Domestic Energy Saver

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ABSTRACT

Most of the activities in the modern world are heavy power consumers. Therefore, wasting of power is identified as a critical factor which is badly impacted the environmental and economic growth. Using electrical appliances such as ceiling fans and bulbs in the commercial and domestic environment unnecessarily is identified as a main way of wasting power. As a solution, this paper proposes the designing and producing of a power saving device for ceiling fans and bulbs. Variables such as room temperature, light intensity and the number of people present in the location were considered as parameters to control ceiling fans and bulb automatically, so as to save power by changing the speed and turning off when not necessary. This device is consisting of six main units namely a main control unit using Arduino Nano microcontroller, bidirectional visitor counter unit using two Passive Infrared motion sensors, temperature and light intensity measuring unit using a LM35 temperature sensor and a light dependent resistor sensor, an output display unit using 1604 LCD display, ceiling fan controller unit using a fan regulator that was constructed using two RC circuits, a relay module and a bulb controller unit. Ceiling fan speed and the delay time to switch off the appliances is controlled using a fuzzy logic controller. Inputs of the fuzzy logic controller are temperature difference with the set temperature, rate of change of temperature difference within a five-minute interval, difference of the number of people inside the location with the set number of people and the rate of change of number of people within a five-minute interval. It was observed that, for the test cases, an average of 318Wh per day could be saved from a single bulb and a ceiling fan while avoiding unnecessary usage of appliances.

KEYWORDS: *Energy saving, fuzzy logic controller, Passive Infrared motion sensor, bidirectional visitor counter, fan regulator, room temperature and light intensity.*

1 INTRODUCTION

As a result of the globalization and industrialization in modern era, electricity is the indispensable and high consume resource in the world. But wasting of electricity is the point to pay more attention to avoid the bad impact on environment and economic growth. Because, most of the generated electricity is wasted by the humans in many ways. This proposed method is a solution for the electricity wastage from the bulbs and ceiling fans in domestic and industrial applications that occurs due to human carelessness. Most of the people do not control the bulbs and ceiling fans as the necessity while considering the temperature, light intensity and number of occupants. As well as, at some times the users do not turn off these two appliances when leave the location due to their carelessness. In modern world there are some home or industrial automated systems to control the ceiling fans and bulbs.

In (K.T. Ahmmed, 2014) a device is designed and implemented to control the ceiling fan and bulb according to the room temperature, light intensity and number of persons inside the room. In this device used two IR sensors to count the number of people inside the room. If the number of people is greater than one, the fan turn on if the temperature is higher than the set value and the bulb turn on when the light intensity is lower than the set intensity value. LM35 temperature sensor and LDR sensor is used to measure the temperature and light intensity. As an additional facility a smoke sensor is used to detect the smoke inside the room and a safety alarm is controlled to inform about the occurred smoke inside the room.

A home automation system is mentioned in (Sharma, 2019) to control two devices using IOT method. Ceiling fan and bulb are used as the two appliances and Wi-FiESP8266 (NodeMCU) module is used as the embedded controller and programmed through Arduino. DHT11 temperature and relative humidity sensor is used to measure the temperature and humidity level of the location. LDR sensor is used to measure the light intensity. The received data can be transmitted over the internet and the devices are controlled according to the commands through web. Arduino program is created to communicate.

(S. Piyush, 2014) This journal article mentioned a temperature controller to control the temperature using a fuzzy logic controller. The fuzzy logic controller has the feedback loop to get the desired response of the output. Fuzzifier, rules, inference engine and defuzzifier are used as the steps to implement the Mamdani type fuzzy controller.

The proposed domestic power saving device is more efficient than modern home automation systems due to the specifications of the device. This device is designed and implemented according to the temperature and number of occupants data collected from the six locations of five member family house. The device used three main factors to control the ceiling fans and bulbs according to the necessity while reducing the power wastage. Those are number of occupants, temperature and light intensity of the location. There are six units in the device. Two PIR motion sensors are used to detect the human motion and to get the bidirectional count of occupants in the location. LM35 temperature sensor is used to measure the temperature and LDR sensor is used to measure the light intensity. Arduino Nano is used as the microcontroller and the algorithm is developed using a Mamdami fuzzy logic controller which is implemented using the gathered data during three weeks. Fuzzy logic controller has four inputs and two outputs. This fuzzy logic controller controls the ceiling fan speed according to the room temperature. The bulb is control using the light intensity. Sometimes person can be go outside from the location for a few time period. So the appliance have to waste power again to turn on when that person come inside again. Therefore, a delay time to switch off the device is controlling according to the number of people present in previous and current status to avoid the power wastage that occurs when power consume to turn on the appliances unnecessarily.

2 DESIGNE OVERVIEW

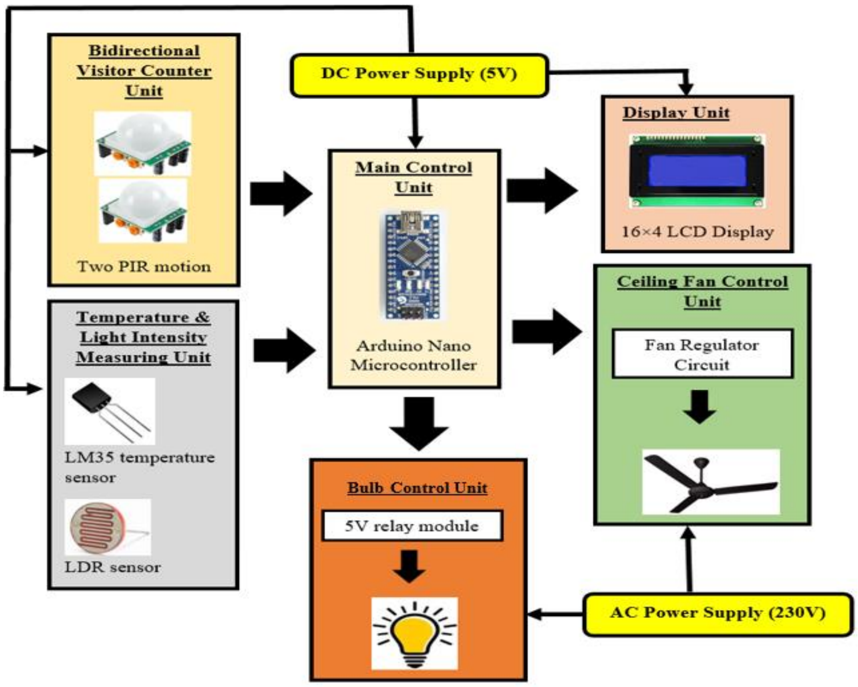

Figure 1. Design overview of domestic energy saving device

The domestic power saving device is consisting with six main units as in the overview diagram which is showing in figure 1 to control the ceiling fans and bulbs to reduce the power wastage while considering three main factors as number of occupants, temperature and light intensity of the relevant location. Six units of the device are main controller unit, bidirectional visitor counter unit, room temperature and light intensity measuring unit, display unit, ceiling fan control unit and blub control unit.

2.1 Main Control Unit

Arduino Nano microcontroller and fuzzy logic controller are the two parts of main controller unit. This unit process the input data and control output data signals according to the conditions of fuzzy logic controller. Main inputs to the microcontroller are digital signals of two PIR sensor modules and analog signals of the LM35 temperature sensor and the LDR sensor. As the outputs, the microcontroller controls the display unit, ceiling fan control unit and the bulb control unit according to these sensor values when the sensor values are adhering to the conditions of fuzzy logic controller.

2.2 Bidirectional Visitor Counter Unit

Bidirectional visitor counter unit is one of the input signal generating units of the proposed project to count the number of person present of the relevant location. Two PIR motion sensors are used to detect the motion of people who entering and exiting from the room. One PIR sensor module is connected inside of the room and the other PIR sensor module is connected outside of the room to count the number of people in bidirectional. PIR motion sensors are constructed mainly using BISS0001 PIR controller and 200BP sensor according to the HC-SR501 PIR sensor datasheet (HC-SR501 DETECTOR. Datasheet , n.d.).

2.3 Room Temperature and Light Intensity Measuring Unit

The main objective of this unit is to measure the temperature and the light intensity of the location. LM35 temperature sensor is used to measure the temperature. LDR sensor is used to measure the light intensity.

2.4 Display Unit

16×4 LCD display is used to display the current and previous status of number of occupants in the relevant location, the current and previous states of the temperature values and the output controller values of fuzzy logic controller.

2.5 Ceiling Fan Control Unit

This device consisting of a fan regulator circuit as one of the output units to control the ceiling fan speed according to the output signals of the microcontroller. This fan regulator circuit is constructed using two safety capacitors and three 5V relay modules which are connected to the digital pins of the microcontroller.

2.6 Bulb Control Unit

The bulb control unit is the other output unit of the device. This unit is connected to the microcontroller through a 5V relay module. Relay module control the electric current to open and close the contacts of the switch according to the output signals of the microcontroller.

3 HARDWARE AND SOFTWARE IMPLEMENTATION OF THE PROPOSED ENERGY SAVING DEVICE

3.1 Proposed Power Saving Device

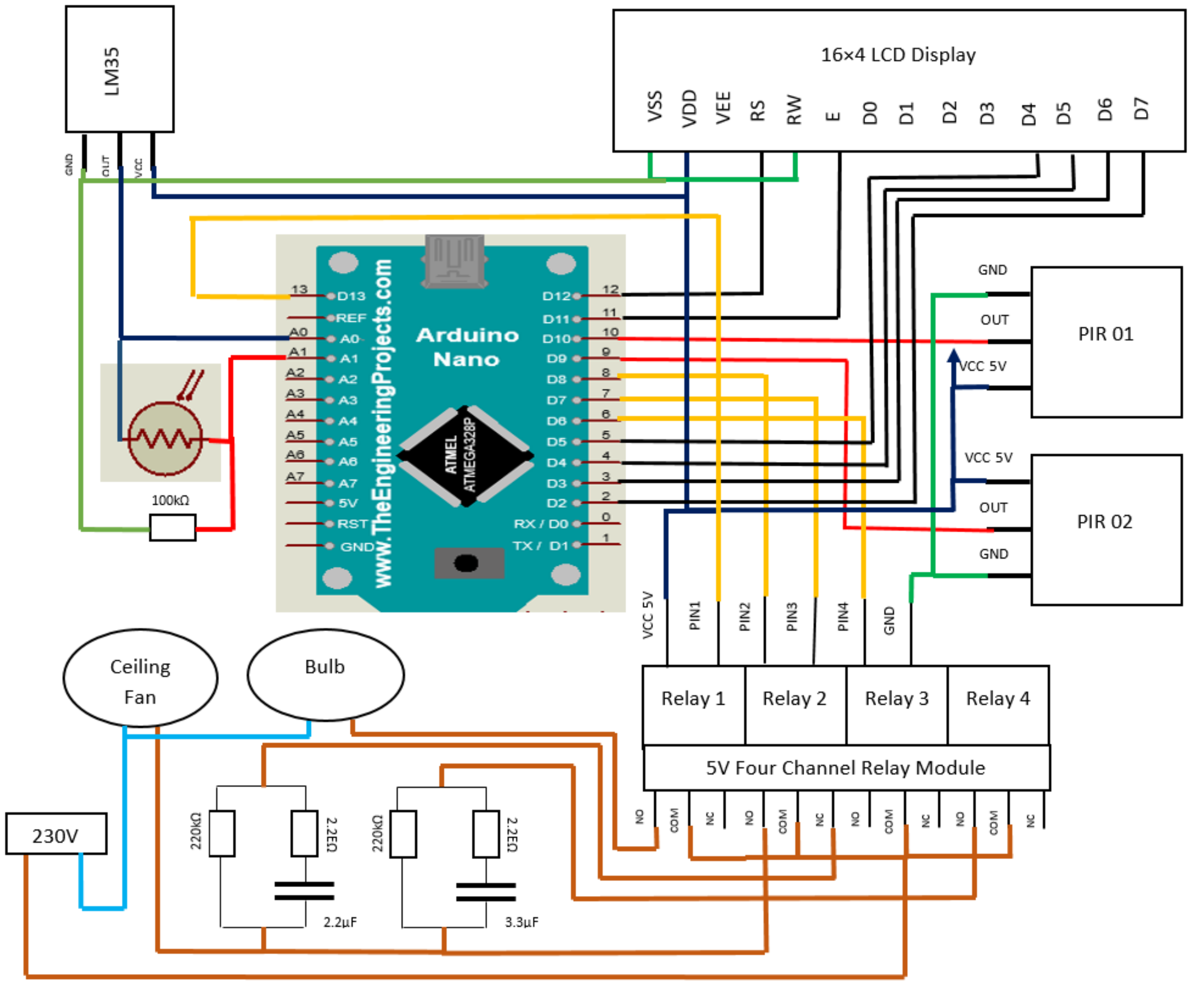

Figure 2. Circuit diagram of proposed power saving device

In figure 2 shows the circuit diagram of the proposed power saving device. Arduino Nano is used as the microcontroller of the device. Pin connection of Arduino Nano microcontroller of the circuit diagram is showing in the table 1.

Table 1. Pin connection of Arduino Nano microcontroller of the circuit diagram

Pin Number	Pin Connection Description
D2	D7 pin of 16×4 Display
D3	D6 pin of 16×4 Display
D4	D5 pin of 16×4 Display
D5	D4 pin of 16×4 Display
D11	E pin of 16×4 Display
D12	RS pin of 16×4 Display
D6, D7, D8	Fan control three 5V relay Modules
D9, D10	Two PIR sensor module
D13	Bulb control 5V relay module
A0	LM35 temperature sensor
A1	LDR sensor

3.2 PIR Sensor Module

Main components used to construct the PIR sensor module are BISS0001 PIR controller and 200BP sensor. BISS001 PIR Controller is the main control IC of the PIR motion sensor circuit. This IC has 16 pins with special noise immunity technique. Supply voltage can be vary in between 3.3V to 5V. Input voltages VSS is approximately (-0.3) V and VDD is 0.3V. The operating temperature range of the IC is -20℃ to 70℃. The storage temperature range is -20℃ to 125℃. 200BP is the pyroelectric passive infrared sensor that used as the sensor of the PIR sensor module.

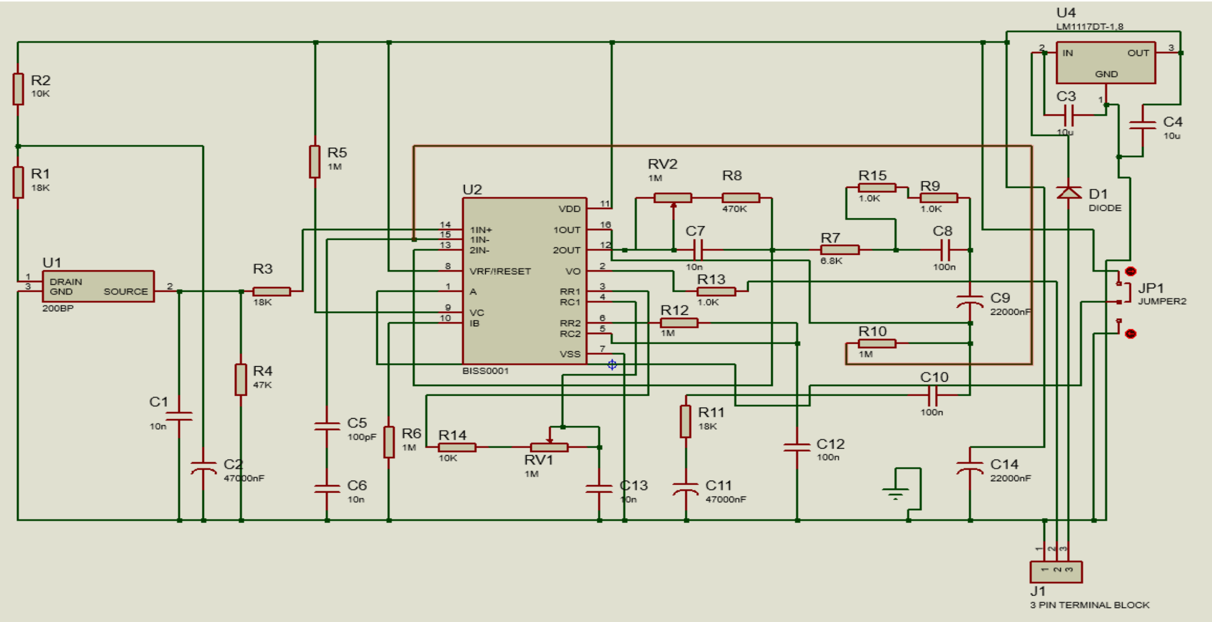

Figure 3. PIR sensor module circuit diagram

Figure 3 shows the PIR sensor module circuit diagram. The circuit diagram is designed by referring to the given specifications of the HC-SR501 PIR sensor module datasheet (HC-SR501 DETECTOR. Datasheet , n.d.) while making some differences to the circuit given in the datasheet.

The output signal of the 200BP PIR sensor is sending to the pin 14 of the BISS001 PIR controller. The PIR controller IC has two operational amplifier units in between the pin 14, 15, 16 and the pin 13, 12 to amplify the small signals from the PIR sensor. A potentiometer is connected to the feedback of the second operational amplifier to control the sensitivity range of the PIR sensor module. PIR controller has a comparator to compare the output voltage of the second operational amplifier with the two internal threshold voltage values. Then output of the comparator goes internally to the pin 9 and the output of the pin 9 is connected with 3.3V through a resister. Pin 1 can use to select the triggered behavior of the circuit. Finally the output of the PIR controller is transmitting via pin 2 as the output of the PIR sensor module.

3.3 Fan Regulator Circuit

Fan regulator circuit is designed to control the fan speed according to the output signals of the microcontroller. A small research based on the reverse engineering method was carried out to identify the pin connections using a four speed level ceiling fan regulator. First of all, the zero to four speed level fan regulator is dismantled and check and identified all the connection using a multimeter. Then designed and constructed the fan regulator circuit.

Required components for fan regulator circuit are two 220kΩ (1/4W) resistors two 2.2Ω (1/2W) resistors, 2.2µF (250VAC) safety Capacitor, 3.3µF (250VAC) safety Capacitor and three channel 5V relay module.

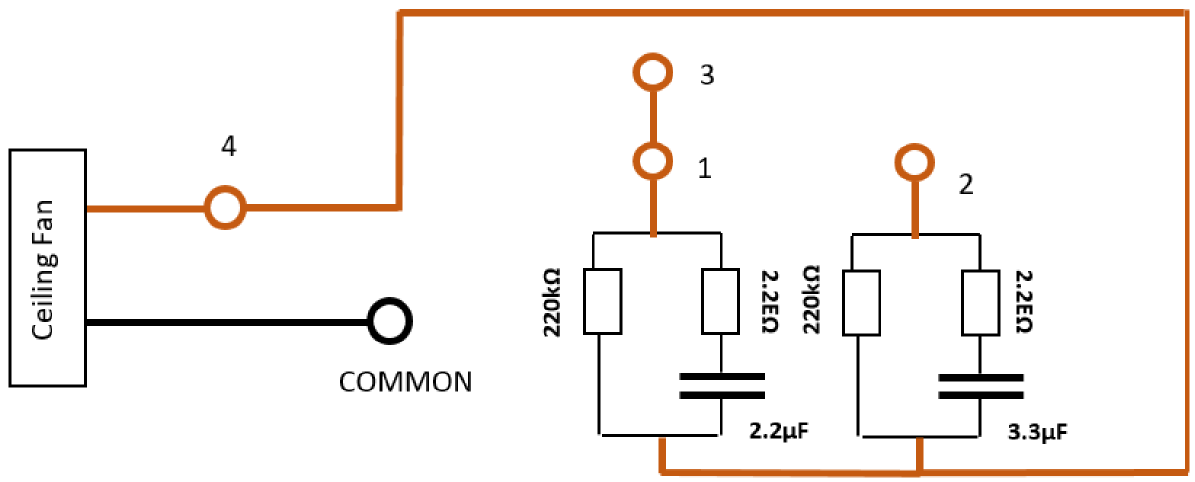

Figure 4. Fan regulator circuit diagram

The circuit diagram of figure 4 shows the designed fan regulator circuit to control the ceiling fan speed from zero to four speed levels. R1 and R3 are the 220kΩ (1/4W) resistors, R2 and R4 are the 2.2Ω (1/2W) resistors. C1 is the 2.2µF (250VAC) capacitor and the C2 is the 3.3µF (250VAC) capacitor. 1, 2, 3 and 4 points connect with the common terminal while limiting the current flowing through the circuit to change the speed levels. Three 5V relays are used to connect the common terminal with the relevant point of the circuit to control the fan speed within speed level zero, one, two and four according to the output signals of the microcontroller.

Speed level zero can be obtained when the common terminal is not connected with any point of the circuit. Therefore, the current flowing through two RC circuit is zero. Point one is connected with the common terminal and the current flowing through the R1, R2 resisters and C1 capacitor of the RC circuit of figure 4 to obtain the speed level 1. The current flowing through the circuit is approximately 153mA. Speed level two can be obtain when the common terminal is connected to the point two and the current flowing through R3, R4 resistors and C2 Capacitor in the circuit of figure 4. The current is approximately 229mA. To control the speed level three the common terminal is connected with the point three in the figure 4 and that point internally connected with the point one and point two. Therefore, the current flowing through both RC circuits and that is about 382mA. If the speed level is four, the common terminal is connected with the point four and the current directly flowing to the fan without flowing through the RC circuits with a maximum current than other speed levels.

3.4 Fuzzy Logic Controller

An algorithm is implemented with a fuzzy logic controller to control the ceiling fan and bulb according to the necessity. Mamdani fuzzy inference system is designed and simulated using MATLAB software based on the collected data of temperature and human presence of six locations of the house during three weeks. The fuzzy inference system has four inputs and two outputs which obtained using if-then rules. Figure 5 shows the Mamdani fuzzy inference system that designed using MATLAB software.

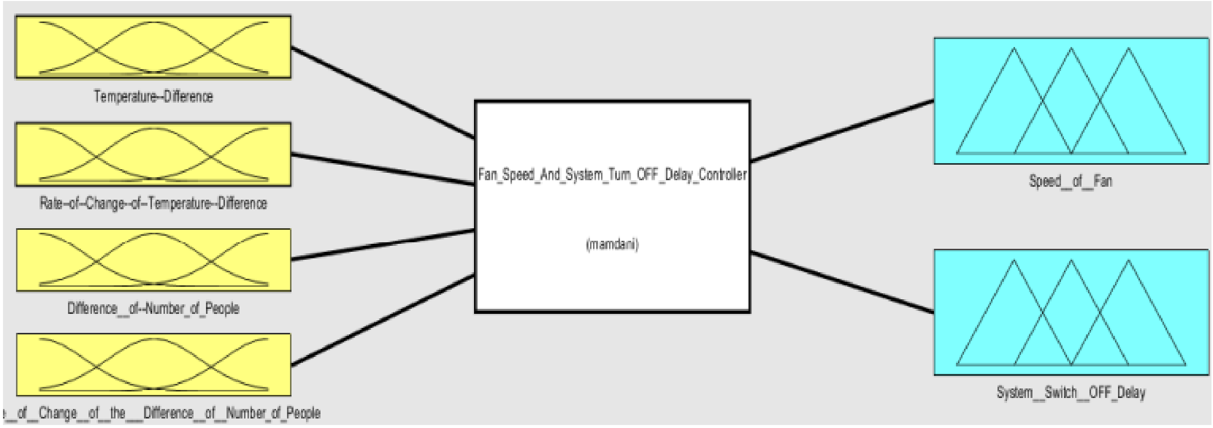

Figure 5. Mamdani fuzzy inference system

Mamdani fuzzy inference system has four input. Those are temperature difference (Diff_Current), Rate of change of temperature difference (D_T), Difference of number of people (Diff_C_Previous) and Rate of change of difference of number of people (D_C).

The temperature difference is obtained from the difference between the temperature (T_k) and a set temperature value. This set temperature value is 27°C. Membership functions are very hot, hot, optimal, cold and very cold.

$$Diff_{Current} = 27°C - T_k \, °C \quad (1)$$

The rate of change of temperature difference is obtained from the difference between the current temperature differences (Diff_Current) and the previous temperature difference (Diff_Previous) within 5 minutes. Membership functions are negative, zero and positive.

$$D_T = \frac{(Diff_{Current} - Diff_{Previous})\,°C}{5min} \quad (2)$$

The difference of number of people is obtained from the difference between the previous person count (N_{k-1}) and a set count of people. This set count of people is 3. Membership functions are very high number, high number, optimal, low number, very low number and zero

$$Diff_{C_{Privious}} = 3 - N_{k-1} \quad (3)$$

The rate of change of difference of number of people is obtained from the difference between the previous person count differences (Diff_C_Previous) and count before previous count difference (Diff_B_C_Previous) within 5 minutes. Membership functions are negative, zero and positive.

$$D_T = \frac{(Diff_{C_{Privious}} - Diff_{B_{C_{privious}}})}{5\ min} \quad (4)$$

Outputs of the Fuzzy Control System are speed of the fan and system switch off delay. Speed of Fan – the speed levels are varied with zero level to speed level 4. Membership functions are very high speed, high speed, medium speed, low speed and zero speed

System switch off delay – the delay periods are vary in between 5 minutes to 15 minutes to switch off the power saving device of the ceiling fan ad bulb. Membership functions are very high delay, high delay, medium delay, low delay, very low delay and zero delay.

1. If (Temperature--Difference is Very__Hot) and (Rate--of--Change--of--Temperature--Difference is Negative) then (Speed__of__Fan is Very__High__Speed) (1)
2. If (Temperature--Difference is Very__Hot) and (Rate--of--Change--of--Temperature--Difference is Zero) then (Speed__of__Fan is Very__High__Speed) (1)
3. If (Temperature--Difference is Very__Hot) and (Rate--of--Change--of--Temperature--Difference is Positive) then (Speed__of__Fan is Very__High__Speed) (1)
4. If (Temperature--Difference is Hot) and (Rate--of--Change--of--Temperature--Difference is Negative) then (Speed__of__Fan is High__Speed) (1)
5. If (Temperature--Difference is Hot) and (Rate--of--Change--of--Temperature--Difference is Zero) then (Speed__of__Fan is High__Speed) (1)
6. If (Temperature--Difference is Hot) and (Rate--of--Change--of--Temperature--Difference is Positive) then (Speed__of__Fan is Very__High__Speed) (1)
7. If (Temperature--Difference is Optimal) and (Rate--of--Change--of--Temperature--Difference is Negative) then (Speed__of__Fan is Medium__Speed) (1)
8. If (Temperature--Difference is Optimal) and (Rate--of--Change--of--Temperature--Difference is Zero) then (Speed__of__Fan is Medium__Speed) (1)
9. If (Temperature--Difference is Optimal) and (Rate--of--Change--of--Temperature--Difference is Positive) then (Speed__of__Fan is High__Speed) (1)
10. If (Temperature--Difference is Cold) and (Rate--of--Change--of--Temperature--Difference is Negative) then (Speed__of__Fan is Low__Speed) (1)
11. If (Temperature--Difference is Cold) and (Rate--of--Change--of--Temperature--Difference is Zero) then (Speed__of__Fan is Low__Speed) (1)
12. If (Temperature--Difference is Cold) and (Rate--of--Change--of--Temperature--Difference is Positive) then (Speed__of__Fan is Medium__Speed) (1)
13. If (Temperature--Difference is Very__Cold) and (Rate--of--Change--of--Temperature--Difference is Negative) then (Speed__of__Fan is Zero__Speed) (1)
14. If (Temperature--Difference is Very__Cold) and (Rate--of--Change--of--Temperature--Difference is Zero) then (Speed__of__Fan is Zero__Speed) (1)
15. If (Temperature--Difference is Very__Cold) and (Rate--of--Change--of--Temperature--Difference is Positive) then (Speed__of__Fan is Low__Speed) (1)
16. If (Difference__of--Number_of_People is Very__High__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Negative) then (System__Switch__OFF_Delay is Low__Delay) (1)
17. If (Difference__of--Number_of_People is Very__High__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Zero) then (System__Switch__OFF_Delay is Very__Low__Delay) (1)
18. If (Difference__of--Number_of_People is High__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Negative) then (System__Switch__OFF_Delay is Medium__Delay) (1)
19. If (Difference__of--Number_of_People is High__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Zero) then (System__Switch__OFF_Delay is Low__Delay) (1)
20. If (Difference__of--Number_of_People is High__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Positive) then (System__Switch__OFF_Delay is Very__Low__Delay) (1)
21. If (Difference__of--Number_of_People is Optimal) and (rate__of__Change__of__the__Difference__of__Number_of_People is Negative) then (System__Switch__OFF_Delay is Low__Delay) (1)
22. If (Difference__of--Number_of_People is Optimal) and (rate__of__Change__of__the__Difference__of__Number_of_People is Zero) then (System__Switch__OFF_Delay is Medium__Delay) (1)
23. If (Difference__of--Number_of_People is Optimal) and (rate__of__Change__of__the__Difference__of__Number_of_People is Positive) then (System__Switch__OFF_Delay is Low__Delay) (1)
24. If (Difference__of--Number_of_People is Low__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Negative) then (System__Switch__OFF_Delay is High__Speed) (1)
25. If (Difference__of--Number_of_People is Low__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Zero) then (System__Switch__OFF_Delay is Medium__Delay) (1)
26. If (Difference__of--Number_of_People is Low__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Positive) then (System__Switch__OFF_Delay is High__Speed) (1)
27. If (Difference__of--Number_of_People is Very__Low__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Negative) then (System__Switch__OFF_Delay is Very__High) (1)
28. If (Difference__of--Number_of_People is Very__Low__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Zero) then (System__Switch__OFF_Delay is Very__High) (1)
29. If (Difference__of--Number_of_People is Very__Low__Number) and (rate__of__Change__of__the__Difference__of__Number_of_People is Positive) then (System__Switch__OFF_Delay is High__Speed) (1)
30. If (Difference__of--Number_of_People is Zero) and (rate__of__Change__of__the__Difference__of__Number_of_People is Zero) then (System__Switch__OFF_Delay is Zero__Delay) (1)
31. If (Difference__of--Number_of_People is Zero) and (rate__of__Change__of__the__Difference__of__Number_of_People is Positive) then (System__Switch__OFF_Delay is Zero__Delay) (1)

Figure 6. Mamdani fuzzy inference system rules

The figure 6 shows the rules that implemented using AND condition to control the outputs. Fifteen rules are implemented for fan speed controller output and sixteen rules are implemented to system switch off delay output. The output controller calculations are mention below.

Final_Output - the output controller of the fan speed control output.

$$\mathrm{Final}_{\mathrm{output}} = \frac{\mathrm{Output}}{\mathrm{Output\_Divide\_}} \tag{5}$$

C_final_Output – the output controller of the system switch off delay

$$C\_Final_{Output} = \frac{C\_Output}{C\_Output\_Divide} \tag{6}$$

4 RESULTS

This proposed device and the algorithm is developed using temperature and number of people within the six locations of five member family house during three weeks. This device control the ceiling fan speed according to the fuzzy logic controller output that based on the temperature deference and rate of change of temperature difference. As well as, control the delay time to switch off the system based on the fuzzy logic controller outputs created using difference of number of people and rate of change of difference of number of people. This proposed power saving device results a saving about 318Wh per day as an average value. The constructed PIR sensor is showing in the figure 7.

Figure 7. Constructed PIR sensor module

The proposed domestic power saving device is showing in the figure 8.

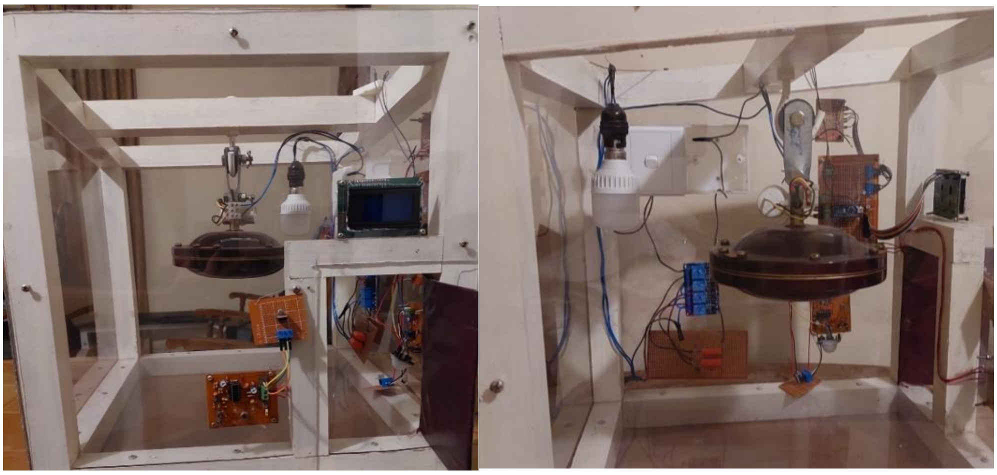
Figure 8. Domestic power saving device

Figure 9 shows the rule viewer of fan speed and system turn off delay controller.

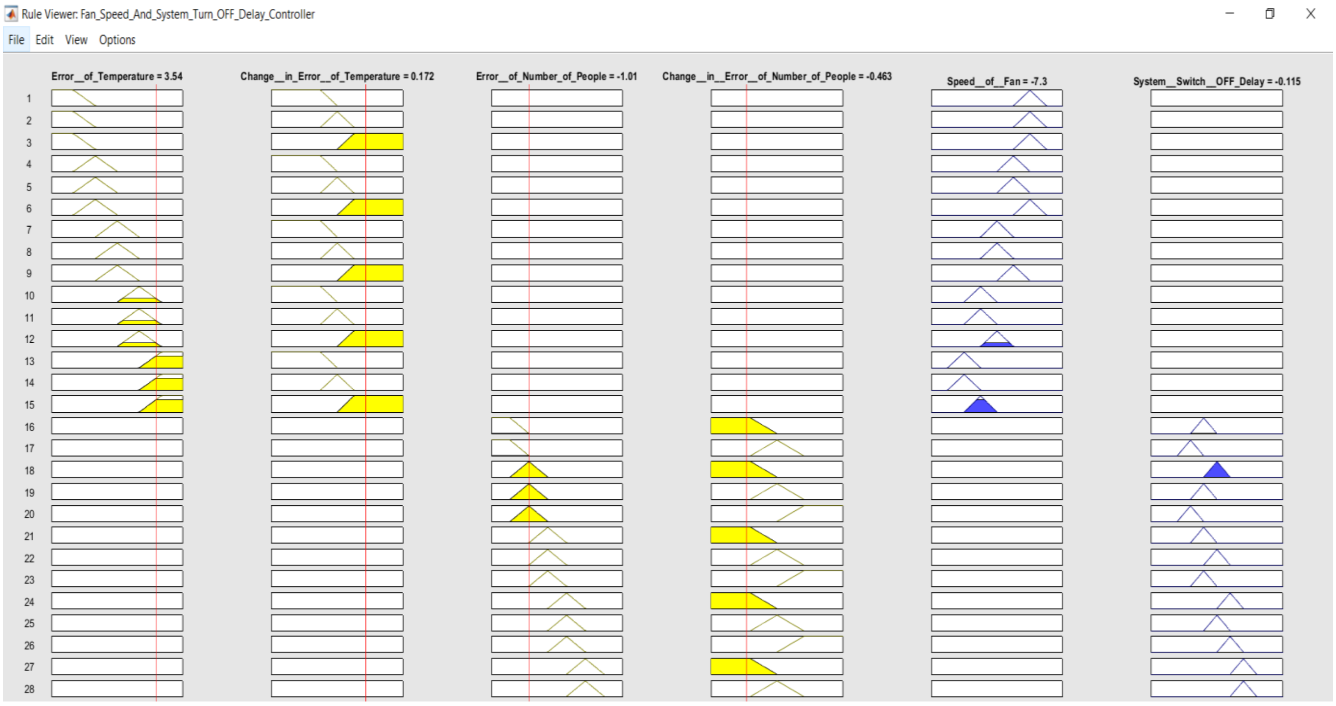

Figure 9. Rule viewer of fan speed and system switch off delay controller

Table 2. Calculated data using designed Fuzzy logic controller for Monday and Tuesday.

Time	Monday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour	Tuseday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour
12.00 a.m - 01.00 a.m	24° C	27-24 = 3 ° C	0 .6	2	27	26° C	1° C	0	1	16
01.00 a.m - 02.00 a.m	24° C	3 ° C	0	0	0	26° C	1° C	0	1	16
02.00 a.m - 03.00 a.m	24.5° C	2.5 ° C	(-0.1)	1	16	25° C	2° C	0.2	2	27
03.00 a.m - 04.00 a.m	24.8° C	2.2° C	(-0.06)	1	16	25° C	2° C	0	1	16
04.00 a.m - 05.00 a.m	25° C	2 ° C	(-0.04)	1	16	25° C	2° C	0	1	16
05.00 a.m - 06.00 a.m	25° C	2 ° C	0	1	16	26.2° C	0.8° C	(-0.24)	1	16
06.00 a.m - 07.00 a.m	25.6° C	1.4° C	(- 0.12)	1	16	26.8° C	0.2° C	(-0.12)	2	27
07.00 a.m - 08.00 a.m	26° C	1° C	(-0.08)	1	16	26.5° C	0.5° C	0.06	2	27
08.00 a.m - 09.00 a.m	27° C	0° C	(-0.2)	2	27	26.9° C	0.1° C	(-0.08)	2	27
09.00 a.m - 10.00 a.m	27° C	0° C	0	2	27	26.5° C	0.5° C	0.08	2	27
10.00 a.m - 11.00 a.m	27.3° C	(-0.3 C)	(-0.06)	2	27	27° C	0° C	(- 0.1)	2	27
11.00 a.m - 12.00 p.m	27.3° C	(-0.3 C)	0	2	27	27° C	0° C	0	2	27
12.00 p.m - 01.00 p.m	28° C	(-1C)	(-0.14)	2	27	27.5° C	(-0.5° C)	(- 0.1)	2	27
01.00 p.m - 02.00 p.m	29° C	(-2 C)	(-0.2)	3	45	28° C	(-1° C)	(- 0.1)	2	27
02.00 p.m - 03.00 p.m	29° C	(-2 C)	0	3	45	28° C	(-1° C)	0	2	27
03.00 p.m - 04.00 p.m	29° C	(-2 C)	0	3	45	30° C	(-3° C)	(-0.4)	3	45
04.00 p.m - 05.00 p.m	27° C	0° C	0.4	3	45	30° C	(-3° C)	0	3	45
05.00 p.m - 06.00 p.m	27° C	0° C	0	2	27	30° C	(-3° C)	0	3	45
06.00 p.m - 07.00 p.m	27° C	0° C	0	2	27	29° C	(-2° C)	0.2	4	55
07.00 p.m - 08.00 p.m	27° C	0° C	0	2	27	29° C	(-2° C)	0	3	45
08.00 p.m - 09.00 p.m	26° C	1° C	0.2	1	16	29° C	(-2° C)	0	3	45
09.00 p.m - 10.00 p.m	26° C	1° C	0	1	16	28° C	(-1° C)	0.2	3	45
10.00 p.m - 11.00 p.m	26.3° C	0.7° C	(-0.06)	1	16	28° C	(-1° C)	0	2	27
11.00 p.m - 12.00 a.m	26° C	1° C	(-0.06)	1	16	26° C	1° C	0.4	2	27
					Total = 583					Total = 729

Table 3. Calculated data using designed Fuzzy logic controller for Wednesday and Thursday.

Wednesday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour	Thursday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour
26° C	1° C	(-0.2)	1	16	26° C	1° C	0	1	16
26° C	1° C	0	1	16	26° C	1° C	0	1	16
26° C	1° C	0	1	16	25° C	2° C	0.2	2	27
26° C	1° C	0	1	16	25° C	2° C	0	1	16
26.6° C	0.4° C	(-0.12)	2	27	25° C	2° C	0	1	16
27° C	0° C	(-0.08)	3	45	26.2° C	0.8° C	(-0.24)	1	16
26.2° C	0.8° C	0.16	2	27	26.8° C	0.2° C	(-0.12)	2	27
26.5° C	0.5° C	(-0.06)	2	27	26.5° C	0.5° C	0.04	2	27
26.9° C	0.1° C	(-0.08)	2	27	26.9° C	0.1° C	(-0.08)	2	27
26.5° C	0.5° C	0.08	2	27	27° C	0° C	(-0.02)	2	27
27° C	0° C	(- 0.1)	2	27	27° C	0° C	0	2	27
27° C	0° C	0	2	27	27° C	0° C	0	2	27
27.9° C	(-0.9° C)	(-0.18)	2	27	28° C	(-1° C)	(-0.2)	2	27
28.3° C	(-1.3 ° C)	(-0.08)	2	27	28° C	(-1° C)	0	2	27
28.3° C	(-1.3 ° C)	0	2	27	28° C	(-1° C)	0	2	27
28.5° C	(-1.5° C)	(-0.04)	3	45	29° C	(-2° C)	(-0.2)	3	45
28.7° C	(-1.7° C)	(-0.04)	3	45	30° C	(-3° C)	(-0.2)	3	45
28.5° C	(-1.5° C)	0.04	3	45	29.7° C	(-2.7° C)	0.06	3	45
29° C	(-2° C)	(- 0.1)	3	45	29.7° C	(-2.7° C)	0	4	55
29.1° C	(-2.1° C)	(-0.02)	3	45	28° C	(-1° C)	0.34	3	45
29° C	(-2° C)	0.02	3	45	28.5° C	(-1.5° C)	(- 0.1)	3	45
29° C	(-2° C)	0	3	45	27° C	0° C	0.3	2	27
28° C	(-1° C)	0.2	3	45	27° C	0° C	0	2	27
26° C	1° C	0	1	16	27° C	0° C	0	2	27
				Total = 755					Total = 711

Table 4. Calculated data using designed Fuzzy logic controller for Friday and Saturday

Friday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour	Saturday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour
26° C	1° C	0.2	1	16	26° C	1° C	0.2	1	16
26° C	1° C	0	1	16	26° C	1° C	0	1	16
27° C	0° C	(-0.2)	1	16	26° C	1° C	0	1	16
26.8° C	0.2° C	0.04	2	27	26° C	1° C	0	1	16
27° C	0° C	(-0.04)	2	27	26.6° C	0.4° C	(-0.12)	2	27
27° C	0° C	0	2	27	27° C	0° C	(-0.08)	2	27
28° C	(-1° C)	(-0.2)	2	27	27.8° C	(-0.8° C)	(-0.16)	2	27
29° C	(-2° C)	(-0.2)	3	45	27.5° C	(-0.5° C)	0.06	3	45
28.5° C	(-1.5° C)	0.1	3	45	26.9° C	0.1° C	0.12	3	45
29° C	(-2° C)	(- 0.1)	4	55	27° C	0° C	(-0.02)	2	27
30° C	(-3° C)	(-0.2)	3	45	27° C	0° C	0	2	27
30.5° C	(-3.5° C)	(- 0.1)	4	55	27° C	0° C	0	2	27
31° C	(-4° C)	(- 0.1)	4	55	27.9° C	(-0.9° C)	(-0.18)	3	45
31° C	(-4° C)	0	4	55	28.3° C	(-1.3° C)	0.12	3	45
30.8° C	(-3.8° C)	0.04	4	55	28.3° C	(-1.3° C)	0	2	27
30.8° C	(-3.8° C)	0	4	55	28.5° C	(-1.5° C)	(-0.04)	3	45
30.6° C	(-3.6° C)	0.04	4	55	29° C	(-2 ° C)	(- 0.1)	3	45
30.6° C	(-3.6° C)	0	4	55	28° C	(-1° C)	0.2	3	45
30.6° C	(-3.6° C)	0	4	55	29° C	(-2° C)	(-0.2)	3	45
30° C	(-3° C)	0.12	4	55	29° C	(-2° C)	0	3	45
30° C	(-3° C)	0	3	45	29° C	(-2° C)	0	3	45
30° C	(-3° C)	0	3	45	29° C	(-2° C)	0	3	45
30° C	(-3° C)	0	3	45	28° C	(-1° C)	0.2	3	45
30° C	(-3° C)	0	3	45	26° C	1° C	0.4	2	27
				Total = 1021					Total = 820

Table 5. Calculated data using designed fuzzy logic controller for Friday to Sunday.

Sunday	ΔT (° C)	(d ΔT)/5 ° C/min	Speed Level	Watt per hour
26° C	1° C	(-0.2)	1	16
26° C	1° C	0	1	16
25° C	2° C	0.2	2	27
25° C	2° C	0	1	16
25° C	2° C	0	1	16
26.2° C	0.8° C	(-0.24)	1	16
26.8° C	0.2° C	(-0.12)	2	27
26.9° C	0.1° C	(-0.02)	2	27
26.9° C	0.1° C	0	2	27
26.9° C	0.1° C	0	2	27
27° C	0° C	(-0.4)	2	27
27° C	0° C	0	2	27
27° C	0° C	0	2	27
28° C	(-1° C)	(-0.2)	2	27
28° C	(-1° C)	0	2	27
30° C	(-3° C)	(-0.4)	3	45
30° C	(-3° C)	0	3	45
30° C	(-3° C)	0	3	45
29° C	(-2° C)	0.2	4	55
29° C	(-2° C)	0	3	45
29° C	(-2° C)	0	3	45
28° C	(-1° C)	0.2	3	45
28° C	(-1° C)	0	2	27
26° C	1° C	0.4	1	16
				Total = 718

The table 2 to 5 show the collected average temperature values for a week. As well as the inputs of temperature difference (Diff_Current) is showing (ΔT) and Rate of change of temperature difference (D_T) is showing (d (ΔT). As well as the calculated consumption of watts per hour of the fuzzy controlled fan speed is showing.

Indian fan was used for the experiment. According to the details given in the (Atomberg, 2017) the ordinary fan consumed 16 watts per hour at speed 1, 27 watts per hour for speed 2, 45 watts per hour for speed 3 and speed 4 consumed 55 watts per hour. Therefore, 1080Wh consumed if the fan use for 24 hours at speed level 3. But according to the calculated data mentioned in table 2 to table 5, the proposed fuzzy controlled ceiling fan consumed 762Wh during the whole day as an average value while changing the speed of the fan according to the temperature of the location. Though, the ceiling fan is in ON mode continuously during 24 hours of a day this proposed device can save about 318Wh (1144.8 kJ). Since the developed algorithm controls the speed of the ceiling fan according to the temperature, the above mentioned efficient power saving occurs. As well as due to the cancellation of unnecessary usage of these appliances results more amount of energy saving. This proposed system can avoid useless switch ON and OFF modes due to the switch off delay of appliances in fuzzy logic control system. This will help to save the lifetime of the appliances while working efficiently.

5 CONCLUSION

Domestic power saving device is proposed in this paper to save the power wastage from the ceiling fans and bulbs which are in active mode unnecessarily. This device control ceiling fan and bulb based on the three factors as number of person presence, room temperature and the light intensity. Manually collected temperature and number of people presence data during three weeks in six locations of five member family house to implement the Mamdani fuzzy inference system membership functions and rules. Six main units consist of this device as main control unit to control the inputs and outputs by using the microcontroller, bidirectional visitor counter unit to detect the motion of people entering and leaving from the location to get the count of people presence, temperature and light intensity measuring unit to measure the room temperature and light intensity, LCD display unit to display the output values of the fuzzy logic controller, ceiling fan controller unit to control the ceiling fan ON/OFF status, fan speed based on the fuzzy logic controller output values and bulb control unit to control the bulb ON/ OFF status based on the fuzzy logic controller output values. As the tested results this device helps to save about 1144.8 kJ per day from a single ceiling fan and bulb while controlling the fan, bulb ON/OFF status and fan speed according to the temperature, number of people presence and light intensity. This is a 5V battery charging device and for the efficient service the installation location of the device should be a covered space within the sensing range (7m 120 degree cone) of PIR motion detectors. The life time of the device about five years. When the comparison in between the proposed device and the existing devices in the industry some modifications and significances can be identified. According to the existing devices, those systems bring the appliances to the ON and OFF modes directly rather than that, this proposed device controls the ceiling fan and bulb towards the OFF mode with a delay time to eliminate the power consumption during the power on stage of the device while enhancing the life time of appliances by reducing the unnecessary OFF modes of appliances. As well as the developed fuzzy logic algorithm to control the ceiling fan and bulb according to the three factors as room temperature, number of people in the specified space and the light intensity of the environment. When comparing with the other devices existing, this proposed device used high quality PIR motion sensors instead of IR sensors to detect the motions. As further developments the algorithm is proposed to build with a new feature to compete with different and various databases in the industrial and domestic systems.

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