An Effective Combination of Microcontroller and PLC for Home Automation System

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***Abstract*—In this paper, a smart home automation system is proposed to control home appliances and to make a home safer using electronic controller. Also, Grid-Eye sensors are used to detect the presence of the occupant in the home upon which the activation of any appliance depends. As a result, all the electric instruments of the home run automatically when necessary, and the residents do not need to turn on/off of any electric appliances like air conditioner, fan, light, water heater or any other home appliances. Also if a person wants to make on/off of any utilities, he can easily make it by using android apps or by using a wireless network which is interfaced with the system. In addition to home automation, when any mishap happens in the home, GSM sends SMS to warn people about the accident. If a person wants to know the status of his home utility system, when he or she out of the home, he can also use GSM technology. Proteus simulation software is used to test the effectiveness of the proposed designed system. To control large electric machines like water pump, elevator and generator, PLC module is used. In this case, we also consider different conditions to run large electric machinery automatically. This designed system provides more convenient and flexible control for a smart home or a building. If implemented, the model will be beneficial for the promotion and popularity of smart home automation system.**

Keywords— Grid-Eye sensor, microcontroller, GSM module, Arduino IDE software, Proteus simulation software, PLC.

I. INTRODUCTION

Smart home system and home safety are vital issues for our modern life. Electronic advancement moves us to this development. But in most of the smart home system, the presence of people is ignored or the residents need to turn on/off electric appliances used in their home. The smart home system is an automated home with control devices associated with lighting, heating, air conditioning, ventilation, and security system [1]. Sensor and microcontroller are the main parts of the smart home system. In this case, sensors collect data from the surroundings and send electric signals to the microcontroller. The microcontroller processes this signal, and depending on the installed program in the microcontroller, necessary actions are taken to control the utilities connected to it. So, we can say that microcontrollers are the central axis of this system, and are sometimes called "gateways". The microcontrollers are usually interfaced with a tablet, mobile phone, or computer; and the network connectivity of the systems is managed by IoT [2]. Using this system, the controlling of all the electric appliances is possible which makes a home automation system. Android apps are also used to build home automation since Wi-Fi or Zigbee is available nowadays.

When designing a smart home system, the system should be flexible, affordable and scalable for integrating new devices into the system [3]. Moreover, the smart home system should be tiredness and boredom reducer to us. An important concern of the smart home system is the reduction of energy consumption and saving money for poor people [4].

There are many smart home research works in the online. In this paper, sensors and microcontroller are considered to control light, air conditioner or other home appliances only when they need to operate. In other words, when people are not present in the home, the light or air conditioner do not need to operate whatever the condition of the surrounding. For this reason, Grid-eye sensors with other sensors are used to detect the presence of the people. The surrounding conditions are only considered by the microcontroller during the presence of an occupant. When the output of danger warning sensors used, in the system, upon a critical level, the microcontroller does not consider the output of Grid-eye sensor and sends a warning to the people. As a result, the home will also be saved. In this designed home automation system, power will be reduced at the lowest level since utilities only run when people present in the home.

In case of controlling water pump, generator and elevator of a building, we interface PLC with the system since it is more reliable in this case. Also, we consider different conditions like the water level in case of the water pump and the presence of people in case of elevator and generator to run these electric appliances.

II. LITERATURE REVIEW

A smart home is the network of physical devices that provide electronic sensors, software, and network connectivity with each other inside a home [1]. Sometimes we consider a significant feature of the smart home is remote controlling [5]. There are numerous research papers related to smart home or home automation. A query on Web of Science, Science Direct, and IEEE Explore found almost 1798 papers in 2017 related to smart home [1]. In 2006, Davidoff et al. [6] published a paper related to the smart home and emphasized on control by end-user programming. Since 2010, researchers have been analyzing smart home based on IoT applications using many approaches. Stankovic [7] discussed the notion of smart car, smart homes, smart phones, and smart devices. An imagination of future intelligent home has been presented in some papers [2][8] where Zigbee (Wi-Fi) technology was considered. For managing power consumption, Zigbee-based smart home system is designed and implemented [9]. The smart home system is also designed by using android apps where

wireless Bluetooth system was used to assist disabled and elderly people [10]. Analyzing an original architecture and integrating it in a system, a smart home system is designed where IoT used in a paper published in 2013 [11]. IoT based home automation is versatile and popular. Numerous IoT based home automation systems are designed using many sensors to control electric appliances and to decrease the energy consumption [12]. Home automation system was designed using Global System for Mobile Technology (GSM) by Teymourzadeh and Rozita [13] in 2013 and their designed system was tested on four loads and its accuracy was 98% [13]. Smart traffic light control system was also designed where the prototype was presented to control traffic congestion using PIR sensor to calculate the number of vehicle on the road even the number plate of a vehicle is captured in this system [14]. Using wireless sensors networks (WSNs) interfaced with IoT to build smart home system is also available nowadays [15][16]. To connect objects like mobile phones, internet televisions, and sensors to the internet where the devices build new forms of communication, IoT is widely used [17]. But the main problem of this system is the cost of the wireless sensors, and the Wi-Fi network needs to keep connected all the time for communication. C. Barz et al. [18] used TIA Portal V12 and Siemens PLC to design smart home automation system where lighting, heating, irrigation, security system were considered. Raspberry Pi-based home automation system is also available nowadays where Raspberry Pi is used as a communication gateway between different home appliances and mobile [19]. To restrict the home automation for certain people, the command of user upon which the activation of home automation depends is proposed in some papers. Many firms assert that a smart home automation system can save 30% energy usage without comprising any comfort of the residents [20]. Home automation system balances demand-supply of power inside a home. As a result, it will reduce energy consumption and increase efficiency [21]. Using robotic system in a large electric machine like generator will not only save energy consumption but also reduce carbon emission in the environment and will help us to reduce the major global concerns of climate change and energy security [22].

III. Methodology

In this paper, we consider a home automation system to overcome many practical difficulties. Among many difficulties, the first one is the absence of residents of a home. Smart home system or home automation is always designed based on the need of people such as when a light or air conditioner will start. When the temperature of a room increases above a certain level or the light intensity of a room decreases below a critical level, the air condition or light turns on automatically. It is controlled by the microcontroller. But, most of the cases, the temperature of a room rises high during the day when people usually go to their office and children go to their school. In this paper, it is considered. We not only think about the fan or air conditioner or light, but we also think about the elevator, motor and other utility systems. Also, safety is added to our design approach. Automatic motor running during the empty state of a water tank and automatic elevator controlling when people need to use it is also considered in this paper.

We have considered our home automation system in two parts. One is an interior home appliances controlling system using a microcontroller and the other one is exterior i.e. building electric appliances controlling system. In the interior home appliance system, we have considered microcontroller to control different appliances using Grid-eye sensors. On the other hand, for controlling building electric appliances, we have considered PLC.

A. Interior System Design

1) System architecture: We have used a light intensity sensor BH 1750 to interface it between microcontroller and light bulb. BH 1750 sensor is set in all the rooms of the home to control the on/off of the light. When the light intensity of a room decreases below a critical level the microcontroller sends a signal to turn on the light bulb. But when there is no person in the room, the microcontroller also sends a signal to turn on the light bulb which is not a desirable design for us. So, we have also interfaced a Grid-eye sensor to detect the presence of people in the room. The microcontroller considers two cases; one is the presence of people in the room and the other is the condition of the room. As a result, our system will be smarter and will save fuel or energy costs. Moreover, safety systems are also included in this design. Manually starting the/stopping system using android apps or using a smartphone can be easily interfaced with this system to control the home appliances when anyone wants to turn on/off home appliances if necessary.

The system consists of a microcontroller which is interfaced with a GSM module. All the utilities are controlled by this microcontroller. Also, some sensors like gas/smoke sensor, temperature sensor are used to keep home safe, and if any mishap happens, then SMS is sent to the user's mobile indicating the temperature or gas presence in the room. In the system, we also consider auto open/close of the doors and windows of the rooms. HC-SR501 Infrared PIR Motion sensor is proposed to use in this case. Also, power generator, elevator, water heater, motor all are considered to automatically on/off upon the presence of people in the home.

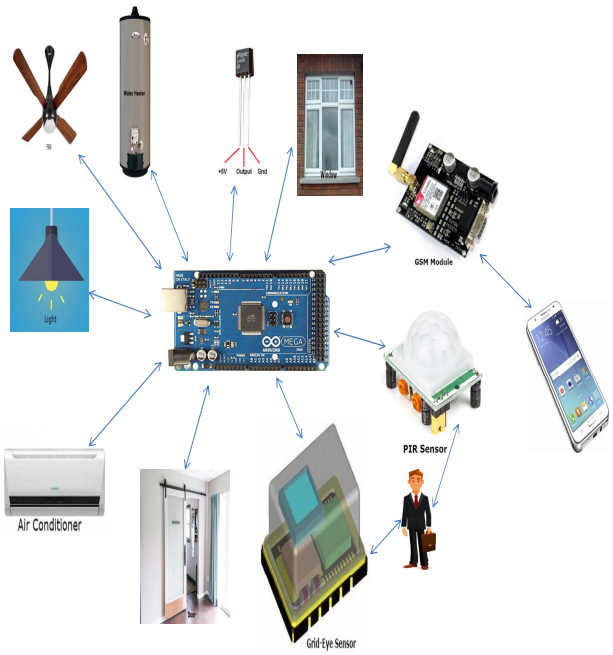

Fig.1. System architecture (inside a flat).

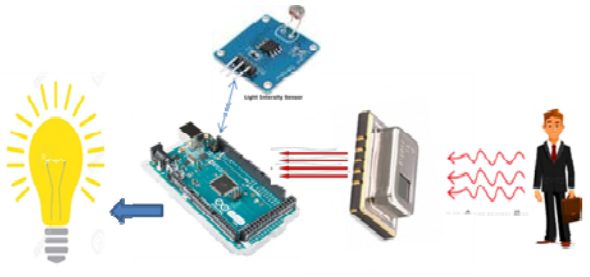

Fig. 2. Utility (Light) active.

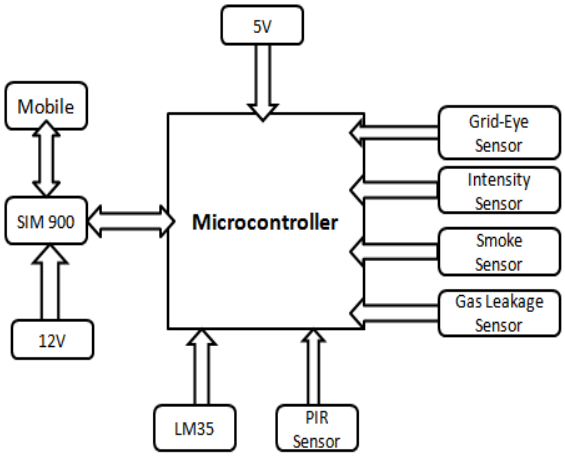

Fig. 3. System Diagram.

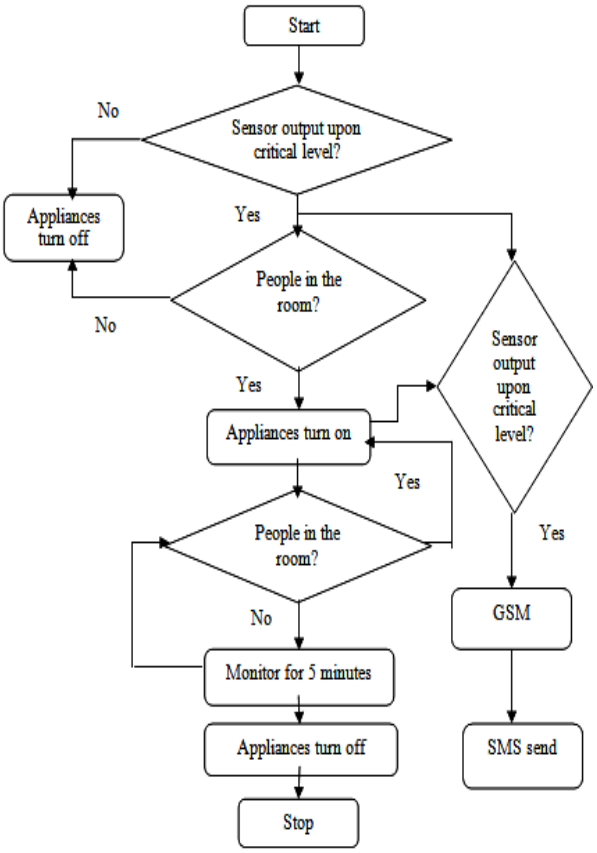

Fig. 4. Flow chart of the system.

2) 4-Room Model: We have implemented our smart home system by considering a 4 room model. In this model, we have used only one microcontroller which is put in the centre of 4 rooms. Four LM35 temperature sensors, four Grid-eye sensors are considered in this 4-room model. All of the 8 sensors are connected to the microcontroller. The microcontroller is programmed using Arduino IDE software. The lower limit of the LM 35 sensors is set at 18ºC and the upper limit is set to 40ºC in the microcontroller. The lower limit is on the condition of a fan, and the upper limit is for fire warning. The Grid-eye sensors are used to detect the presence of the people in the rooms.

When a person enters in room 1, the fan of this room switched on automatically since the temperature was 28ºC of the room on that day. The fan continues to remain on condition till the person present in the room. The fans of other rooms are in off condition since no one present in these rooms. When the person left room 1, the fan keeps running, and then it will stop after 5 minutes (Condition is set in the microcontroller). If the person now enters in room 2, the fan of room 2 becomes on, and it will also take 5 minutes to stop after leaving of that person. The same result will be found for the other 2 rooms. As a result, the person does not need to use android apps or Bluetooth or internet, in this case, to turn on/off of any electric appliances.

3) Programming the microcontroller: For the 4-room model, we have programmed the Arduino AT Mega 2560 microcontroller using Arduino IDE software. The programming is compiled following the flow chart of Fig.5. The four LM 35 temperature sensors have been connected with four analog pin A1, A2, A3, and A4 of the microcontroller. Also, four HC-SR501Infrared PIR Motion sensors instead of Grid-eye sensors are used which are connected with digital input pin 11,12,13, and 14. Both the LM 35 connection pins and PIR sensor connection pins are defined in the programming. When a person leaves from a room, the pin output of PIR becomes low. Since we set a delay (300000), the microcontroller monitors 5 minutes and makes the appliance turn off after it. We use "if ….else" loop for input to the microcontroller from LM35 sensors, and the upper critical value of temperature sensors is set to 40 ºC (inputPin >=40). A SIM 900 GSM module is interfaced, and AT+CMGF=1 command is used for sending SMS when LM 35 output goes over the upper critical level. The mobile number is set by using AT+CMGS command.

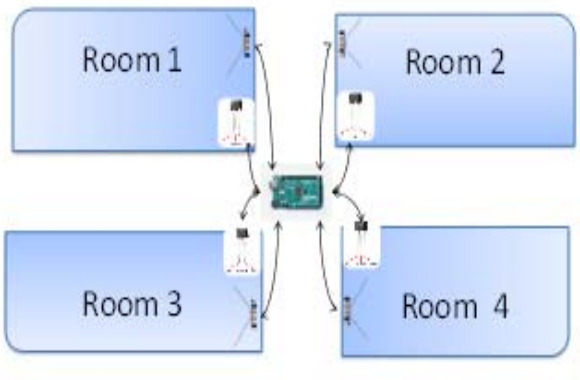

Fig.5. Four-room model

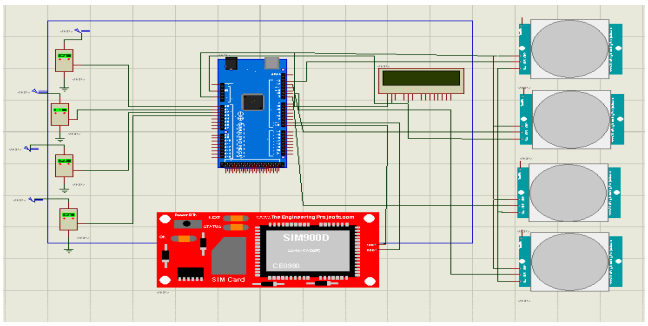

Fig. 6. Proteus simulation of the 4 Room Model.

4) Simulation: Using Proteus simulation software, we have simulated 4-room model which is shown in Fig.6. Also, fire warning to the mobile is simulated by using SIM900 GSM module in the simulation.

B. PLC based Exterior Automation

In our designed system, exterior electric machines such as water pump, generator, and elevator are controlled by using PLC. Though PLC is used especially in the industrial automation system, in the high rise building PLC can be used because of its reliability. We think about the automatic control of water pump, elevator, and generator such that our electricity cost minimizes.

a) Water Pump Control: For controlling water pump, two water level sensors (I1 and I2) are utilized. Ultrasonic sensors (HC-SR04) can be used to determine water level in the tank [23]. I1 is the upper water level indicating sensor and I2 is the lower water level indicating sensor. When the outputs of the two sensors are low, the water pump starts, and when the outputs of the two sensors are high, the water pump stops. In this case, when I1 is high, I2 becomes automatically high. Hence, when I1 becomes high, the water pump stops. Data transmission to control the water pump was provided by the PLC. A flow chart is shown in Fig.7. Simulation of this flow chart is shown in Fig. 8 where using Siemens LOGOsoft Comfort software is used.

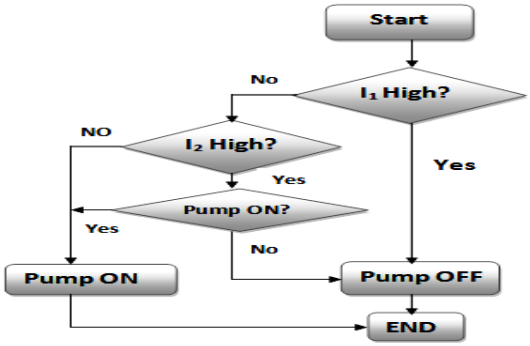

Fig.7. Flow chart of water pump control.

Table I . Truth Table Of Pump On/Off.

I1	I2	Q1	Q2	Pump (On/Off)
0	0	1	0	On
0	1	1	0	On
1	1	0	1	Off
0	1	0	1	Off
0	0	1	0	On

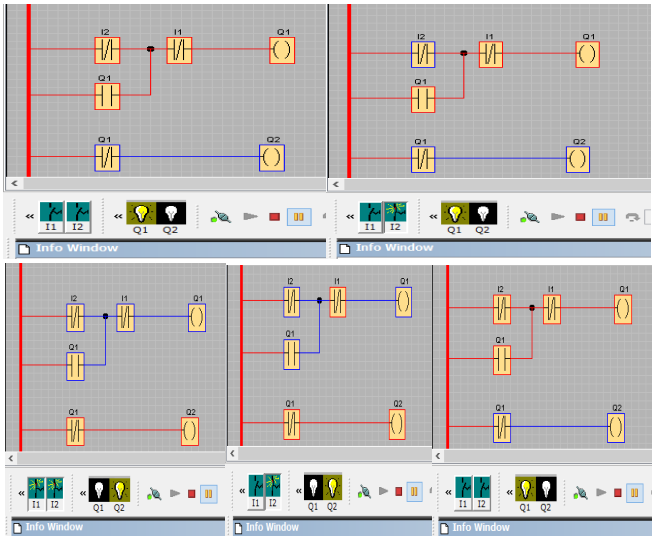

Fig. 8. The water pump on/off simulation.

b) Elevator and Generator controlling: The elevator and generator of a building will only start if people present in the elevator. To demonstrate this case, we only consider the on/off of a generator connected to the elevator during load-shedding. We have implemented our desired design using a load sensor connected to the elevator. The load sensor is used to detect the presence of a person in the elevator. When the load (weight) is applied to the base of the elevator the output of load cell will be high.

The elevating system is operated and controlled by stored programs in the PLC and is designed as an on-off controller. The operation of a power generator connected to an elevator is also controlled by PLC. Here we will design a controlling system of elevator and generator connected to PLC.

In our designed system, several cases are considered to control the generator connected to the elevator when grid electricity is not present.

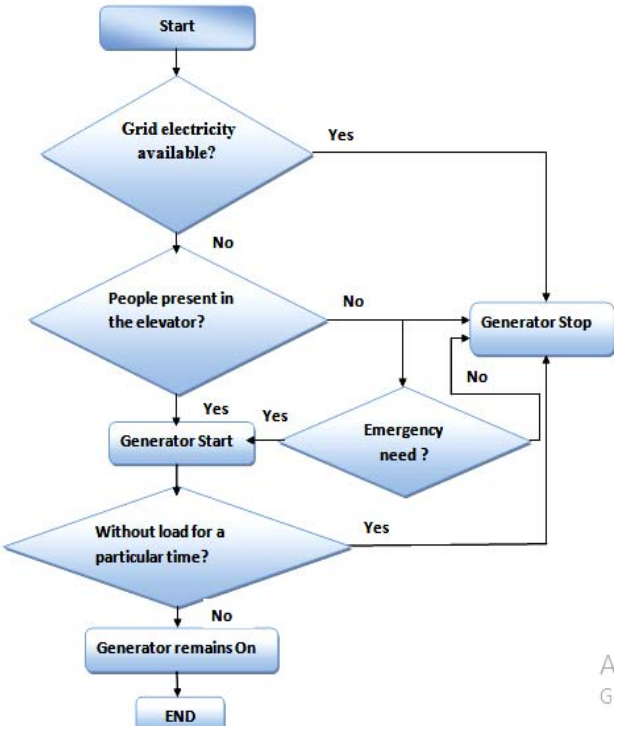

Fig.9. Flow chart of controlling elevator and generator connected to it by considering the presence of people.

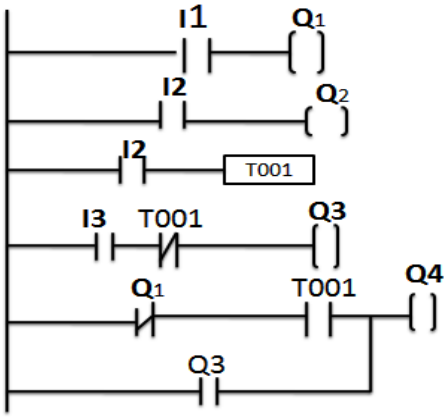

Fig.10. PLC ladder diagram for controlling generator connected to elevator according to the flow chart of Fig. 9.

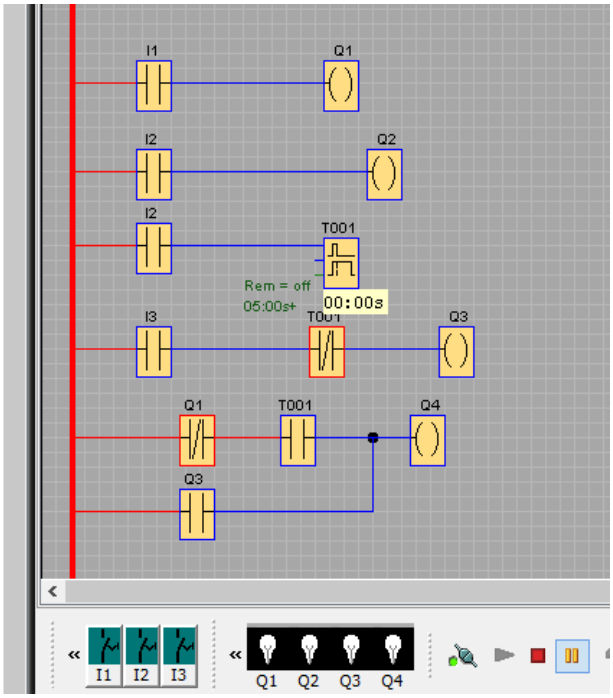

Fig.11. Simulation of controlling generator connected to elevator depending on the presence of person.

The ladder diagram using "Siemens LOGOsoft Comfort" software for the flow chart of Fig.9 is shown in Fig.12. In the ladder diagram,

- I1 indicates whether electricity supplying from the grid or not.
- I2 indicates whether people (load) present in the elevator or not.
- I3 indicates emergency needs (when anyone needs to run the elevator when both electricity and people (load) in the elevator are absent).
- T001 is an off-delay timer that keeps a generator running for 10 second after people leave the elevator (during load-shedding). As a result, another person can ride on the elevator within this time.
- Q1 output indicates the presence of electricity.
- Q2 output indicates the presence of people (load) in the elevator.
- Q3 indicates emergency need.
- Q4 output indicates the on /off of the generator connected to the elevator.

IV. Result and Discussion

Using this automation system, the utilities of the home automatically turn on/off considering the presence of people in a room and the condition of the environment. As a result, people need not concern about on/off of any utilities even when they out of a home. We have implemented a prototype of a smart home for 4-room model using microcontroller, sensors and SIM900 GSM module. Also, automatically opening system of the doors and windows have been interfaced with our designed prototype. It is possible to implement this system for a multi-room house even in the whole building. Moreover, the safety sensors will give important warnings by sending SMS to the mobile phone about any danger in the home via the GSM module. By using smoke and gas sensor and GSM module, we have implemented and verified safety system of the designed home automation. Also, controlling of an elevator is implemented using a Siemens PLC module and TIA PORTAL v12 software. In the future, we will investigate transactive control of demand response for flexible loads which can be used for energy efficiency programs [24], [25].

V. Conclusion

The main advantages of the proposed system are the low cost and user-friendliness. Another main advantage of this system is flexibility and automation. Though there are many smart home system using IoT, Bluetooth, Zigbee, cloud-based, smartphone-based, Tablet or PC based, among them this designed system is simple, low cost, energy saving and flexible for common people. People will feel relax and free from the manual switching system. Even people need not use any mobile apps to turn on/off of any utilities in normal situations. We have used PIR sensors instead of Grid-eye sensors in the Proteus simulation to detect people in a room since the library file for Grid-eye sensors is not available. We do not make an android app to control the utilities (turn on/off) when people want to change the pre-set condition of on/off of any utilities in any particular situation. Many papers have already published to control home appliance using android or wireless network, and people can use any convenient system like an android app or Bluetooth or IoT in this case.

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