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Smart Energy Saver System for Home Appliances

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ABSTRACT

This study presents a smart energy saver system design that saves energy by coordinating the manner of use of electrical appliances and devising a means of reducing the need for human intervention in the control of electrical appliances in a building. In most developing countries like Nigeria, the demand for electrical energy outweighs the supply and with the recent increase in electricity tariff, there is an urgent need to efficiently regulate power consumption to reduce its overbearing cost effect. The system uses an ATMEGA328P microcontroller that utilizes a Grid-EYE sensor to detect occupants' presence either in motion or static. The system also incorporates a light-dependent resistor (LDR) and temperature sensor to determine ambient lighting and ambient temperature respectively. The results of these sensors determine the state of the appliances connected to the system which is either switched on or off through a relay. The results show that the Grid-EYE sensor is only sensitive to a distance within four metres and a human temperature of 27°C. Whereas the light intensity response of the system was as expected—triggers a switch off command when the room is bright and otherwise when the room is dark.

1.0. Introduction

In the past when electricity consumption was not metered, consumers were not paying attention to efficient energy management. The campaigns by utility power providers, for example in Nigeria, on efficient energy management were meaningless to the consumers thereby overstressing the power system components and appliances. Nowadays because energy consumption has been metered, both domestic and industrial users have come to realize the economic implication of efficient energy management [1]. An energy-saving system focuses on reducing energy wastage in the home/office by operating the appliances intelligently. Humans poorly engage in energy-saving and while all attention is directed towards the generation of more electrical energy, little or no attention is given to how to manage the “not enough” energy generated to reduce wastage [2].

Moreover, it is estimated that over 50% of electrical energy generated in most world countries including Nigeria is wasted and there is a poor energy conservation policy and a lack of public awareness of the need for efficient utilization of electricity [3]. Awareness is one way to reduce the waste, but more effectively, if the traditional mechanical switches were replaced by intelligent systems, then electrical energy can be saved [2]. While most of the government’s attention is geared towards increasing electricity generation in Nigeria, not much effort is being given to how the few available energy could be managed effectively to serve the masses and reduce the cost of electricity tariffs. Hence, this work presents the smart energy saver system for home appliances, which saves energy, reduces electrical tariff, and eases the stress of mechanical switching by controlling electrical loads.Some recent researches in energy-saving include a project developed on ARM 7 TDMI microcontroller with automatic functioning of home/office appliances using PIR sensors, LDR sensors and temperature sensors [4]. However, one major practice these days for effective utilization of the available electrical energy is the use of energy-saving electrical loads. Using the College of Agricultural Management and Rural Development (COLAMRUD) and College of Engineering (COLENG) at the Federal University of Agriculture, Abeokuta (FUNAAB) in Nigeria as a case study, load audit and energy efficiency calculations were carried out considering both the conventional and energy-saving components for electrical services. Results of the analysis showed that an average of about 38% of the electrical energy would be saved if the energy-saving components were employed for use instead of the conventional electrical load [5]. Finally,[6]observed that PIR motion sensors can detect the infrared rays released by the human body in motion only. The light or any other electrical appliances can be activated automatically by the active presence of a human body within the detection range and when there is no presence, the light will be deactivated automatically. Also, the infrared thermopile array sensor also known as the Grid-EYE sensor was observed to detect the infrared rays released by the human body that is either in motion orstationary. Hence, it was concluded that the Grid-EYE sensor is preferable in building a more efficient energy-saving system [6]. This study will implement a smart energy-saver using the Grid-EYE sensor for home appliances.

2.0.Materials And Method

This work was built around two main sections; hardware and software. The hardware section comprises the component selection and design while the software section involves the program that runs in the microcontroller. The system consists of sensor components such as the light-dependent resistor (LDR), the passive infrared sensor (PIR), and the barometric sensor, BMP 180. The outputs of these sensors are electrical signals that are useful for control[7]. The control unit was designed using a microcontroller (ATMEGA328P). The outputs of the sensors were fed into the microcontroller and the output of the microcontroller was used to drive the LCD to trigger the load driver circuit to power and control the target load circuit. This load driver circuit energizes and de-energizes automatically according to the condition of the parameter sensed. The simple block diagram representation of the automated system is shown in Figure 1.

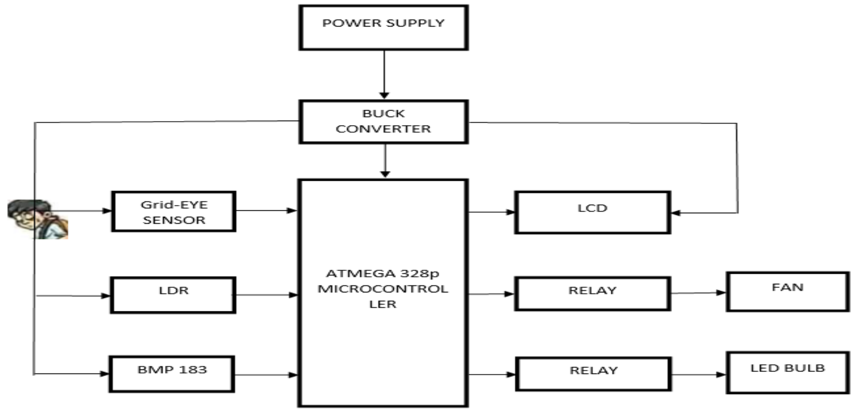

Figure 1 Energy saver block diagram

2.1.Power supply unit.

A 12volt switch mode power supply was used because it can maintain a steady current flow as load increases. Figure 2 shows the circuit of the power supply unit.

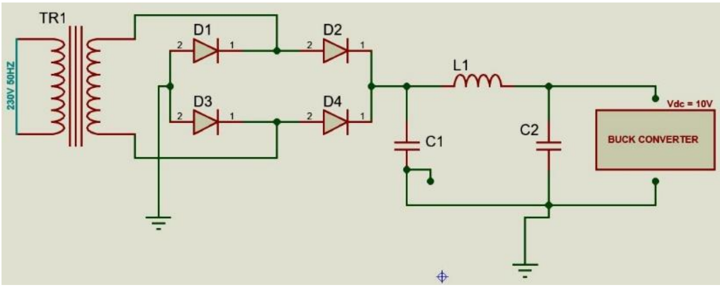

Figure 2 Circuit diagram of the Power Supply Unit

The DC voltage (V_{dc}) across the buck converter is:

V_{dc}= (2 x V_{pp})/π. (1)

The V_{rms} output from the secondary of the transformer is 12V, hence the peak AC voltage (V_{pp}) is:

V_{pp} = V_{rms} x 1.4142 (2)

Thus, the peak voltage is 12 × 1.4142 (half-cycle) = 16.97V.

However, during each half cycle, the current flows through two diodes, so the amplitude of the output voltage is two voltage drops ($2 \times 0.7 \; = \; 1.4V$) less than the input V_{pp} amplitude.

The ripple frequency is now twice the supply frequency i.e., $2 \times 50Hz = 100Hz$ whereas the ripple voltage is equivalent to 10% of V_{pp}.

The peak-to-peak voltage after rectification (V_{pp}^*) is what is left after the drop across the diodes given as V_{pp}^* = 16.97 – 1.4 = 15.57V.

Therefore, from equation (1) the DC voltage across the buck converter is

V_{dc} = (2 x 15.57) / π = 10V.

2.2.Buck converter

The buck converter is a DC-DC step-down device used to create a steady DC voltage and current[8]. It is needed to down-convert the 12V supply to the desired rating of voltage required for the microcontroller.

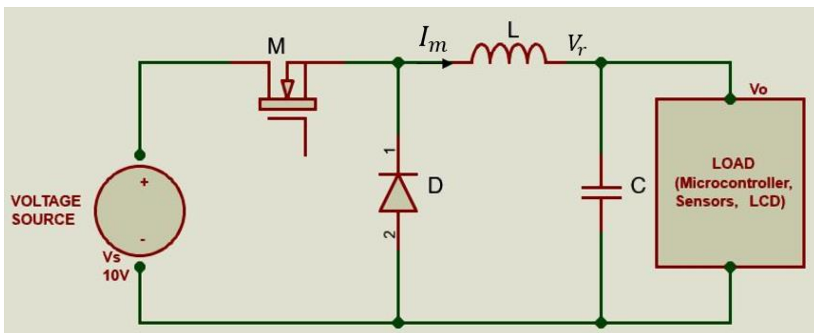

Figure 3 Buck Converter Circuit

At close switch:

Voltage is stepped down while current increases.

I_m = Current across inductor increases.

B_m = Magnetic field across inductor increases.

$$V_r = V_s - V_o[8]. \quad (4)$$

Where V_r = Voltage across the inductor.

V_s = Source voltage and

V_o = output voltage across the load resistor.

$$V_o = V_s(D). \quad (5)$$

D = duty cycle $\left(\frac{time\ when\ the\ switch\ is\ closed}{time\ for\ one\ complete\ cycle}\right)$ which is given as Equation (6)

$$D = \frac{t}{T} \tag{6}$$

Let $t = 1ms,\ T = 2ms,\ V_s = 10V = V_{DC}$. From Equation (4) $D = 0.5$ then from Equation (4) the output voltage is $V_o = V_s \times D$ = 5V.

2.3.Microcontroller

The microcontroller is a small computer on an integrated circuit. It is responsible for the coordination of all operations of the entire system. The microcontroller receives data from the load cells and ultrasonic sensor and process them into readable data and then display them on the liquid crystal (LCD). The safe working operation of the microcontroller is achieved when it is driven by a 16MHz oscillator [9]. Therefore, to make the microcontroller work at its best conditions, a 16MHz crystal oscillator was connected to the microcontrollers XTAL 1 and XTAL 2 pins as shown in Figure 4.

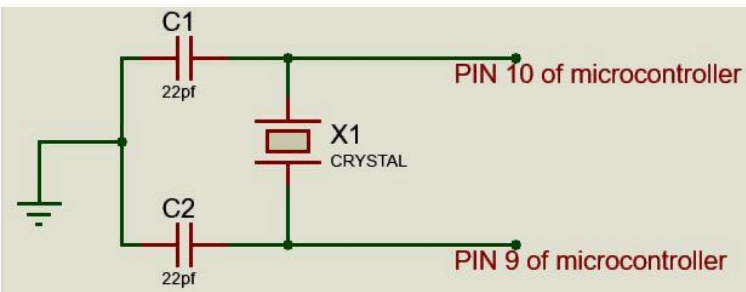

Figure 4 Circuit diagram of a Crystal Oscillator

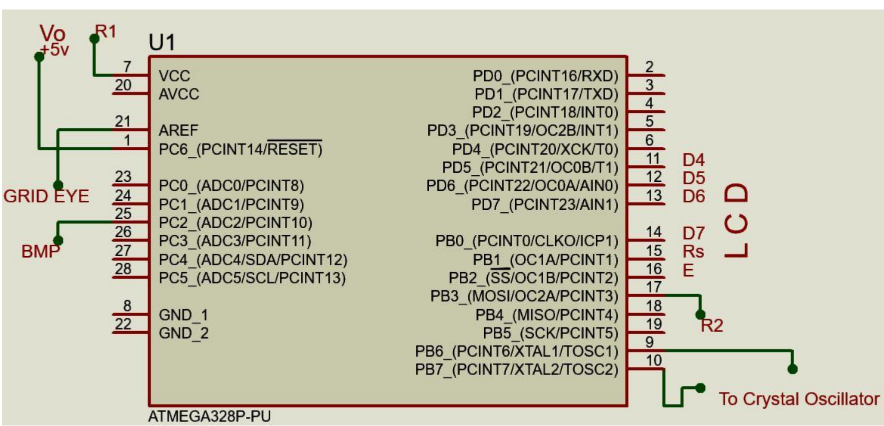

Figure 5 Microcontroller Pinout

2.4.Infrared thermopile array (grid—EYE) sensor

This is an 8×8 (64) pixel infrared array sensor with a viewing angle of 60-degree. The Grid-EYE sensor detects humans, using the infrared radiation radiated by the human body[10]. Every human radiates the infrared energy of a specific wavelength range. The schematic diagram is shown in Figure 6.

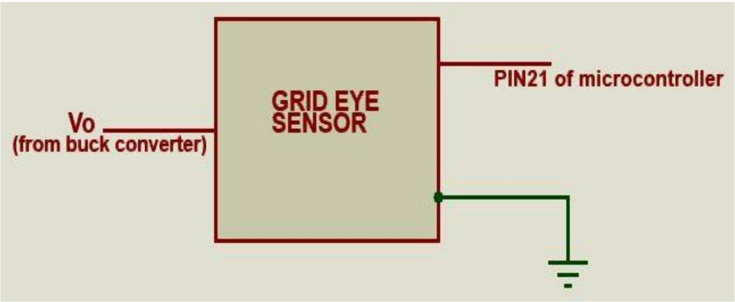

Figure 6 Grid Eye Sensor Internal Circuit.

2.5.Light-dependent resistor (LDR)

Light-dependent resistor (LDR) is a component that has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits.

2.6.Liquid crystal display

The LCD is used for displaying alphanumeric characters and allows for good design. The system that was designed used a 20×4 LCD module connected in the 8-mode as shown in Figure 7.

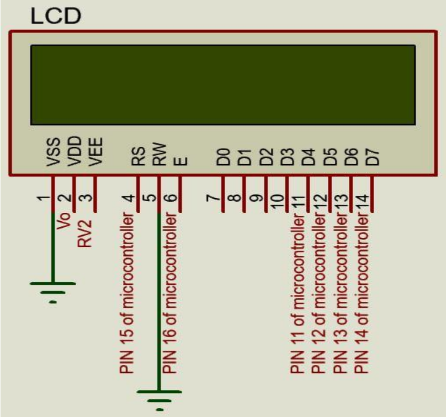

Figure 7 Circuit diagram of an LCD.

2.7.Relay

A relay is an electrically operated switch that closes when they receive current signals. Relays often have two ratings: the AC rating and the DC ratings. These ratings determine how much power can be switched through the relays[11].

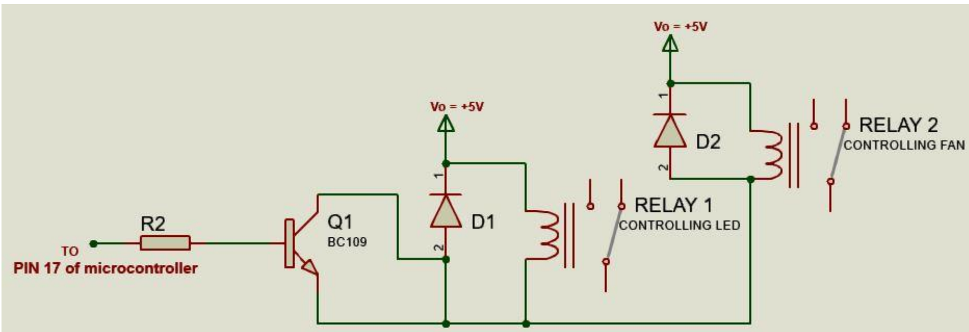

Figure 8 Relay Circuit diagram.

Let's suppose the power of the load (fan) on relay 1 is 50Watt. The power relationship is given as

$$Power = I_{rms} \times V_{rms}(230). \quad (7)$$

Thus, the rms current through the relay is $I = \frac{50}{230} = 0.22A$.

Similarly, suppose the power of the load (lighting bulb) on relay 2 is 50Watt. Then, from equation (7) is $I = \frac{50}{230} = 0.22A$.

The total current $I = (0.21 + 0.21) = 0.42A$.

Hence, we can use a relay that switches at 0.42A, $230V_{AC}$ and the maximum relay that was available was 5A, $230V_{AC}$ rated i.e., 5A x $230V_{AC}$= 1150Watt.

2.8.Transistor

It is a semiconductor device for amplifying and switching electrical signals. It is needed to switch 'on' the relay and thus, it is interfaced between the microcontroller and the relay. In the switching process, a diode is connectedacross the inductor coil of the relay to eliminate flyback (the sudden voltage spike that is seen across an inductor when its supply current is suddenly reduced or interrupted).

2.9.BMP 180

BMP 180 is both a temperature and pressure sensor. It works with a 5volt DC voltage. It helps to monitor the temperature of the place to be able to vary the speed of the fan. The schematic diagram is shown in Figure 7 and the pin description is given in Table 1.

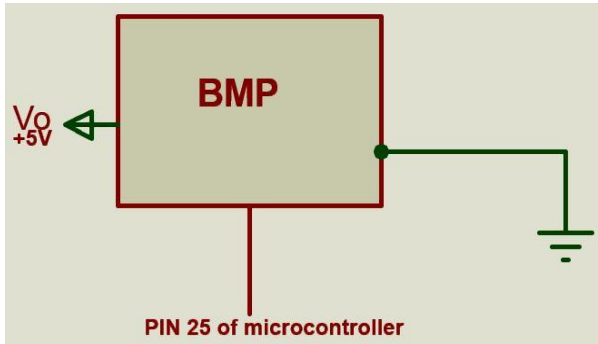

Figure 9 BMP 180 Circuit diagram

Table 1 Pin Description for BMP 180 Sensor

Pin	Symbol	Description
1	SDA	Data input/output pin
2	SCL	Clock input/output pin
3	VCC	Supply voltage input power pin
4	GND	Ground pin

The major steps in the construction of the energy-saving system [12] are shown below.

simulation

soldering and build-up

microcontroller programming

casing and packaging

The simulation of the energy-saving system was done with the Proteus 8 professional simulator software. Proteus 8 professional simulator is a suitable simulation software for various designs with a microcontroller. It is popular because of the availability of almost all microcontrollers in it. The complete simulated circuit is given in Figure 10.

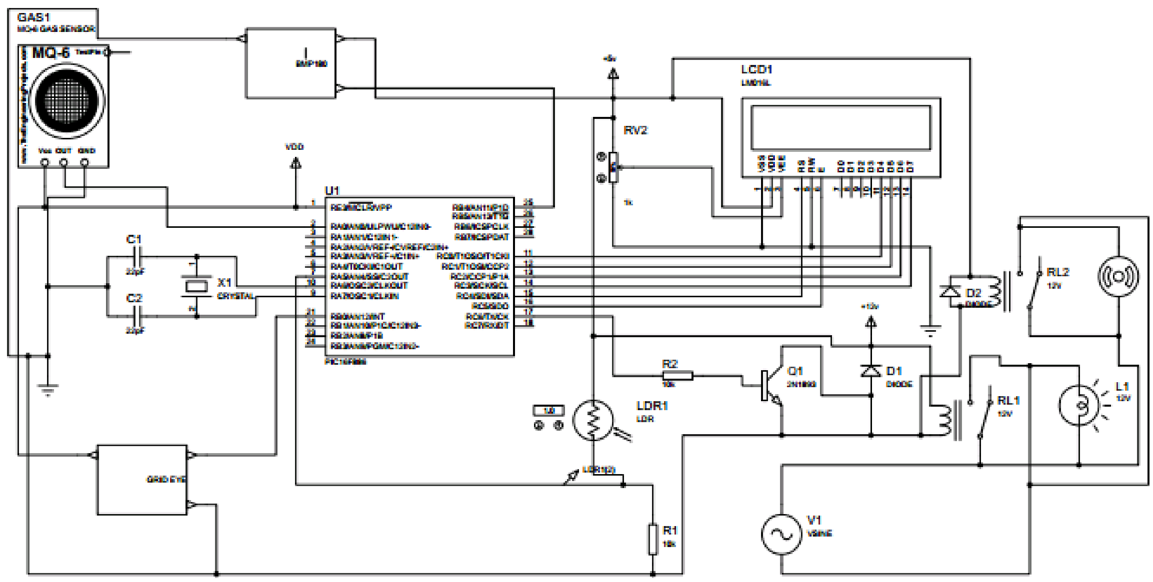

Figure 10 Complete simulated circuit in Proteus

The software section involves program development in an integrated development environment (IDE) and the burning of a microcontroller—transferring the written program from the compiler memory to the microcontroller. Arduino development programmer and zip tile were used to program the energy-saving and safety system. The Arduino development programmer and zip tile are a low-cost development tools with an easy to use interface for programming and debugging microchips' family of microcontrollers and serial EEPROM devices. Arduino development programmer is connected to the programmer computer via its USB port which is one of the possible interfaces.

Table 2:Bill of Engineering Measurement and Estimation

S/N	COMPONENT	QUANTITY	RATE	AMOUNT
1.	Grid-eye sensor	1	15,000	15,000
2.	Buck converter	1	1,500	1,500
3.	LCD	1	150	1500
4.	Microcontroller	1	1,000	1,000
5.	Power supply unit	1	1,500	1,500
6.	Relay	2	500	1,000
7.	LDR	1	500	500
8.	BMP 183	1	500	500
9.	Crystal oscillator	1	500	500
10	Transistor	2	150	300
11	Resistor	2	150	300
12	Feedback diode	2	150	300

13	Vero board	1	500	500
14	Detachable terminal screw	1	200	200
15	LED	1	100	100
16	Reset button	1	100	100
17	Switch	1	100	100
18	DC jack	1	100	100
19	Ribbon cable	1	100	100
20	Adaptable bus	1	700	700

3. Results and Discussion

The implemented circuitry for the energy-saver is given in Figure 11.

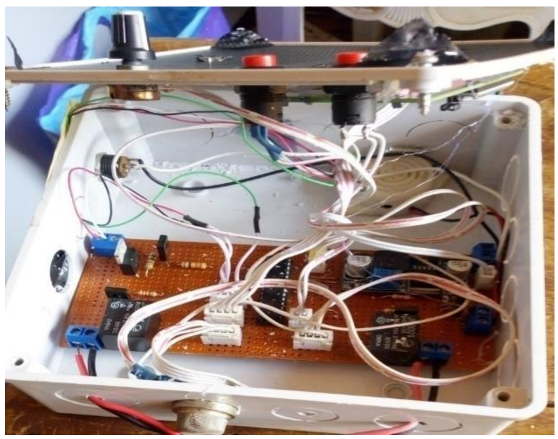

Figure 11 Energy saver circuitry implementation

After the complete implementation of the system, several tests were carried out for validation of proper implementation. The first test that was carried out was the sensitivity test. The test was conducted simply to check the ability of the Grid-Eye sensor to detect human presence at various distances from the device. It was carried out by taking four evenly spaced distances (starting from zero in steps of two meters) from the Grid—EYE sensor and checking the response on the part of the device. The result is shown in Table 3. It shows the sensitivity of the sensor with distance. It was observed that the Grid Eye sensor can detect humans from close range at a distance of three meters from the system device, and fails to sense any presence at a distance above three meters

Table 3 Sensitivity test of the Grid-EYE sensor

Distance from sensor unit (meters)	Light and fan Response
0	OFF
2	OFF
4	ON
6	ON

Another test that was conducted was the accuracy test of the Grid-EYE. It is simply a test to check the ability of the Grid-EYE sensor to accurately respond to the range of infra-red heat emitted by human presence only. The result is shown in Table 4. It can be observed that the system can detect human temperature range of 27℃ and above, and fails to respond to temperature range below 27℃.

Table 4 Accuracy test of the Grid-EYE sensor

Human temperature range (℃)	**LED and fan Response**
7	OFF
12	OFF
17	OFF
22	OFF
27	ON
32	ON
37	ON

There is the load test that is carried out to check if the lighting bulb and fan are powered ON at the detection of human presence. The results are also given in Table 5. It can be seen that when a load that is above a 100watts power rating of the system is connected to the device, there was a total collapse in operation as a result of an overload of the device.

Table 5: Load test of the system using a lighting bulb and fan

Load	**Rating (Watt)**	**Response**
Light	50	ON
Light and Fan	100	ON
Light, Fan, TV	100 and above	OFF

4. Conclusion

The energy saver system that was implemented in this study controlled the energy wastage successfully. The various tests that were carried out explored the sensitivity and accuracy of the Grid-EYE sensor and overall, the performance of the system. Also, the load test showed the control feature of the implementation towards common home appliances.

Acknowledgment

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Conflict of Interest

There is no conflict of interest associated with this work.

References

[1] Mordeson, J. N., Mathew, S. & Malik, D. S., 2018. *Fuzzy graph theory with applications to human trafficking.* s.l.:Springer.

[2] Adejumobi, I. A., Oyagbinrin, S. G., Akinboro, F. G. & Olajide, M. B., 2011. Hybrid solar and wind power: an essential for information communication technology infrastructure and people in rural communities. *IJRRAS,* Volume 9, p. 130–138.

[3] Agbeja, O., Adelakun, O. J. & Olufemi, F. I., 2015. Capital adequacy ratio and bank profitability in Nigeria: A linear approach. *International Journal of Novel Research in Marketing Management and Economics,* Volume 2, p. 91–99.

[4] Renuka, P. & Praveena, R., 2017. *Intelligent Energy-Saving And Safety Control.* s.l., s.n.

[5] Adejumobi, I. A., Wara, S. T., Adebisi, O. I. & Akinwande, O. A., 2016. Economics of Using Energy Saving Loads for Electrical Services. *Umudike Journal of Engineering And Technology (UJET),* Volume 2, p. 144–152.

[6] Shetty, A. D., Shubha, B. & Suryanarayana, K., 2017. *Detection and tracking of a human using the infrared thermopile array sensor—"Grid-EYE".* s.l., IEEE, p. 1490–1495.

[7] Ajibola, O. O. E. & Balogun, A. O., 2019. Development of Smart Switch for Household Appliances Using Web-Based TechnologyDevelopment of Smart Switch for Household Appliances Using Web-Based Technology. *Journal of Applied Sciences and Environmental Management,* Volume 23, p. 145–149–145–149.

[8] Ejury, J., 2013. Buck converter design. *Infineon Technologies North America (TFNA) Corn Desion Note,* Volume 1.

[9] ATMEGA328P, D., 2008. Atmel Corporation. *San Jose, CA.*

[10] Qu, D., Yang, B. & Gu, N., 2019. Indoor multiple human targets localization and tracking using thermopile sensor. *Infrared Physics & Technology,* Volume 97, p. 349–359.

[11] Uk.rs-online.com. 2022. *The Complete Guide to Solid State Relays | RS Components*. [online] Available at: <https://uk.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/solid-state-relays-guide> [Accessed 19 March 2022].

[12] Habibie, R. F. & Ikbal, I., 2018. The development of paragliding's pilot monitoring system and weather station based on internet of things (iot) in paralayang gunung panten majalengka.