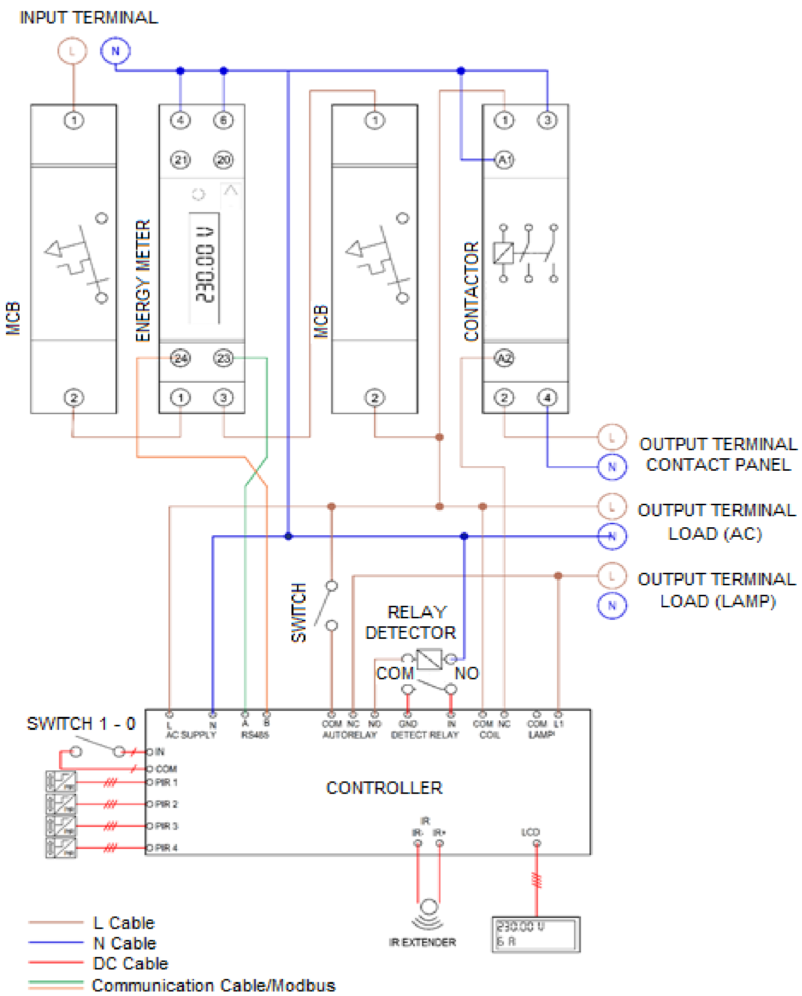


Figure 2. Controller circuit

Third, connection of controller device and webserver. At this stage, communication between controller device and webserver use wi-fi feature in microcontroller ESP32. It has 25 general purpose input output (GPIO) pins and analog inputs. It can be programmed to store data via internet. The circuit of controllers can communicate with the web server via a wi-fi network. Communication is done by two-way communication via message queuing telemetry transport (MQTT) protocol. MQTT gives a mechanisms to asynchronous communication. It has a range of implementations, and it is operational on internet protocol (IP) [13]. MQTT is an extension of the open protocol message for queuing telemetry transport [14]. MQTT can be design for synchronizing IoT device with multiple client nodes [15]. Advantage of MQTT is lite. This is suitable for devices with limited resources and it helps energy efficiency. In addition, by MQTT publish/subscribe model provides clients independence. When one client is down, whole system can still continue to work properly. We decide that MQTT is more suitable for IoT application which is able to send faster with limited bandwidth resources. Connection of controller device and webserver as shown in Figure 3.

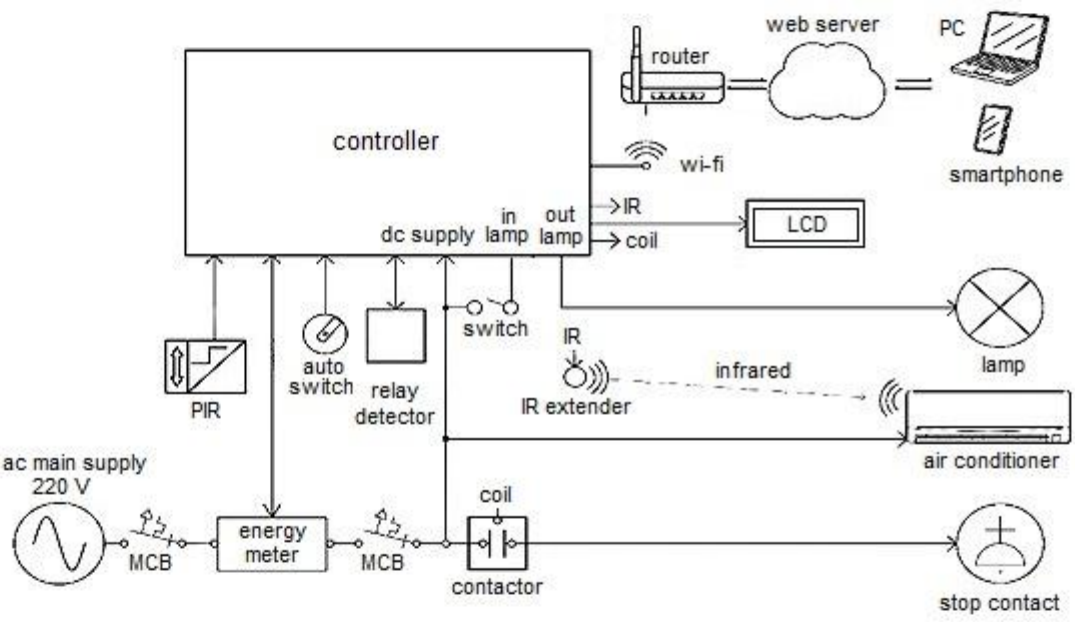


Figure 3. Connection of controller device and webserver

Fourth, sisdece software design. Design of sisdece software use C++ programming and android studio as graphical user interface (GUI) on mobile programming. Data storage use cloud based on thingspeak technology. Figure 4 is flowchart of sisdece algorithm as reference to develop software application. Embedded system has to be main part for programming on IoT devices. Many programmers are comfortable with embedded system. Many applications have been built using embedded system such as artificial vision ability [16], activities of education [17], smart taxi in smart city [18], to reduce vehicles congestion on traffic lights [19], to monitor pH and temperature level [20], implementation of smart wireless for aquaculture [21], to detect water quality [22], to measure water quality using picture from smartphone [23], to monitor pH, and temperature level using wireless sensor network (WSN) [24].

When sisdece device is activated, controller (microcontroller ESP32) will initialize and then it will be connected to wifi to read data from memory. Sisdece device uses the time taken from internet via NTP (network time protocol) server and real-time clock (RTC). RTC is used as backup if system is not connecting to internet. According to Figure 3, system has 2 modes, namely automatic and manual. In automatic mode, system will divide into 2 session, namely operational hours and idle time. Operational hours and idle time are set by the time. During operational hours, electrical current to lamp and AC will be turned on according to time session. If operational hours is the end and then next session is idle time. At idle time, electrical current to lamp and AC will be cut along this time. In manual mode, PIR sensor is utilized to detect human activity. If there is human activity then electrical current is turn on, and vice versa. System will send data and status to webserver for displayed. Any changes will be stored into memory and last condition will be displayed at system restarted. Electrical data is taken from energy meter such as voltage (Voltage), current (Ampere), power (Watt), and electrical energy (Watt Hour). System calculates daily power consumption in a room and system will reset daily power consumption data at 00:00 a.m. Sisdece performance can be monitored by PC and smartphone via internet. Fifth, software testing. Programming is divided into 4 subprogram, such as controller programming, web programming and mobile programming. Controller programming is consist of:

a. PIR sensor data
b. Read PIR sensor data
c. Read electrical data from energy meter
d. Send electrical data to server using MQTT protocol

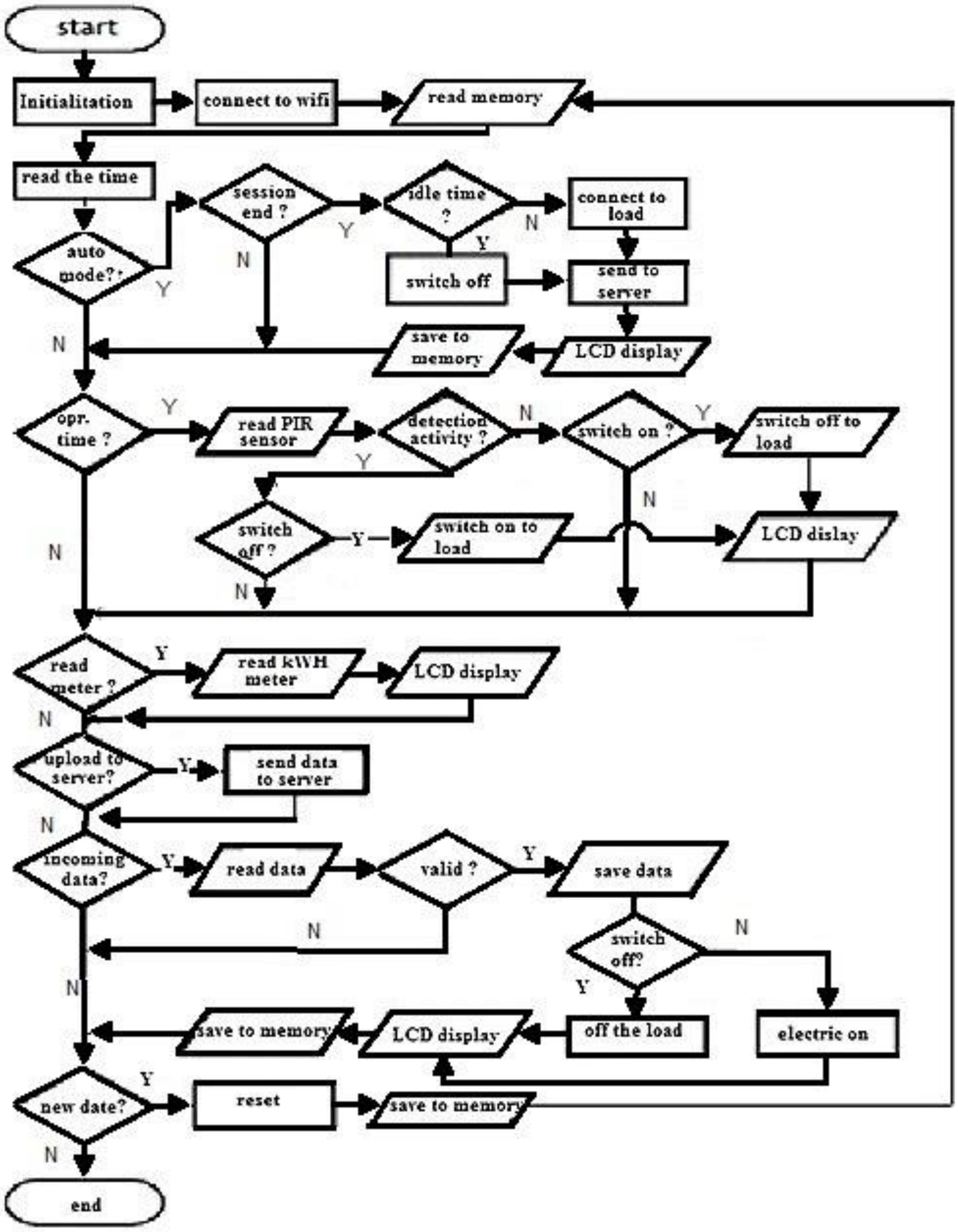


Figure 4. Flowchart of Sisdece algorithm

This is a sample for reading of PIR data using C++:

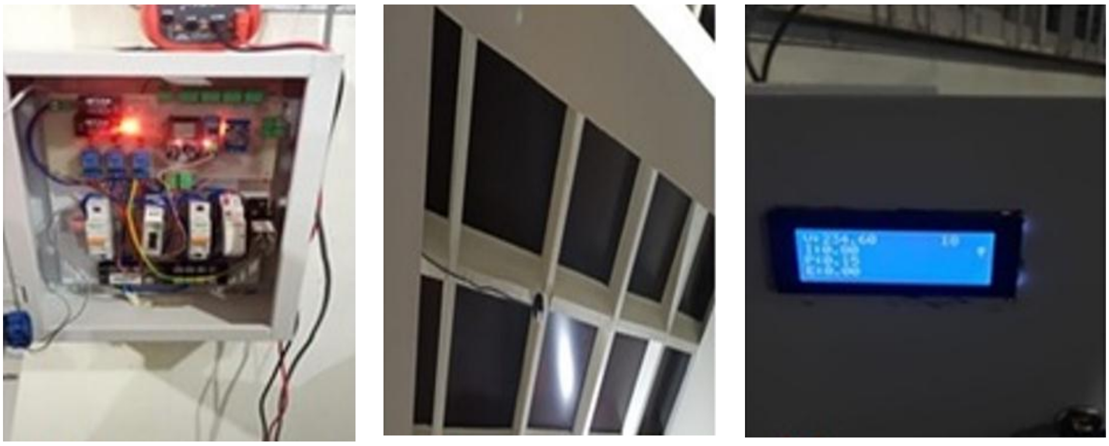
```
bool bacaPIR(){
flagSample = false;
j = 0;
while(j < 4){
 pirStat[j] = false;
 j++;
}
if(pirSens[0] == false){
if(digitalRead(PIN_PIR_1) == HIGH){
pirStat[0] = true;
}
else {
 pirStat[0] = false;
 }
}
```

```
if(pirSens[1] == false){
 if(digitalRead(PIN_PIR_2) == HIGH){
 pirStat[1] = true;
 }
 else{
 pirStat[1] = false;
 }
}
if(pirSens[2] == false){
if(digitalRead(PIN_PIR_3) == HIGH){
 pirStat[2] = true;
 }
 else{
 pirStat[2] = false;
 }
}
if(pirSens[3] == false){
 if(digitalRead(PIN_PIR_4) == HIGH){
 pirStat[3] = true;
 }
 else{
 pirStat[3] = false;
 }
 }
 j = 0;
 while(j < 4){
 if(pirStat[j] == pirSens[j] == true){
 flagSample = true;
 break;
 }
 j++;
 }
 return flagSample;
 }
```

3. RESULTS AND DISCUSSION

3.1. Sisdece prototype installation

Sisdece prototype has been installed in Telecommunication Lab. Politeknik Negeri Medan. Sisdece prototype is installed at one of lecture room. This is consist of control panel, PIR sensor and LCD display, as shown in Figure 5.



(a) (b) (c)

Figure 5. Sisdece prototype, (a) control panel, (b) PIR sensor, (c) LCD display

3.2. Software development

Measurement can be monitored by PC and smartphone. Parameters of measurement are voltage (V), current (A), power (W), and electrical energy (Wh). Sisdece software interface is shown in Figure 6.

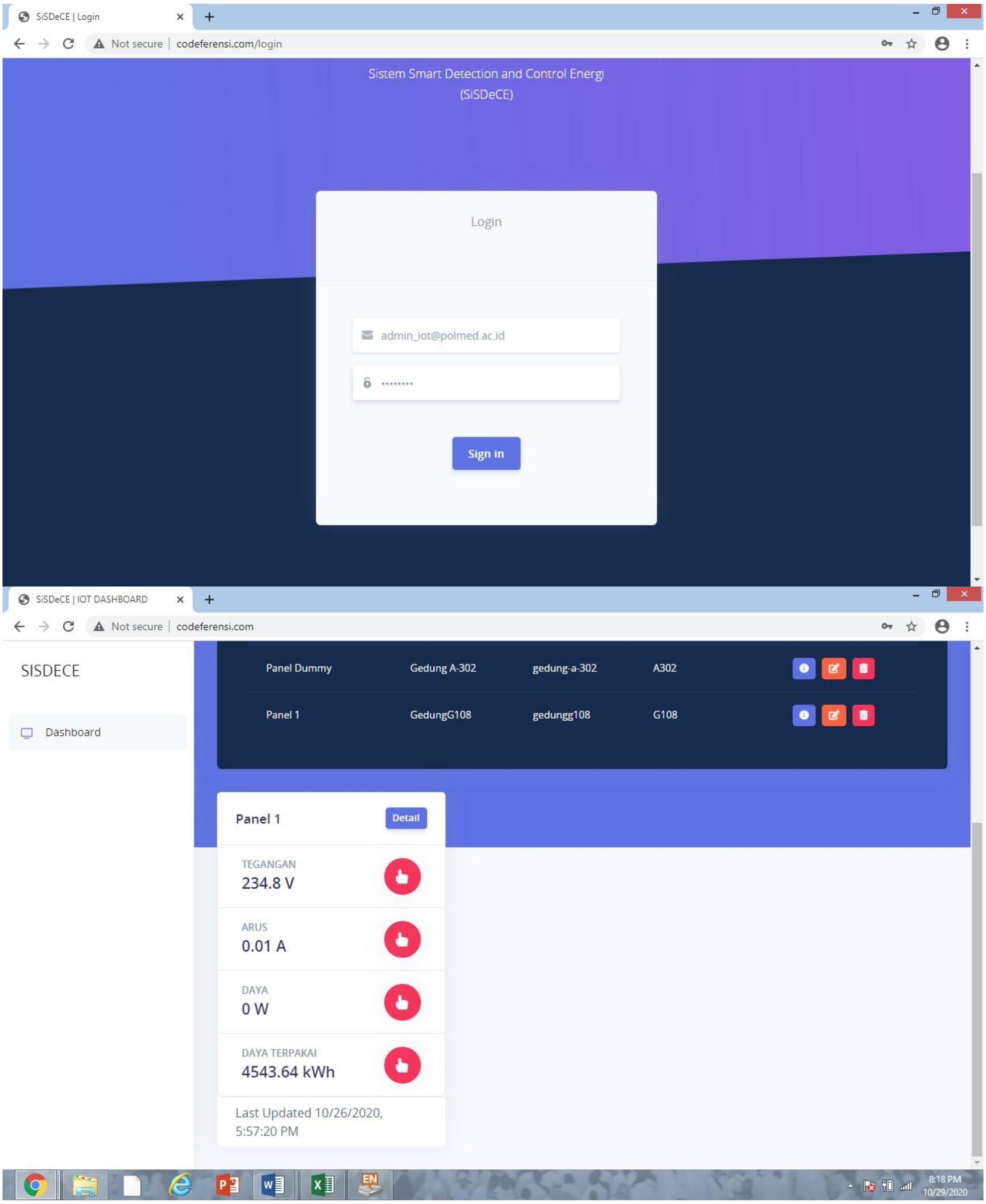


Figure 6. Sisdece software interface

3.3. Data collection

Data has been collected by Sisdece based on predetermined sessions, namely idle time and operating hours. Data has been collected during a month. It starts from 2 November 2020 up to 30 November 2020 and 7.00 a.m up to 6.00 p.m. Usage of Sisdece on the first day is not able to calculate the saving energy. Sisdece accumulates data along 24 hours. Result of measurement on first day is shown in Table 1. Usage of Sisdece on second day gives us saving energy data. Average value is 1,189.43 Wh or 1.19 kWh in that day. Usage of Sisdece gives average value 58.86 Wh or 0,058 kWh on third day. Results of measurement can be seen at Table 1, Table 2, and Table 3. Measurement is continued during a month on November 2020.

Table 1. Result of measurement on 1st day

Voltage (V)	Current (A)	Power (kW)	Electrical energy (Wh)	Operational hour	Idle time (second)	Information
234.85	0.39	0.08	0.00	7:00 a.m	Not calculated	While operating hours starting
225.10	5.94	1.18	1078.92	8:00 a.m	Not calculated	Operational session
225.84	6.34	1.26	2317.92	9:00 a.m	Not calculated	Operational session
225.83	6.34	1.26	3534.95	10:00 a.m	Not calculated	Operational session
225.06	5.92	1.17	4648.35	11:00 a.m	Not calculated	Operational session
225.46	6.14	1.22	5764.85	12:00 a.m	Not calculated	Operational session
226.41	6.65	1.32	7022.65	1:00 p.m	Not calculated	Operational session
225.83	6.34	1.26	8239.68	2:00 p.m	Not calculated	Operational session
224.79	5.77	1.14	9362.65	3:00 p.m	Not calculated	Operational session
224.61	5.68	1.12	10484.65	4:00 p.m	Not calculated	Operational session
225.11	5.95	1.18	11662.65	5:00 p.m	Not calculated	Operational session
224.73	5.74	1.14	12759.82	6:00 p.m	Not calculated	While operating hours ending

Table 2. Result of measurement on 2nd day

Voltage (V)	Current (A)	Power (kW)	Electrical energy (Wh)	Operational hour	Idle time (second)	Information	Energy saved (Wh)
235.00	0.38	0.08	0.00	7:00 a.m	0	While operating hours starting	0.00
224.75	5.93	1.17	489.96	8:00 a.m	1,795	Operational session	1,045.14
225.56	6.34	1.26	1,726.99	9:00 a.m	0	Operational session	392.75
225.57	6.34	1.26	2,944.03	10:00 a.m	0	Operational session	3,887.42
224.75	5.93	1.17	3,728.94	11:00 a.m	1,009	Operational session	302.60
225.18	6.15	1.22	4,744.62	12:00 a.m	298	Operational session	0.00
226.18	6.66	1.33	4,966.19	1:00 p.m	2,818	Operational session	3,894.02
225.56	6.34	1.26	6,120.05	2:00 p.m	178	Operational session	299.62
225.16	6.14	1.22	7,315.79	3:00 p.m	0	Operational session	4,207.27
225.06	6.08	1.21	7,929.00	4:00 p.m	1,768	Operational session	0.00
224.77	5.94	1.17	9,064.19	5:00 p.m	119	Operational session	1,045.14
224.38	5.73	1.13	9,665.72	6:00 p.m	1,567	While operating hours ending	392.75
						Average of energy saved	1,189.43

Table 3. Result of measurement on 3rd day

Voltage (V)	Current (A)	Power (kW)	Electrical energy (Wh)	Operational hour	Idle time (second)	Information	Energy saved (Wh)
234.20	0.38	0.08	0.00	7:00 a.m	0	While operating hours starting	0.00
223.80	6.02	1.17	178.08	8:00 a.m	2753	Operational session	136.18
224.52	6.39	1.25	1405.28	9:00 a.m	0	Operational session	0.00
224.63	6.44	1.26	2622.31	10:00 a.m	0	Operational session	0.00
224.61	6.43	1.26	3631.75	11:00 a.m	529	Operational session	533.67
223.76	6.00	1.17	4693.34	12:00 a.m	28	Operational session	36.50
235.10	0.01	0.00	4694.76	1:00 p.m	0	Operational session	0.00
234.89	0.01	0.00	4696.31	2:00 p.m	0	Operational session	0.00
234.45	0.01	0.00	4697.78	3:00 p.m	0	Operational session	0.00
235.10	0.01	0.00	4699.58	4:00 p.m	0	Operational session	0.00
234.89	0.00	0.00	4700.58	5:00 p.m	0	Operational session	0.00
234.90	0.01	0.00	4702.52	6:00 p.m	0	While operating hours ending	0.00
						Average of energy saved	58.86

By overall, measurement has been done which to drawn into graphic. Comparative analysis will be seen easier if we draw in graphic. Some information is easier to explain when represented by visual. Visual information is very important for reasoning, imagining and problem solving [25], [26]. Graphic has served user to find out ideas and solve problem. Graphic gives a thousand words [27]. In this study, comparative analysis graphic toward power (kW), electrical energy (kWh), energy saved (kWh) and idle time (hour). Increasing of energy saved is directly proportional to idle time. Increasing of electrical energy is inversely proportional to idle time. In Figure 7, it has not been able to show a trend of energy saved. It caused by Sisdece has not finished yet to calculate idle time. On second day usage, Sisdece starts accumulation the day before. In Figure 8, we can see the directly proportional energy saved between idle time. Energy saved (green line) will increase if idle time (purple line) is long. In Figure 9, we can see the inversely proportional electrical energy between idle time. Electrical energy (red line) will increase if idle time (purple line) is short. Idle time mechanism is made by detection and control section in Sisdece. They are PIR sensor, microcontroller ESP32 and relay contactor.

Result of measurement has been done in a month. This is to find out a trend of energy saving. Figure 10 shows that electrical energy graphic (red line) against energy saved graphic (green line). This is inversely proportional. Daily data can be made into average value and then it is recapitulated during a month.

Implication of energy reduction can be estimated in term of cost saving. According to Figure 10, average of energy saved is 12.51 kWh along November 2020. Total electrical energy along November 2020 is 105.86 kWh. If we compare between electrical energy and energy saved then Sisdece has saved 11.81%. This is a significant reduction. Estimation of cost saving can be seen in Table 4.

According to Table 4, we are able to know how much cost that can be saved. Sisdece gives a significant saving. Annual energy saved is 150.12 kWh/year and annual cost saving is IDR 220,226.04. This cost saving is only for 1 lecture room. What if Sisdece is implemented to all lecture room at campus. It will effect to short term expense.

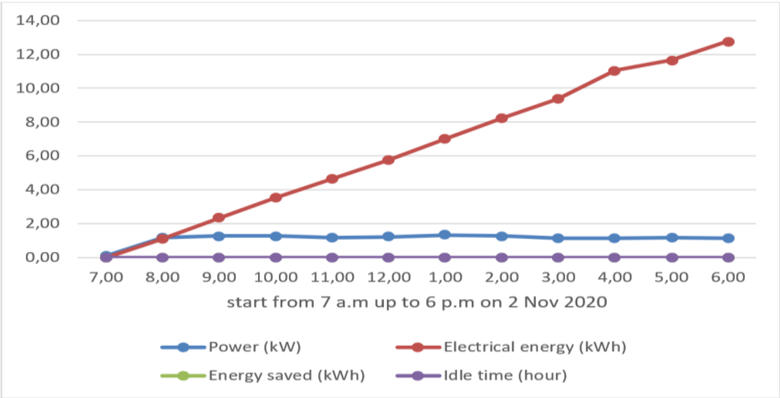


Figure 7. Measurement result on first day

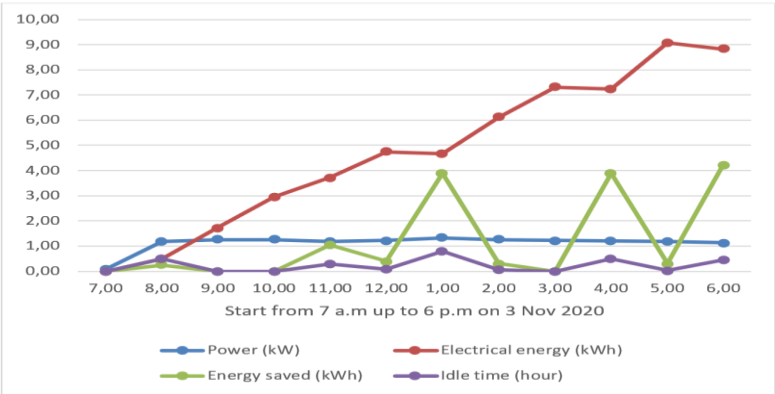


Figure 8. Measurement result on second day

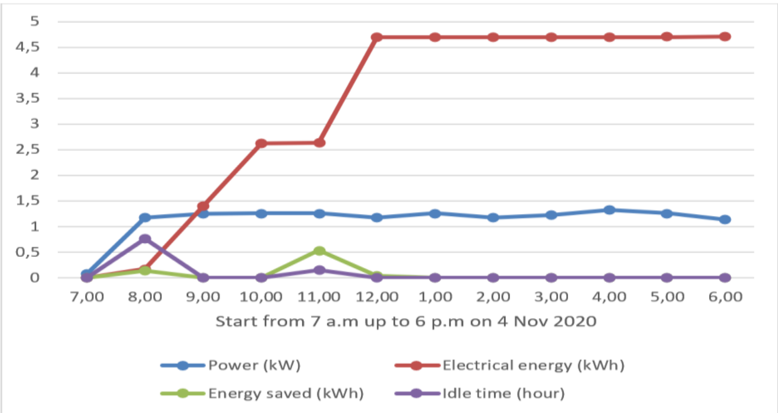


Figure 9. Measurement result on third day

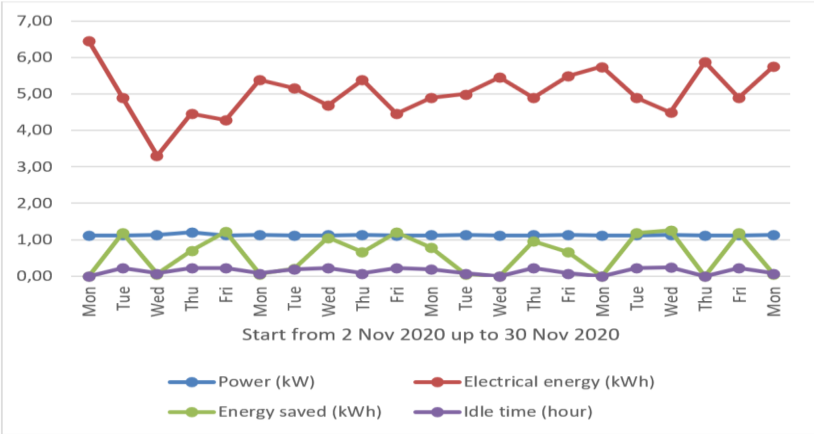


Figure 10. Accumulation of measurement in a month

Table 4. Estimation of cost saving

Criteria	Estimation of cost saving use Sisdece prototype
Average of electrical energy per a month (kWh)	105.86
Average of energy saved per a month (kWh)	12.51
Annual electrical energy consumption (kWh/year)	1,270.32
Annual energy saved (kWh/year)	150.12
Rates (IDR per kWh)	1,467
Monthly cost (IDR)	155,296.62
Annual cost (IDR)	1,863,559,44
Monthly cost saving (IDR)	18,352.17
Annual cost saving (IDR)	220,226.04

4. CONCLUSION

Sisdece is able to detect and control electrical energy consumption in room both in idle time and operating hour. They switch off electrical energy during operational hour if there is no human activity. We can find out the energy saved by usage of Sisdece. Data of measurement can be known daily, monthly and annually. According to measurement in November 2020, energy saved is 12.51 kWh and cost saving is IDR 18,352.17. This is a potential movement in energy saving. Saving value can be estimated for 1 year and it is expected to be beneficial to campus management. For further research, it is necessary to add Sisdece with ability to detect human movement by capturing based on image processing.

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